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Grocholski, O., Howil, K., Rakowski, S., Maksymiuk, P.
57210160320;57295738900;57295513700;57295301400;
Using the Carnot cycle to determine changes of the phase transition temperature
(2022) American Journal of Physics, 90 (1), pp. 15-19.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-85122249872&doi=10.1119%2f10.0006455&partnerID=40&md5=432cc20d1759f3c79b4be3eaad2f4ba8

DOI: 10.1119/10.0006455
AFFILIATIONS: Faculty of Physics, University of Warsaw, Pasteura 5, Warsaw, 02-093, Poland; Polish Children's Fund, Pasteura 7, Warsaw, 02-093, Poland
ABSTRACT: The Clausius-Clapeyron relation and its analogs in other first-order phase transitions, such as type-I superconductors, are derived using very elementary methods without appealing to the more advanced concepts of entropy or Gibbs free energy. The reasoning is based on Kelvin's formulation of the second law of thermodynamics and should be accessible to high school students. After recalling some basic facts about the Carnot cycle, we present two very different systems that undergo discontinuous phase transitions (ice/water and normal/superconductor) and construct engines that exploit the properties of these systems to produce work. In each case, we show that if the transition temperature T tr was independent of other parameters, such as pressure or magnetic field, it would be possible to violate Kelvin's principle, i.e., to construct a perpetuum mobile of the second kind. Since the proposed cyclic processes can be realized reversibly in the limit of infinitesimal changes in temperature, their efficiencies must be equal to that of an ordinary Carnot cycle. We immediately obtain an equation of the form d T / d X = f (T, X), which governs how the transition temperature changes with the parameter X. © 2022 Author(s).
DOCUMENT TYPE: Article
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SOURCE: Scopus

Davies, P.C.W., Thomas, L., Zahariade, G.
7403894758;57224728294;53065136500;
The harmonic quantum Szilárd engine
(2021) American Journal of Physics, 89 (12), pp. 1123-1131.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-85120053802&doi=10.1119%2f10.0005946&partnerID=40&md5=e0970d797fcc909c0c3148617f0f6d6b

DOI: 10.1119/10.0005946
AFFILIATIONS: Department of Physics and beyond, Center for Fundamental Concepts in Science, Arizona State University, Tempe, AZ 85287, United States
ABSTRACT: The Szilárd engine is a mechanism (akin to Maxwell's demon) for converting information into energy, which seemingly violates the second law of thermodynamics. Originally a classical thought experiment, it was extended to a quantized treatment by Zurek. Here, we examine a new, elegant model of a quantum Szilárd engine by replacing the traditional rigid box with a harmonic potential, extending the scope of the model. Remarkably, almost all calculations are exact. This article is suitable for students, researchers, and educators interested in the conceptual links among information, entropy, and quantum measurement. © 2021 Author(s).
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Nicacio, F.
24174766000;
Williamson theorem in classical, quantum, and statistical physics
(2021) American Journal of Physics, 89 (12), pp. 1139-1151.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-85120053425&doi=10.1119%2f10.0005944&partnerID=40&md5=1ab94a314c408224f9e49eeed0326e37

DOI: 10.1119/10.0005944
AFFILIATIONS: Instituto de Física, Universidade Federal Do Rio de Janeiro, RJ21941-972, Brazil; Universität Wien, NuHAG, Fakultät für Mathematik, Wien, A-1090, Austria
ABSTRACT: In this work, we present (and encourage the use of) the Williamson theorem and its consequences in several contexts in physics. We demonstrate this theorem using only basic concepts of linear algebra and symplectic matrices. As an immediate application in the context of small

oscillations, we show that applying this theorem reveals the normal-mode coordinates and frequencies of the system in the Hamiltonian scenario. A modest introduction of the symplectic formalism in quantum mechanics is presented, using the theorem to study quantum normal modes and canonical distributions of thermodynamically stable systems described by quadratic Hamiltonians. As a last example, a more advanced topic concerning uncertainty relations is developed to show once more its utility in a distinct and modern perspective. © 2021 Author(s).
DOCUMENT TYPE: Article
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Burgos, A., Santos, A.
57222114889;35599136800;
The Newcomb-Benford law: Scale invariance and a simple Markov process based on it
(2021) American Journal of Physics, 89 (9), pp. 851-861.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-85113377478&doi=10.1119%2f10.0004957&partnerID=40&md5=3688d9f00e69d223de3c9a0a15a676d3

DOI: 10.1119/10.0004957
AFFILIATIONS: Departamento de Física, Universidad de Extremadura, Badajoz, 06006, Spain
ABSTRACT: The Newcomb-Benford law, also known as the first-digit law, gives the probability distribution associated with the first digit of a dataset so that, for example, the first significant digit has a probability of 30.1% of being 1 and 4.58% of being 9. This law can be extended to the second and next significant digits. This article presents an introduction to the discovery of the law and its derivation from the scale invariance property as well as some applications and examples. Additionally, a simple model of a Markov process inspired by scale invariance is proposed. Within this model, it is proved that the probability distribution irreversibly converges to the Newcomb-Benford law, in analogy to the irreversible evolution toward equilibrium of physical systems in thermodynamics and statistical mechanics. © 2021 Author(s).
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Durand, M.
7202661430;
Mechanical approach to surface tension and capillary phenomena
(2021) American Journal of Physics, 89 (3), pp. 261-266.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-85101319315&doi=10.1119%2f10.0002411&partnerID=40&md5=9478d4f0ba7c20bd92ada20de7dea31f

DOI: 10.1119/10.0002411
AFFILIATIONS: Matière et Systèmes Complexes (MSC), UMR 7057 CNRS, Université de Paris, 10 rue Alice Domon et Léonie Duquet, Paris Cedex 13, 75205, France
ABSTRACT: Many textbooks dealing with surface tension favor the thermodynamic approach (minimization of some thermodynamic potential such as free energy) over the mechanical approach (balance of forces) to describe capillary phenomena, stating that the latter is flawed and misleading. Yet, a mechanical approach is more intuitive for students than free energy minimization, and does not require any knowledge of thermodynamics. In this paper, we show that capillary phenomena can be correctly described using the mechanical approach, as long as the system on which the forces act is properly defined. After reviewing the microscopic origin of a tangential tensile force at the interface, we derive the Young-Dupré equation, emphasizing that this relation should be interpreted as an interface condition at the contact line, rather than a force balance equation. This correct interpretation avoids misidentification of capillary forces acting on a given system. Moreover, we show that a reliable method to correctly identify the acting forces is to define a control volume that does not embed any contact line on its surface. Finally, as an illustration of this method, we apply the mechanical approach in a variety of ways on a classic example: the derivation of the equilibrium height of capillary rise (Jurin's law). © 2021 American Association of Physics Teachers.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Roll, M.F.
24081198400;
Generalizing thermal resistance and a general thermal engine
(2020) American Journal of Physics, 88 (10), pp. 819-824.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-

85092450440&doi=10.1119%2f10.0001612&partnerID=40&md5=9df329c9c8b3803951b895db7e01104b

DOI: 10.1119/10.0001612
AFFILIATIONS: Department of Chemical and Materials Engineering, University of Idaho, Moscow, ID 83844-3024, United States
ABSTRACT: This article outlines a generalization of the thermal resistance concept used to model and quantify the rates of spontaneous heat transfer. This leads to the natural corollary that a Carnot cycle possesses zero thermal resistance and provides restatements of the Clausius and Kelvin statements of the second law of thermodynamics. Subsequently, basic aspects of a general thermal engine are modeled by the series combination of two non-zero thermal resistances with a Carnot cycle. With constant thermal resistances, the efficiency at maximum power is found to be in agreement with previous literature also concluding that engine power is zero at the Carnot efficiency. An explicit form limiting maximum power output to system thermal resistance and reservoir temperatures is given. Minimizing the thermal resistance maximizes power output, congruent with maximizing heat flow and entropy production. Implications of this model towards practical power generation are presented. © 2020 American Association of Physics Teachers.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Romanelli, A.
56219780800;
Stirling engine operating at low temperature difference
(2020) American Journal of Physics, 88 (4), pp. 319-324. Cited 3 times.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-85082429355&doi=10.1119%2f10.0000832&partnerID=40&md5=665165829a7216fd59003dd76acacc78

DOI: 10.1119/10.0000832
AFFILIATIONS: Instituto de Física, Facultad de Ingeniería, Universidad de la República, C.C. 30, Montevideo, C.P. 11000, Uruguay
ABSTRACT: This paper develops the dynamics and thermodynamics of Stirling engines that run with temperature differences below 100 °C. The working gas pressure is analytically expressed using an alternative thermodynamic cycle. The shaft dynamics is studied using its rotational equation of motion. It is found that the initial volumes of the cold and hot working gas play a non-negligible role in the functioning of the engine. © 2020 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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Zuckerman, D.M.
57203258161;
Key biology you should have learned in physics class: Using ideal-gas mixtures to understand biomolecular machines
(2020) American Journal of Physics, 88 (3), pp. 182-193. Cited 1 time.
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DOI: 10.1119/10.0000634
AFFILIATIONS: Department of Biomedical Engineering, Oregon Health and Science University, Portland, OR 97239, United States
ABSTRACT: The biological cell exhibits a fantastic range of behaviors, but ultimately, these are governed by a handful of physical and chemical principles. Here, we explore a simple theory, known for decades and based on the simple thermodynamics of mixtures of ideal gases, that illuminates several key functions performed within the cell. Our focus is the free-energy-driven import and export of molecules, such as nutrients and other vital compounds, via transporter proteins. Complementary to a thermodynamic picture is a description of transporters via "mass-action" chemical kinetics, which lends further insights into biological machinery and free energy use. Both thermodynamic and kinetic descriptions can shed light on the fundamental non-equilibrium aspects of transport. On the whole, our biochemical-physics discussion will remain agnostic to chemical details, but we will see how such details ultimately enter a physical description through the example of the cellular fuel ATP. © 2020 American Association of Physics Teachers.
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Boyer, T.H.
7006188060;
Diamagnetic behavior in random classical radiation
(2019) American Journal of Physics, 87 (11), pp. 915-923. Cited 4 times.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-85073774487&doi=10.1119%2f1.5123158&partnerID=40&md5=57e945717ab198f493626fad32573963

DOI: 10.1119/1.5123158
AFFILIATIONS: Department of Physics, City College of the City, University of New York, New York, NY 10031, United States
ABSTRACT: Calculations for diamagnetic behavior involving Faraday induction appear in classical electromagnetism textbooks. These calculations give the charged particle motions correctly but then inaccurately introduce the statement that diamagnetism is incompatible with classical thermodynamics, and that quantum theory is required for diamagnetic behavior. Actually, if classical radiative equilibrium in classical zero-point radiation holds before the application of a magnetic field, then it will hold afterwards and will preserve the diamagnetic behavior obtained by the application of Faraday's law. Here, we consider the classical diamagnetism of a charged particle in an isotropic harmonic potential which follows from the four famous spectra of random classical radiation. The zero-point radiation spectrum fully justifies the analysis appearing in the textbooks of classical electromagnetism and in the work of Langevin. The Rayleigh-Jeans spectrum gives no diamagnetic behavior, as is consistent with the Bohr-van Leeuwen theorem. The Planck spectrum without zero-point radiation (surprisingly) gives no magnetic moment at low temperature and paramagnetic behavior at high temperature! Finally, the Planck spectrum with zero-point radiation gives diamagnetic behavior at low temperature and no magnetic moment at high temperature. This last result is in agreement with elementary quantum theory. Once again the Planck spectrum with zero-point radiation provides the best classical description. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Lemons, D.S.
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Thermodynamics of Benford's first digit law
(2019) American Journal of Physics, 87 (10), pp. 787-790. Cited 1 time.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-85072564395&doi=10.1119%2f1.5116005&partnerID=40&md5=7d4e0475741d33a714d19a67aab92554

DOI: 10.1119/1.5116005
AFFILIATIONS: Bethel College, North Newton, KS  87501, United States
ABSTRACT: According to Benford's first digit law, the frequency of appearance of the first digit d taken from various sets of data is log (1 + (1 / d)) where d = 1, 2,...9. I present a thermodynamic derivation of this law that follows from the unbiased partitioning of a conserved quantity whose pieces may fragment and combine. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Wang, J., Moniz, N.J.
22965300100;57210635990;
Analysis of thermodynamic problems with the Lambert W function
(2019) American Journal of Physics, 87 (9), pp. 752-757.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-85071167724&doi=10.1119%2f1.5115334&partnerID=40&md5=f70376c824cf03f5663c89249d3716e0

DOI: 10.1119/1.5115334
AFFILIATIONS: Department of Physics, University of Massachusetts Dartmouth, North Dartmouth, MA 02747, United States;
Naval Undersea Warfare Center, Newport, RI  02841, United States
ABSTRACT: We present an analysis of two problems in thermodynamics in terms of the Lambert W function, including the mean-field approximation of the Ising model, and Bose-Einstein condensation. Both problems are well known to exhibit the critical behavior of phase transition. Standard treatment of the problems involves numerical or graphical solutions. Utilizing justified simplifying approximations, we find a closed-form mean-field solution for the Ising model in terms of the special W function. With the same special function, we present an analysis of Bose-Einstein condensation, allowing approximate quantitative determination of the dependence of the chemical potential on

temperature without full numerical computation. The analysis helps to facilitate understanding and to gain insight on these processes involving phase transitions in a straightforward manner. © 2019 American Association of Physics Teachers.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Samuelsson, C.R., Elmgren, M., Xie, C., Haglund, J.
57205702440;6508139840;41461929600;36117486300;
Going through a phase: Infrared cameras in a teaching sequence on evaporation and condensation
(2019) American Journal of Physics, 87 (7), pp. 557-582. Cited 3 times.
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DOI: 10.1119/1.5110665
AFFILIATIONS: Department of Physics and Astronomy, Uppsala University, Box 516, Uppsala, 75120, Sweden;
Department of Chemistry - Ångström Laboratory, Uppsala University, Box 516, Uppsala, 75120, Sweden;
Concord Consortium, Concord, MA 01742, United States;
Department of Engineering and Physics, Karlstad University, Karlstad, 65188, Sweden
ABSTRACT: Phase transitions are everyday occurring phenomena, but students often find them difficult to comprehend, not least in terms of the principles of thermal physics. To be able to explain phase transitions in primary school, teachers need to understand various concepts and phenomena, such as condensation, evaporation, energy, and temperature. As energy is absorbed or released during phase transitions, changes in temperature can occur. Infrared (IR) cameras can thus be utilized to visually observe and explore surface phenomena such as condensation and evaporation. In line with the resources framework, we have designed a teaching sequence which involves both everyday experiences and observations through IR cameras, and which is designed to encourage students to leverage common resources associated with evaporation and condensation. In testing our teaching sequence, we presented three thermal phenomena to a group of pre-service teacher students. Two of these phenomena, namely, walking out of a shower and sitting in a sauna, were anchored in embodied experiences to hopefully activate the students' resources and to make the students pay attention to the thermally relevant aspects. The third phenomenon was less familiar, involving the condensation of water on a piece of paper. The result shows that the students managed to carry out the sequence with the three phenomena and applied an explanatory model across all three to consistently explain evaporation. However, the lack of a more general model of chemical bonding and an overreliance on the second law of thermodynamics seem to have acted as barriers for the students' forming of a coherent understanding of both evaporation and condensation. © 2019 American Association of Physics Teachers.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Bauer, C.F., Chan, J.Y.K.
7402388464;56493789600;
Non-science majors learn about heat, temperature, and thermodynamics using the particulate nature of matter and guided-inquiry instruction
(2019) American Journal of Physics, 87 (7), pp. 550-557.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-85067556734&doi=10.1119%2f1.5110500&partnerID=40&md5=fbb6b4d725e52ab890f660bed998dc73

DOI: 10.1119/1.5110500
AFFILIATIONS: Department of Chemistry, University of New Hampshire, Durham, NH 03824, United States;
Department of Chemistry, Biochemistry, and Physics, University of Tampa, Tampa, FL 33606, United States
ABSTRACT: Using a strong cooperative learning structure, an inquiry-based course Fire & Ice for non-science majors addresses the concepts of heat and temperature, as well as the historical development of these ideas. A coherent line of inquiry is developed based on the particulate nature of matter which guides students in constructing the concepts of kinetic molecular theory, absolute zero, thermal equilibrium, thermal conduction, energy conservation, and energy degradation. This is accomplished by interleaving hands-on explorations, question-based team discussions, data sharing, and whole class reviews. Student performance on an established thermal concept inventory shows significant improvement. Students also provided more mechanistic and detailed descriptions even as they struggle with precision of language. They perceived this course as different, challenging, accessible, social, and true to the label "inquiry." A complete video and materials record of the course is available at the UNH Scholars Repository. © 2019 American Association of Physics Teachers.

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PUBLICATION STAGE: Final
SOURCE: Scopus

Romanelli, A.
56219780800;
The Fluidyne engine
(2019) American Journal of Physics, 87 (1), pp. 33-37. Cited 1 time.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-85059318493&doi=10.1119%2f1.5078518&partnerID=40&md5=c2c04d3d8e691ed48598fdc54cf45960

DOI: 10.1119/1.5078518
AFFILIATIONS: Instituto de Física, Facultad de Ingeniería, Universidad de la República, C. C. 30, C.P. 11000, Montevideo, Uruguay
ABSTRACT: The Fluidyne is a two-part hot-air engine which has the peculiarity that both its power piston and displacer are liquids. Both parts operate in tandem with the common working gas (air) transferring energy from the displacer to the piston side, from which work is extracted. We describe analytically the thermodynamics of the Fluidyne engine using the approach previously developed for the Stirling engine. We obtain explicit expressions for the amplitude of the power piston movement and for the working gas temperatures and pressure as functions of the engine parameters. We also study numerically the power and efficiency of the engine in terms of the phase shift between the motions of the piston and displacer. © 2019 American Association of Physics Teachers.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Bizarro, J.P.S.
6602981277;
Erratum: The thermodynamic efficiency of heat engines with friction (American Journal of Physics (2012) 80 (298-305) DOI: 10.1119/1.3680168)
(2018) American Journal of Physics, 86 (10), p. 786.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-85053874587&doi=10.1119%2f1.5049354&partnerID=40&md5=d205f09a8ce6aa4601dc0fa9b8528be8

DOI: 10.1119/1.5049354
AFFILIATIONS: Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Universidade de Lisboa, Lisboa, 1049-001, Portugal
ABSTRACT: In the above article,1 p(1-γ)/γ in Eq. (29) should be replaced by p(1-γ)/γ, so this equation should read Th/Tc + ΔTc = Th - ΔTh/Tc = p(1-γ)/γ. (1) This was an isolated misprint, and the subsequent formulas were not affected in any way. © 2018 American Association of Physics Teachers.
DOCUMENT TYPE: Erratum
PUBLICATION STAGE: Final
SOURCE: Scopus

Leff, H.S.
36854071400;
Reversible and irreversible heat engine and refrigerator cycles
(2018) American Journal of Physics, 86 (5), pp. 344-353. Cited 9 times.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-85045831772&doi=10.1119%2f1.5020985&partnerID=40&md5=b3890aa11972e7934a1da19162aa39f8

DOI: 10.1119/1.5020985
AFFILIATIONS: California State Polytechnic University, Pomona, CA  91768, United States; Reed College, Portland, OR  97202, United States
ABSTRACT: Although no reversible thermodynamic cycles exist in nature, nearly all cycles covered in textbooks are reversible. This is a review, clarification, and extension of results and concepts for quasistatic, reversible and irreversible processes and cycles, intended primarily for teachers and students. Distinctions between the latter process types are explained, with emphasis on clockwise (CW) and counterclockwise (CCW) cycles. Specific examples of each are examined, including Carnot, Kelvin and Stirling cycles. For the Stirling cycle, potentially useful task-specific efficiency measures are proposed and illustrated. Whether a cycle behaves as a traditional refrigerator or heat engine can depend on whether it is reversible or irreversible. Reversible and irreversible-quasistatic CW cycles both satisfy Carnot's inequality for thermal efficiency, $\eta \leq \eta_{Carnot}$. Irreversible CCW cycles with two reservoirs satisfy the coefficient of performance inequality $K \leq K_{Carnot}$. However, an arbitrary reversible cycle satisfies $K \geq K_{Carnot}$ when compared with a

reversible Carnot cycle operating between its maximum and minimum temperatures, a potentially counterintuitive result. © 2018 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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SOURCE: Scopus

Romanelli, A.
56219780800;
Alternative thermodynamic cycle for the Stirling machine
(2017) American Journal of Physics, 85 (12), pp. 926-931. Cited 9 times.
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DOI: 10.1119/1.5007063
AFFILIATIONS: Instituto de Física, Facultad de Ingeniería, Universidad de la República, C.C. 30, Montevideo, C.P. 11000, Uruguay
ABSTRACT: We develop an alternative thermodynamic cycle for the Stirling machine, where the polytropic process plays a central role. Analytical expressions for pressure and temperatures of the working gas are obtained as a function of the volume and the parameter that characterizes the polytropic process. This approach achieves closer agreement with the experimental pressure-volume diagram and can be adapted to any type of Stirling engine. © 2017 American Association of Physics Teachers.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Dickerson, R.H., Mottmann, J.
57189460840;57212314689;
Reply to "Comment on 'Not all counterclockwise thermodynamic cycles are refrigerators'" [Am. J. Phys. 85, 861-863 (2017)]
(2017) American Journal of Physics, 85 (11), pp. 864-865. Cited 2 times.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-85049172319&doi=10.1119%2f1.5005929&partnerID=40&md5=6d0f98aab99c90b9951d51621d046028

DOI: 10.1119/1.5005929
AFFILIATIONS: Department of Physics, California Polytechnic State University, San Luis Obispo, CA 93407, United States
DOCUMENT TYPE: Letter
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Bizarro, J.P.S.
6602981277;
Comment on "Not all counter cloc kwise thermo dynamic cycles are refrigerators" [Am. J. Phys. 84, 413-418 (2016)]
(2017) American Journal of Physics, 85 (11), pp. 861-863. Cited 2 times.
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DOI: 10.1119/1.5005928
AFFILIATIONS: Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Universidade de Lisboa, Lisboa, 1049-001, Portugal
ABSTRACT: Contrary to what Dickerson and Mottmann [Am. J. Phys. 84, 413-418 (2016)] state, the temperatures at which a refrigerator's working fluid absorbs heat need not always lie below those at which it expels heat; nor must a refrigerator's thermodynamic cycle have two adiabats. Moreover, what Dickerson and Mottmann call a "comparison Carnot cycle" cannot always be defined. These conclusions are illustrated here using a counter-clockwise Stirling cycle without regeneration. A refrigerator's cold reservoir can absorb some heat and its hot reservoir can expel some heat, so long as the net heat flow is still out of the cold reservoir and into the hot reservoir. © 2017 American Association of Physics Teachers.
DOCUMENT TYPE: Note
PUBLICATION STAGE: Final
SOURCE: Scopus

Norton, J.D.

7402442406;
Thermodynamically reversible processes in statistical physics
(2017) American Journal of Physics, 85 (2), pp. 135-145. Cited 5 times.
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DOI: 10.1119/1.4966907
AFFILIATIONS: Department of History and Philosophy of Science, University of Pittsburgh, Pittsburgh, PA 15260, United States
ABSTRACT: Equilibrium states are used as limit states to define thermodynamically reversible processes. When these processes are understood in terms of statistical physics, these limit states can change with time due to thermal fluctuations. For macroscopic systems, the changes are insignificant on ordinary time scales and what little change there is can be suppressed by macroscopically negligible, entropy-creating dissipation. For systems of molecular sizes, the changes are large on short time scales. They can only sometimes be suppressed with significant entropy-creating dissipation, and this entropy creation is unavoidable if any process is to proceed to completion. As a result, at molecular scales, thermodynamically reversible processes are impossible in principle. Unlike the macroscopic case, they cannot be realized even approximately when we account for all sources of dissipation, and argumentation invoking them on molecular scales can lead to spurious conclusions. © 2017 American Association of Physics Teachers.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Mishchenko, E.G., Pshenichka, P.F.
7004354850;57192555513;
Reversible temperature exchange upon thermal contact
(2017) American Journal of Physics, 85 (1), pp. 23-29. Cited 2 times.
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DOI: 10.1119/1.4965292
AFFILIATIONS: Department of Physics and Astronomy, University of Utah, Salt Lake City, UT 84112, United States;
Lyceum #1, 2 Steinbarg St., Chernivtsi, 58002, Ukraine
ABSTRACT: According to a well-known principle of thermodynamics, the transfer of heat between two bodies is reversible when their temperatures are infinitesimally close. As we demonstrate, a little-known alternative exists: two bodies with temperatures different by an arbitrary amount can completely exchange their temperatures in a reversible way if split into infinitesimal parts that are brought into thermal contact sequentially. © 2016 American Association of Physics Teachers.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Opatrnỳ, T., Richterek, L., Bakala, P.
8388472100;55993191700;23026647000;
Life under a black sun
(2017) American Journal of Physics, 85 (1), pp. 14-22. Cited 10 times.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-85006757728&doi=10.1119%2f1.4966905&partnerID=40&md5=18319c7a3bda64e076fe6925459acef2

DOI: 10.1119/1.4966905
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Institute of Physics, Faculty of Philosophy and Science, Silesian University in Opava, Bezručovo nám. 13, Opava, CZ-74601, Czech Republic
ABSTRACT: Life is dependent on the income of energy with low entropy and the disposal of energy with high entropy. On Earth, the low-entropy energy is provided by solar radiation and the high-entropy energy is disposed of as infrared radiation emitted into cold space. Here, we turn the situation around and imagine the cosmic background radiation as the low-entropy source of energy for a planet orbiting a black hole into which the high-entropy energy is expelled. We estimate the power that can be produced by thermodynamic processes on such a planet, with a particular interest in planets orbiting a fast rotating Kerr black hole as in the science fiction movie Interstellar. We also briefly discuss a reverse Dyson sphere absorbing cosmic background radiation from the outside and dumping waste energy to a black hole inside. © 2016 American Association of Physics Teachers.

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Ribeiro, W.L., Landi, G.T., Semião, F.L.
57192182409;48662262400;6507256119;
Quantum thermodynamics and work fluctuations with applications to magnetic resonance
(2016) American Journal of Physics, 84 (12), pp. 948-957. Cited 8 times.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-84999788870&doi=10.1119%2f1.4964111&partnerID=40&md5=6efa416d08e7680d27d05ea9657357cf

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AFFILIATIONS: Universidade Federal do ABC, Santo André, 09210-580, Brazil;
Instituto de Física, Universidade de São Paulo, São Paulo, 05314-970, Brazil
ABSTRACT: In this paper, we give a pedagogical introduction to the ideas of quantum thermodynamics and work fluctuations, using only basic concepts from quantum and statistical mechanics. After reviewing the concept of work as usually taught in thermodynamics and statistical mechanics, we discuss the framework of non-equilibrium processes in quantum systems together with some modern developments, such as the Jarzynski equality and its connection to the second law of thermodynamics. We then apply these results to the problem of magnetic resonance, where all calculations can be done exactly. It is shown in detail how to build the statistics of the work, both for a single particle and for a collection of non-interacting particles. We hope that this paper will serve as a tool to bring the new student up to date on the recent developments in non-equilibrium thermodynamics of quantum systems. © 2016 American Association of Physics Teachers.
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Dickerson, R.H., Mottmann, J.
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Not all counterclockwise thermodynamic cycles are refrigerators
(2016) American Journal of Physics, 84 (6), pp. 413-418. Cited 7 times.
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DOI: 10.1119/1.4945266
AFFILIATIONS: Physics Department, California Polytechnic State University, San Luis Obispo, CA 93407, United States
ABSTRACT: Clockwise cycles on PV diagrams always represent heat engines. It is therefore tempting to assume that counterclockwise cycles always represent refrigerators. This common assumption is incorrect: most counterclockwise cycles cannot be refrigerators. This surprising result is explored here for quasi-static ideal gas cycles, and the necessary conditions for refrigeration cycles are clarified. Three logically self-consistent criteria can be used to determine if a counterclockwise cycle is a refrigerator. The most fundamental test compares the counterclockwise cycle with a correctly determined corresponding Carnot cycle. Other criteria we employ include a widely accepted description of the functional behavior of refrigerators, and a corollary to the second law that limits a refrigerator's coefficient of performance. © 2016 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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Bohren, C.F.
7004199444;
What my dogs forced me to learn about thermal energy transfer
(2015) American Journal of Physics, 83 (5), pp. 443-446. Cited 2 times.
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DOI: 10.1119/1.4901975
AFFILIATIONS: Department of Meteorology, Pennsylvania State University, University Park, PA 16820, United States
ABSTRACT: Some objects feel colder to the touch than others at the same (room) temperature. But explaining why by linear, single-factor reasoning is inadequate because the time-dependent thermal energy transfer at solid interfaces initially at different temperatures is determined by the thermal inertia $\sqrt{k\rho c}$, a function of three thermophysical properties: thermal conductivity k, density ρ, and

specific heat capacity per unit mass c. In time-dependent problems 1/√kpc plays the role of a resistance. As an example, although the thermal conductivity of aluminum is 16 times that of stainless steel, this does not translate into a 16-fold difference in interfacial thermal energy flux densities. Nor does it result in a markedly greater perceived coldness of aluminum; the difference is barely perceptible. Similarly, despite the 600-fold difference in the thermal conductivity of iron relative to that of wood, the ratio of thermal energy flux densities is only about 4.6. © 2015 American Association of Physics Teachers.
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De Palma, G., Sormani, M.C.
55781428900;55631744400;
Counterintuitive effect of gravity on the heat capacity of a solid sphere: Re-examination of a well-known problem
(2015) American Journal of Physics, 83 (8), pp. 723-729. Cited 1 time.
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DOI: 10.1119/1.4922257
AFFILIATIONS: NEST, Scuola Normale Superiore and Istituto Nanoscienze-CNR, Pisa, I-56127, Italy;
INFN, Pisa, Italy;
Rudolf Peierls Centre for Theoretical Physics, 1 Keble Road, Oxford, United Kingdom
ABSTRACT: A well-known high-school problem asking the final temperature of two identical spheres that are given the same amount of heat, one lying on a table and the other hanging from a thread, is re-examined. The conventional solution states that the sphere on the table ends up colder, because thermal expansion raises its center of mass. This solution violates the second law of thermodynamics and is therefore incorrect. Two different new solutions are proposed. The first uses statistical mechanics, while the second is based on purely classical thermodynamical arguments. Gravity produces a counterintuitive effect on the heat capacity, and the new answer to the problem goes in the opposite direction of what has been traditionally thought. © 2015 American Association of Physics Teachers.
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Marsland, R., III, Brown, H.R., Valente, G.
6602920011;7401500338;22735245700;
Time and irreversibility in axiomatic thermodynamics
(2015) American Journal of Physics, 83 (7), pp. 628-634. Cited 4 times.
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DOI: 10.1119/1.4914528
AFFILIATIONS: Department of Physics, Massachusetts Institute of Technology, Cambridge, MA 02139-4307, United States;
Faculty of Philosophy, University of Oxford, Radcliffe Humanities, Woodstock Road, Oxford, OX2 6GG, United Kingdom;
Department of Philosophy, University of Pittsburgh, 1001 Cathedral of Learning, Pittsburgh, PA 15260, United States
ABSTRACT: Thermodynamics is the paradigm example in physics of a time-asymmetric theory, but the origin of the asymmetry lies deeper than the second law. A primordial arrow can be defined by the way of the equilibration principle ("minus first law"). By appealing to this arrow, the nature of the wellknown ambiguity in Carathéodory's 1909 version of the second law becomes clear. Following Carathéodory's seminal work, formulations of thermodynamics have gained ground that highlight the role of the binary relation of adiabatic accessibility between equilibrium states, the most prominent recent example being the important 1999 axiomatization due to Lieb and Yngvason. This formulation can be shown to contain an ambiguity strictly analogous to that in Carathéodory's treatment. © 2015 American Association of Physics Teachers.
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Swendsen, R.H.
57206454584;

The ambiguity of "Distinguishability" in statistical mechanics
(2015) American Journal of Physics, 83 (6), pp. 545-554. Cited 7 times.
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DOI: 10.1119/1.4906793
AFFILIATIONS: Physics Department, Carnegie Mellon University, Pittsburgh, PA 15213, United States
ABSTRACT: Differences of opinion concerning fundamental issues in statistical mechanics directly related to the thermodynamic entropy have persisted through more than a century of debate. One reason is the lack of consensus on the definitions of key terms, especially the terms " distinguishable," " indistinguishable," and " identical." Several definitions occur in the literature, but are not always made explicit. The multiplicity of definitions has created confusion about the basic conditions under which entropy is to be defined. In this paper, I present an overview of definitions in current use for terms associated with distinguishability and relate them to various definitions that have been suggested for entropy. My hope is that consensus will be achievable if the definitions are clarified and agreed upon. © 2015 American Association of Physics Teachers.
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Dreyfus, B.W., Geller, B.D., Meltzer, D.E., Sawtelle, V.
7005570793;56008630300;7004705182;22952114300;
Resource Letter TTSM-1: Teaching Thermodynamics and Statistical Mechanics in Introductory Physics, Chemistry, and Biology
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DOI: 10.1119/1.4891673
AFFILIATIONS: Department of Physics, University of Maryland, College Park, MD 20742, United States;
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Department of Physics, University of Maryland, College Park, MD 20742, United States
ABSTRACT: This Resource Letter draws on discipline-based education research from physics, chemistry, and biology to collect literature on the teaching of thermodynamics and statistical mechanics in the three disciplines. While the overlap among the disciplinary literatures is limited at present, we hope this Resource Letter will spark more interdisciplinary interaction. © 2015 American Association of Physics Teachers.
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Boozer, A.D.
57206527054;
Thermodynamic time asymmetry and the Boltzmann equation
(2014) American Journal of Physics, 83 (3), pp. 223-230. Cited 2 times.
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DOI: 10.1119/1.4898433
AFFILIATIONS: Department of Mathematics, University of California Los Angeles, Los Angeles, CA 90095, United States
ABSTRACT: An important result of statistical mechanics is the Boltzmann equation, which describes the evolution of the velocity distribution of a gas towards the equilibrium Maxwell distribution. We introduce the Boltzmann equation by considering a dynamical model of a two-dimensional gas consisting of hard disks. We derive the Boltzmann equation for the model and compare the behavior predicted by this equation against the actual behavior of the system as observed in computer simulations. A puzzling feature of the Boltzmann equation is that although the dynamical laws governing the gas are time-reversal invariant, the behavior predicted by the Boltzmann equation is time asymmetric. We show that this time asymmetry arises from assumptions made in the derivation of the Boltzmann equation, and we use computer simulations of the model system to investigate the circumstances under which these assumptions hold. © 2015 American Association of Physics Teachers.
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Popp, T.R., III, Hollingshead, K.B., Truskett, T.M.
56529226000;25651538400;6701644278;
Web applet for predicting structure and thermodynamics of complex fluids
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DOI: 10.1119/1.4898626
AFFILIATIONS: McKetta Department of Chemical Engineering, The University of Texas at Austin, Austin, TX 78712, United States
ABSTRACT: Based on a recently introduced analytical strategy [Hollingshead et al., J. Chem. Phys. 139, 161102 (2013)], we present a web applet that can quickly and semi-quantitatively estimate the equilibrium radial distribution function and related thermodynamic properties of a fluid from knowledge of its pair interaction. We describe the applet's features and present two (of many possible) examples of how it can be used to illustrate concepts of interest for introductory statistical mechanics courses: the transition from ideal gas-like behavior to correlated-liquid behavior with increasing density, and the tradeoff between dominant length scales with changing temperature in a system with ramp-shaped repulsions. The latter type of interaction qualitatively captures distinctive thermodynamic properties of liquid water, because its energetic bias toward locally open structures mimics that of water's hydrogen-bond network. © 2015 American Association of Physics Teachers.
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Frenkel, D., Warren, P.B.
7005702293;55777516700;
Gibbs, Boltzmann, and negative temperatures
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DOI: 10.1119/1.4895828
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ABSTRACT: In a recent paper, Dunkel and Hilbert [Nat. Phys. 10, 67-72 (2014)] use an entropy definition due to Gibbs to provide a "consistent thermostatistics" that forbids negative absolute temperatures. Here, we argue that the Gibbs entropy fails to satisfy a basic requirement of thermodynamics, namely, that when two bodies are in thermal equilibrium, they should be at the same temperature. The entropy definition due to Boltzmann does meet this test, and moreover, in the thermodynamic limit can be shown to satisfy Dunkel and Hilbert's consistency criterion. Thus, far from being forbidden, negative temperatures are inevitable, in systems with bounded energy spectra. © 2015 American Association of Physics Teachers.
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Hughes, A.P., Archer, A.J., Thiele, U.
56427452000;7007125603;7004209209;
An introduction to inhomogeneous liquids, density functional theory, and the wetting transition
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https://www.scopus.com/inward/record.uri?eid=2-s2.0-84912010798&doi=10.1119%2f1.4890823&partnerID=40&md5=49dbfe49cd23273914466b7037d3c62c

DOI: 10.1119/1.4890823
AFFILIATIONS: Department of Mathematical Sciences, Loughborough University, Loughborough, Leicestershire, LE11 3TU, United Kingdom;
Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster, Wilhelm Klemm Str. 9, Münster, D-48149, Germany
ABSTRACT: Classical density functional theory (DFT) is a statistical mechanical theory for calculating the density profiles of the molecules in a liquid. It is widely used, for example, to study the density distribution of the molecules near a confining wall, the interfacial tension, wetting behavior, and many other properties of nonuniform liquids. DFT can, however, be somewhat

daunting to students entering the field because of the many connections to other areas of liquid-state science that are required and used to develop the theories. Here, we give an introduction to some of the key ideas, based on a lattice-gas (Ising) model fluid. This approach builds on knowledge covered in most undergraduate statistical mechanics and thermodynamics courses, so students can quickly get to the stage of calculating density profiles, etc., for themselves. We derive a simple DFT for the lattice gas and present some typical results that can readily be calculated using the theory. © 2014 American Association of Physics Teachers.
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Swendsen, R.H.
6701588841;
Unnormalized probability: A different view of statistical mechanics
(2014) American Journal of Physics, 82 (10), art. no. 480, . Cited 10 times.
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DOI: 10.1119/1.4883480
AFFILIATIONS: Physics Department, Carnegie Mellon University, Pittsburgh, PA 15213, United States
ABSTRACT: All teachers and students of physics have absorbed the doctrine that probability must be normalized. Nevertheless, there are problems for which the normalization factor only gets in the way. An important example of this counter-intuitive assertion is provided by the derivation of the thermodynamic entropy from the principles of statistical mechanics. Unnormalized probabilities provide a surprisingly effective teaching tool that can make it easier to explain to students the essential concept of entropy. The elimination of the normalization factor offers simpler equations for thermodynamic equilibrium in statistical mechanics, which then lead naturally to a new and simpler definition of the entropy in thermodynamics. Notably, this definition does not change the formal expression of the entropy based on composite systems that I have previously offered. My previous definition of entropy has been criticized by Dieks, based on what appears to be a misinterpretation. I believe that the new definition presented here has the advantage of greatly reducing the possibility of such a misunderstanding-either by students or by experts. © 2014 American Association of Physics Teachers.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Redish, E.F., Bauer, C., Carleton, K.L., Cooke, T.J., Cooper, M., Crouch, C.H., Dreyfus, B.W., Geller, B.D., Giannini, J., Gouvea, J.S., Klymkowsky, M.W., Losert, W., Moore, K., Presson, J., Sawtelle, V., Thompson, K.V., Turpen, C., Zia, R.K.P.
6602125605;7402388464;6603395298;7103141020;35766303800;35565291200;7005570793;56008630300;57195955809;56008790800;7004889703;7006183654;57198867776;6603713515;22952114300;56213291700;6603223407;7005437844;
NEXUS/Physics: An interdisciplinary repurposing of physics for biologists
(2014) American Journal of Physics, 82 (5), art. no. 1.4870386, . Cited 48 times.
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DOI: 10.1119/1.4870386
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College of Computer, Mathematical and Natural Sciences, University of Maryland, College Park, MD 20742, United States;
Department of Physics, Virginia Tech, Blacksburg, VA 24061, United States;

Department of Physics and Astronomy, Iowa State university, Ames, IA  50011, United States
ABSTRACT: In response to increasing calls for the reform of the undergraduate science curriculum for life science majors and pre-medical students (Bio2010, Scientific Foundations for Future Physicians, Vision & Change), an interdisciplinary team has created NEXUS/Physics: a repurposing of an introductory physics curriculum for the life sciences. The curriculum interacts strongly and supportively with introductory biology and chemistry courses taken by life-science students, with the goal of helping students build general, multi-discipline scientific competencies. NEXUS/Physics stresses interdisciplinary examples and the content differs markedly from traditional introductory physics to facilitate this: it extends the discussion of energy to include interatomic potentials and chemical reactions, the discussion of thermodynamics to include enthalpy and Gibbs free energy and includes a serious discussion of random vs coherent motion including diffusion. The development of instructional materials is coordinated with careful education research. Both the new content and the results of the research are described in a series of papers for which this paper serves as an overview and context. © 2014 American Association of Physics Teachers.
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Geller, B.D., Dreyfus, B.W., Gouvea, J., Sawtelle, V., Turpen, C., Redish, E.F.
56008630300;7005570793;56008790800;22952114300;6603223407;6602125605;
Entropy and spontaneity in an introductory physics course for life science students
(2014) American Journal of Physics, 82 (5), art. no. 1.4870389, . Cited 23 times.
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DOI: 10.1119/1.4870389
AFFILIATIONS: Department of Physics, University of Maryland, College Park, MD  20742, United States
ABSTRACT: Life science students develop a variety of resources for thinking about entropy and spontaneity in their biology, chemistry, and introductory physics courses. Helping students to develop a deeper and more coherent conceptual framework for organizing these varied ideas means attending carefully to the ways in which students interact with different disciplinary descriptions and to the ways in which these descriptions may be in tension. Canonical introductory physics treatments of the second law of thermodynamics, while useful in some contexts, may not be the most productive ones in authentic biological or chemical contexts. We draw on case-study interviews with introductory physics for life science students to argue that an approach to the second law of thermodynamics that emphasizes the interplay of energy and entropy in determining spontaneity (one that involves a central role for free energy) is one that draws on students' resources from biology and chemistry in particularly effective ways. We see the positioning of entropic arguments alongside energetic arguments in the determination of spontaneity as an important step toward making our life science students' biology, chemistry, and physics experiences more coherent. © 2014 American Association of Physics Teachers.
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Krafcik, M., Velasco, E.S.
56638633100;56637942200;
Beyond Clausius-Clapeyron: Determining the second derivative of a first-order phase transition line
(2014) American Journal of Physics, 82 (4), art. no. 1.4858403, . Cited 3 times.
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DOI: 10.1119/1.4858403
AFFILIATIONS: Department of Physics, Truman State University, Kirksville, MI  63501, United States; Purdue University, School of Materials Engineering, Neil Armstrong Hall of Engineering, 701 West Stadium Avenue, West Lafayette, IN  47907-2045, United States
ABSTRACT: We obtain an expression for the second derivative of the line in a PT diagram denoting a first-order phase transition for a pure hydrostatic system. Our result goes beyond the classical Clausius-Clapeyron equation, which provides only the first derivative of the pressure with respect to the temperature along the transition line. We present two pedagogical derivations suitable for an undergraduate thermodynamics class; the first one uses derivatives of the entropy while the second one uses derivatives of the enthalpy. The final expression for the second derivative involves only standard thermodynamic quantities such as the specific heats, the isothermal compressibilities, and the coefficients of thermal expansion of the two phases at the transition line. As an illustration, we compute the second derivatives of the freezing and vaporization lines of water at atmospheric

pressure, and show that at this pressure the freezing line is concave down (negative second derivative) while the vaporization line is concave up (positive second derivative). © 2014 American Association of Physics Teachers.
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Shieh, L.-Y., Kan, H.-C.
56637923300;7101603405;
Advantages of using a logarithmic scale in pressure-volume diagrams for Carnot and other heat engine cycles
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DOI: 10.1119/1.4860656
AFFILIATIONS: Department of Physics, National Chung Cheng University, Chia-Yi, 621, Taiwan
ABSTRACT: We demonstrate that plotting the P-V diagram of an ideal gas Carnot cycle on a logarithmic scale results in a more intuitive approach for deriving the final form of the efficiency equation. The same approach also facilitates the derivation of the efficiency of other thermodynamic engines that employ adiabatic ideal gas processes, such as the Brayton cycle, the Otto cycle, and the Diesel engine. We finally demonstrate that logarithmic plots of isothermal and adiabatic processes help with visualization in approximating an arbitrary process in terms of an infinite number of Carnot cycles. © 2014 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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Zürcher, U.
55900237100;
Thermodynamics of bread baking: A two-state model
(2014) American Journal of Physics, 82 (3), art. no. 1.4848135, . Cited 1 time.
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DOI: 10.1119/1.4848135
AFFILIATIONS: Physics Department, Cleveland State University, Cleveland, OH  44115, United States
ABSTRACT: Bread baking can be viewed as a complex physico-chemical process. It is governed by transport of heat and is accompanied by changes such as gelation of starch, the expansion of air cells within dough, and others. We focus on the thermodynamics of baking and investigate the heat flow through dough and find that the evaporation of excess water in dough is the rate-limiting step. We consider a simplified one-dimensional model of bread, treating the excess water content as a two-state variable that is zero for baked bread and a fixed constant for unbaked dough. We arrive at a system of coupled, nonlinear ordinary differential equations, which are solved using a standard Runge-Kutta integration method. The calculated baking times are consistent with common baking experience. © 2014 American Association of Physics Teachers.
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Patitsas, S.N.
6507799760;
Onsager symmetry relations and ideal gas effusion: A detailed example
(2014) American Journal of Physics, 82 (2), art. no. 1.4827829, . Cited 1 time.
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DOI: 10.1119/1.4827829
AFFILIATIONS: Department of Physics and Astronomy, University of Lethbridge, 4401 University Drive, Lethbridge, AB  T1K3M4, Canada
ABSTRACT: Onsager coefficients are calculated for the approach of a gas to equilibrium by effusion between two chambers. Using kinetic gas theory, the Onsager symmetry relation is explicitly verified. The approach to equilibrium is determined by two time scales that are explicitly calculated; this is followed by example calculations for dynamics of the system approaching equilibrium in several ways. Also, calculations for the cross-correlation functions for this system are presented, which are used

to calculate various noise spectral functions. This study provides students of statistical mechanics and thermodynamics with a good example to aid in understanding some of the general concepts encountered in studies of non-equilibrium systems. © 2014 American Association of Physics Teachers.
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Roundy, D., Kustusch, M.B., Manogue, C.
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Name the experiment! Interpreting thermodynamic derivatives as thought experiments
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DOI: 10.1119/1.4824548
AFFILIATIONS: Department of Physics, Oregon State University, Corvallis, OR 97331, United States
ABSTRACT: We introduce a series of activities to help students understand the partial derivatives that arise in thermodynamics. Students construct thought experiments that would allow them to measure given partial derivatives. These activities are constructed with a number of learning goals in mind, beginning with helping students to learn to think of thermodynamic quantities in terms of how one can measure or change them. A second learning goal is for students to understand the importance of the quantities held fixed in either a partial derivative or an experiment. Students additionally are given an experimental perspective-particularly when this activity is combined with real laboratory experiments-on the meaning of either fixing or changing entropy. In this paper, we introduce the activities and explain their learning goals. We also include examples of student work from classroom video and follow-up interviews. © 2014 American Association of Physics Teachers.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Price, T., Swendsen, R.H.
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DOI: 10.1119/1.4822174
AFFILIATIONS: Department of Physics, Carnegie Mellon University, Pittsburgh, PA 15213, United States
ABSTRACT: The study of ideal quantum gases reveals surprising quantum effects that can be observed in macroscopic systems. The properties of bosons are particularly unusual because a macroscopic number of particles can occupy a single quantum state. We describe a computational approach that supplements the usual analytic derivations applicable in the thermodynamic limit. The approach involves directly summing over the quantum states for finite systems and avoids the need for doing difficult integrals. The results display the unusual behavior of quantum gases even for relatively small systems. © 2013 American Association of Physics Teachers.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Romanelli, A., Bove, I., González Madina, F.
56219780800;6507693223;55862889800;
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DOI: 10.1119/1.4811116
AFFILIATIONS: Instituto de Física, Facultad de Ingeniería, Universidad de la República, C.C. 30, C.P. 11300, Montevideo, Uruguay
ABSTRACT: We study the thermodynamics of a water rocket in the thrust phase, taking into account the expansion of the air with water vapor, vapor condensation, and the corresponding latent heat. We set up a simple experimental device with a stationary bottle and verify that the gas expansion in the bottle is well approximated by a polytropic process $PV^{\beta}$ = constant, where the parameter $\beta$ depends on the initial conditions. We find an analytical expression for $\beta$ that depends only on the thermodynamic

initial conditions and is in good agreement with the experimental results. © 2013 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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Swendsen, R.H.
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Using computation to teach the properties of the van der Waals fluid
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DOI: 10.1119/1.4819166
AFFILIATIONS: Department of Physics, Carnegie Mellon University, Pittsburgh, PA 15213, United States
ABSTRACT: The calculation of the thermodynamic properties of the van der Waals fluid is not trivial and most of its properties are rarely discussed because of mathematical difficulties. I describe a numerical approach that produces the full thermodynamic behavior of the van der Waals fluid with little effort. The numerical approach is particularly useful for showing the behavior of the specific heat, the isothermal compressibility, and the coefficient of thermal expansion at and near the critical point. The results of these computations show some surprising properties and give new insights into the mean-field description of the liquid-gas transition. © 2013 American Association of Physics Teachers.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Gangopadhyaya, A., Ramsey, G.
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Unintended consequences of imprecise notation: An example from mechanics
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DOI: 10.1119/1.4769255
AFFILIATIONS: Department of Physics, Loyola University Chicago, 1032 W. Sheridan Rd., Chicago IL 60660, United States
ABSTRACT: We present a conundrum that results from the imprecise use of notation for partial derivatives. Taking an example from mechanics, we show that lack of proper care in representing partial derivatives in the Lagrangian and Hamiltonian formulations paradoxically leads to two different values for the time derivative of the canonical momentum. Similar apparent paradoxes occur in other areas of physics, such as thermodynamics. © 2013 American Association of Physics Teachers.
DOCUMENT TYPE: Note
PUBLICATION STAGE: Final
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Penelet, G., Biwa, T.
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Synchronization of a thermoacoustic oscillator by an external sound source
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DOI: 10.1119/1.4776189
AFFILIATIONS: LUNAM Université, Université du Maine, CNRS UMR 6613, Laboratoire d'Acoustique de l'Université du Maine, Avenue Olivier Messiaen, 72085 Le Mans Cedex 9, France;
Department of Mechanical Systems and Design, Tohoku University, 980-8579 Sendai, Japan
ABSTRACT: Since the pioneering work of Christiaan Huygens on the sympathy of pendulum clocks, synchronization phenomena have been widely observed in nature and science. In this paper, we describe a simple experiment, with a thermoacoustic oscillator driven by a loudspeaker, which exhibits several aspects of synchronization. Both the synchronization region of leading order around the oscillator's natural frequency f0 and regions of higher order (around f0/2 and f0/3) are measured as functions of the loudspeaker voltage and frequency. We also show that increasing the coupling between the loudspeaker and the oscillator gives rise under some circumstances to the death of self-sustained oscillations (quenching). Moreover, two additional set of experiments are performed: the first

investigates a feedback loop in which the signal captured by the microphone is delivered to the loudspeaker through a phase-shifter; the second investigates the nontrivial interaction between the loudspeaker and the oscillator when the latter acts as a relaxation oscillator (spontaneous and periodic onset/damping of self-sustained oscillations). The experiment is easy to build and highly demonstrative; it might be of interest for classroom demonstrations or an instructional lab dealing with nonlinear dynamics. © 2013 American Association of Physics Teachers.
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Noda, D., Ueda, Y.
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A thermoacoustic oscillator powered by vaporized water and ethanol
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DOI: 10.1119/1.4766940
AFFILIATIONS: Graduate school of Bio-Applications and Systems Engineering, Tokyo University of Agriculture and Technology, 2-24-16 Nakacho, Koganei, Tokyo 184-8588, Japan
ABSTRACT: We measure the temperature difference required to drive a thermoacoustic oscillator containing air, water vapor, and liquid water as the working fluids. The oscillator is composed of a large tube containing an array of narrow tubes connected at one end to a tank of liquid water. When the water is heated, the temperature difference across the tube array increases until thermoacoustic oscillations occur. The temperature difference at the onset of oscillation is measured to be 56 °C, significantly smaller (by ~200 °C) than the temperature measured when the tank is filled with dry air instead of water. The temperature difference can be further reduced to 47 °C by using ethanol instead of water. © 2013 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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Rezaeizadeh, A., Mameghani, P.
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Thermodynamic model for bouncing charged particles inside a capacitor
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DOI: 10.1119/1.4812322
AFFILIATIONS: Department of Electrical Engineering, Sharif University of Technology, Tehran, 11155-9161, Iran
ABSTRACT: We introduce an equation of state for a conducting particle inside a charged parallel-plate capacitor and show that it is similar to the equation of state for an ideal gas undergoing an adiabatic process. We describe a simple experiment that shows reasonable agreement with the theoretical model. © 2013 American Association of Physics Teachers.
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Exploring the thermodynamics of a rubber band
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DOI: 10.1119/1.4757908
AFFILIATIONS: Department of Physics, Oregon State University, Corvallis, OR 97331, United States; Department of Physics, Ithaca College, Ithaca, NY 14850, United States
ABSTRACT: We describe an upper-division experiment in thermal physics where students measure the tension of a rubber band as a function of temperature and length and use a Maxwell relation to find the change in internal energy and entropy for an isothermal stretch. This allows students to experimentally check the predictions of the entropic spring model for elastomers and observe that the entropy does indeed decrease as a rubber band is stretched. © 2013 American Association of Physics

Teachers.
DOCUMENT TYPE: Article
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Binder, K., Block, B.J., Virnau, P., Tröster, A.
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DOI: 10.1119/1.4754020
AFFILIATIONS: Institut für Physik, Johannes Gutenberg-Universität, Staudinger Weg 7, 55099 Mainz, Germany;
Vienna University of Technology, Wiedner Hauptstr. 8-10/136, A-1040 Vienna, Austria
ABSTRACT: As a rule, mean-field theories applied to a fluid that can undergo a transition from saturated vapor at density ρ υ to a liquid at density ρ ℓ yield a van der Waals loop. For example, isotherms of the chemical potential μ(T,ρ) as a function of the density ρ at a fixed temperature T less than the critical temperature T c exhibit a maximum and a minimum. Metastable and unstable parts of the van der Waals loop can be eliminated by the Maxwell construction. Van der Waals loops and the corresponding double minimum potentials are mean-field artifacts. Simulations at fixed μ=μ coex for ρ υ<ρ<ρ ℓ yield a loop, but for sufficiently large systems this loop does not resemble the van der Waals loop and reflects interfacial effects on phase coexistence due to finite size effects. In contrast to the van der Waals loop, all parts of the loop found in simulations are thermodynamically stable. The successive umbrella sampling algorithm is described as a convenient tool for seeing these effects. It is shown that the maximum of the loop is not the stability limit of a metastable vapor but signifies the droplet evaporation-condensation transition. The descending part of the loop contains information on Tolman-like corrections to the surface tension, rather than describing unstable states. © 2012 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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Rebilas, K.
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DOI: 10.1119/1.4728999
AFFILIATIONS: Katedra Chemii i Fizyki, Uniwersytet Rolniczy im. Hugona Kołłataja w Krakowie, Al. Mickiewicza 21, 31-120 Kraków, Poland
ABSTRACT: This article derives and explains the emergence of one-time-direction macroscopic evolution of a classical system of two mixed gases having different temperatures. The analysis performed at the microscopic level, where the time-symmetric laws of mechanics govern the particle collisions, leads to a time-asymmetric macroscopic heat transfer equation and a theorem analogous to the Boltzmann H-theorem. The velocity distributions of the incoming and outgoing particles should satisfy some statistical symmetries. The time-reversed evolution is highly improbable because it would break these symmetries. Additionally, some remarks explaining implicit time-asymmetry of the Boltzmann Stosszahlansatz (collision number assumption) are made. © 2012 American Association of Physics Teachers.
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Kramer, E.M., Myers, D.R.
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DOI: 10.1119/1.4722325
AFFILIATIONS: Physics Department, Bard College at Simon's Rock, Great Barrington, MA 01230, United States;
Chemistry Department, Bard College at Simon's Rock, Great Barrington, MA 01230, United States
ABSTRACT: Osmosis is the flow of solvent across a semipermeable membrane from a region of lower to higher solute concentration. It is of central importance in plant and animal physiology and finds many uses in industry. A survey of published papers, web resources, and current textbooks reveals that numerous misconceptions about osmosis continue to be cited and taught. To clarify these issues, we re-derive the thermodynamics of osmosis using the canonical formalism of statistical mechanics and go on to discuss the main points that continue to lead to misunderstandings. © 2012 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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De Abreu, R., Guerra, V.
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Introducing thermodynamics through energy and entropy
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DOI: 10.1119/1.3698160
AFFILIATIONS: Departamento de Física, Instituto Superior Técnico, Universidade Técnica de Lisboa, 1049-001 Lisboa, Portugal
ABSTRACT: We suggest a simple approach to introducing thermodynamics, beginning with the concept of internal energy of deformable bodies. From a series of thought experiments involving ideal gases, we show that the internal energy depends on the volume and on a second parameter, leading to the development of the concept of entropy. By introducing entropy before the notions of temperature and heat, the proposed approach avoids some of the major conceptual difficulties with the traditional presentation. The relationship between mechanics and thermodynamics naturally emerges, mechanics corresponding to isentropic thermodynamics. The questions of evolution to equilibrium and irreversibility are studied under the light of the action of the "dynamic force" and its dissipative character, evincing the benefits of keeping in mind the microscopic picture. © 2012 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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Strombom, E.H., Caicedo-Carvajal, C.E., Thyagu, N.N., Palumbo, D., Shinbrot, T.
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DOI: 10.1119/1.4709384
AFFILIATIONS: Swarthmore College, Swarthmore, PA, 19081, United States;
3D Biotek, North Brunswick, NJ, United States;
Rutgers University, Piscataway, NJ 08902, United States;
Rutgers University, Piscataway, NJ 08854, United States
ABSTRACT: In 1855, Lord Kelvin's brother, James Thomson, wrote a paper describing "certain curious motions" on liquid surfaces. In the present paper, we describe several curious motions produced in the simplest possible manner: by introducing a droplet of food coloring into a shallow dish of water. These motions include the spontaneous formation of labyrinthine stripes, the periodic pulsation leading to chaotic stretching and folding, and the formation of migrating slugs of coloring. We use this simple experiment to demonstrate that the formation of ordered macroscopic patterns is consistent with the requirement of the second law of Thermodynamics that microscopic disorder must increase. This system is suitable for undergraduate experimentation and can be modeled by advanced students in a straightforward finite difference simulation that reproduces the labyrinths and other patterns. © 2012 American Association of Physics Teachers.
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Leff, H.S.
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DOI: 10.1119/1.3694034
AFFILIATIONS: Department of Physics, Reed College, Portland, OR 97202, United States
ABSTRACT: Published data imply an average thermal efficiency of about 0.34 for U.S. electricity generating plants. With clever use of thermodynamics and technology, modern gas and steam turbines can be coupled, to effect dramatic efficiency increases. These combined-cycle power plants now reach thermal efficiencies in excess of 0.60. It is shown how the laws of thermodynamics make this possible. © 2012 American Association of Physics Teachers.
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Bizarro, J.P.S.
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The thermodynamic efficiency of heat engines with friction
(2012) American Journal of Physics, 80 (4), pp. 298-305. Cited 19 times.
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DOI: 10.1119/1.3680168
AFFILIATIONS: Associação Euratom-IST, Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Universidade Técnica de Lisboa, 1049-001 Lisboa, Portugal
ABSTRACT: The presence of the work done against friction is incorporated into the analysis of the efficiency of heat engines based on the first and second laws of thermodynamics. We obtain the efficiencies of Stirling and Brayton engines with friction and recover results known from finite-time thermodynamics. We show that $\eta fric/\eta \approx (1-Wfric/W)$, where $\eta fric/\eta$ is the ratio of the efficiencies with and without friction and Wfric/W is the fraction of the work W performed by the working fluid which is spent against friction forces. © 2012 American Association of Physics Teachers.
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Corti, D.S.
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Comment on "The Gibbs paradox and the distinguishability of identical particles," by M. A. M. Versteegh and D. Dieks [Am. J. Phys. 79, 741-746 (2011)]
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DOI: 10.1119/1.3657773
AFFILIATIONS: School of Chemical Engineering, Purdue University, 480 Stadium Mall Drive, West Lafayette, IN 47907-2100, United States
ABSTRACT: We revisit recent discussions concerning the Gibbs paradox-the apparent discrepancy between the entropy change upon mixing identical gases as evaluated from the statistical mechanics of classical distinguishable particles and macroscopic thermodynamics. Contrary to what is often stated, we show that thermodynamics does not require this entropy of mixing to be zero. A zero value follows from the implicit assumption that the identical gas particles are indistinguishable. If the identical particles are explicitly assumed to be distinguishable, thermodynamics yields the same entropy of mixing as classical statistical mechanics. © 2012 American Association of Physics Teachers.
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Zypman, F.R.
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DOI: 10.1119/1.3645965
AFFILIATIONS: Department of Physics, Yeshiva University, New York, NY 10033, United States
ABSTRACT: We consider the motion of a charged ring in the presence of the electric field produced by an infinite line of charge. We first introduce a clock based on small oscillations of the ring which oscillates with a period in the range of seconds. The same system is next considered beyond the small angle approximation, an integrable problem in classical mechanics. The partition function for an ensemble of these oscillators is also obtained, making the system a fruitful playground for courses in thermodynamics and statistical mechanics. Finally, we consider purely spinning motion of the ring to gain insight into the effective mass, a concept useful in condensed matter physics. © 2012 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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Opatrný, T., Richterek, L.
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DOI: 10.1119/1.3633692
AFFILIATIONS: Faculty of Science, Palacký University, 17. Listopadu 12, 77146 Olomouc, Czech Republic
ABSTRACT: Two black holes can merge to create a bigger black hole, thus increasing the entropy of the universe. Alternatively, they can be used as two heat reservoirs from which work can be extracted. We discuss a process during which two black holes are transformed into one while the total entropy is kept as constant. The resulting black hole has a smaller mass than the total mass of the input black holes and the mass difference is converted into work. Although the process will probably not be used within the next 1011 yr for energy production, we can speculate that it might be an energy source for those who might inhabit our universe after that. We discuss the basic thermodynamics of the proposed system. © 2012 American Association of Physics Teachers.
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Langbeheim, E., Livne, S., Yerushalmi, E., Safran, S.A.
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DOI: 10.1119/1.3647995
AFFILIATIONS: Department of Science Teaching, Department of Materials and Interfaces, Weizmann Institute of Science, Rehovot, 76100, Israel;
Department of Science Teaching, Weizmann Institute of Science, Rehovot, 76100, Israel;
Department of Materials and Interfaces, Rehovot, 76100, Israel
ABSTRACT: We describe an elective course on soft matter at the level of introductory physics. Soft matter physics serves as a context that motivates the presentation of basic ideas in statistical thermodynamics and their applications. It also is an example of a contemporary field that is interdisciplinary and touches on chemistry, biology, and physics. We outline a curriculum that uses the lattice gas model as a quantitative and visual tool, initially to introduce entropy, and later to facilitate the calculation of interactions. We demonstrate how free energy minimization can be used to teach students to understand the properties of soft matter systems such as the phases of fluid mixtures, wetting of interfaces, self-assembly of surfactants, and polymers. We discuss several suggested activities in the form of inquiry projects which allow students to apply the concepts they have learned to experimental systems. © 2012 American Association of Physics Teachers.
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Salagaram, T., Chetty, N.
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Enhancing the understanding of entropy through computation
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DOI: 10.1119/1.3623416
AFFILIATIONS: Department of Physics, University of Pretoria, Pretoria 0001, South Africa;
Department of Physics, University of Pretoria, Pretoria 0001, South Africa;
National Institute for Theoretical Physics, Johannesburg 2000, South Africa
ABSTRACT: We devise an algorithm to enumerate the microstates of a system comprising N independent, distinguishable particles. The algorithm is applicable to a wide class of systems such as harmonic oscillators, free particles, spins, and other models for which there are no analytical solutions, for example, a system with single particle energy spectrum given by ε(p,q) = ε0(p2 + q4), where p and q are non-negative integers. Our algorithm enables us to determine the approach to the limit N → ∞ within the microcanonical ensemble, and makes manifest the equivalence with the canonical ensemble. Various thermodynamic quantities as a function of N can be computed using our methods. © 2011 American Association of Physics Teachers.
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DOI: 10.1119/1.3619866
AFFILIATIONS: Physique et Mécanique des Milieux Hétérogènes, UMR 7636 ESPCI - CNRS, Université Paris-Diderot, 10 rue Vauquelin, 75005, Paris, France;
Physics of Fluids Group and J. M. Burgers Centre for Fluid Dynamics, University of Twente, P.O. Box 217, 7500 AE Enschede, Netherlands
ABSTRACT: A paperclip can float on water. Drops of mercury do not spread on a surface. These capillary phenomena are macroscopic manifestations of molecular interactions and can be explained in terms of surface tension. We address several conceptual questions that are often encountered when teaching capillarity and provide a perspective that reconciles the macroscopic viewpoints from thermodynamics and fluid mechanics and the microscopic perspective from statistical physics. © 2011 American Association of Physics Teachers.
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Zaldévar, F., del Réo-Correa, J.L., Garcéa-Marténez, E., Fernández-Guasti, M.
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DOI: 10.1119/1.3610179
AFFILIATIONS: Departamento de Matemáticas, Universidad Autónoma Metropolitana-I, 09340 México, D.F., Mexico;
Departamento de Fésica, Universidad Autónoma Metropolitana-Iztapalapa, Ap. Postal 55-534, 09340 México D.F., Mexico
ABSTRACT: We show that any group-theoretic differentiable operation in an open interval of real numbers is isomorphic to the usual addition of real numbers. Given the composition law, it is possible to establish the transformation relation. Alternatively, given a transformation, it is possible to obtain the composition relation in terms of the new variable. We show that some well known cases such as entropy and the relativistic addition of parallel velocities are included in this general framework. The composition rules for a wide variety of phenomena ranging from electrical circuits to thermodynamic systems are treated in a unified way. © 2011 American Association of Physics Teachers.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final

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Kerr, W.C., Macosko, J.C.
7103299776;6602340230;
Thermodynamic Venn diagrams: Sorting out forces, fluxes, and Legendre transforms
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DOI: 10.1119/1.3599177
AFFILIATIONS: Olin Physical Laboratory, Wake Forest University, Winston-Salem, NC 27109-7507, United States
ABSTRACT: We show how to use a Venn diagram to illuminate the relations among the different thermodynamic potentials, forces, and fluxes of a simple system. A single diagram shows all of the thermodynamic potentials obtainable by Legendre transformations starting from the internal energy as the fundamental potential. From the diagram, we can also read off the Maxwell relations deduced from each of these potentials. We construct a second Venn diagram that shows the analogous information for the Massieu functions, obtained by Legendre transformations starting from the entropy as the fundamental thermodynamic function. © 2011 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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Yoder, T.J., Adkins, G.S.
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Resolution of the ellipsoid paradox in thermodynamics
(2011) American Journal of Physics, 79 (8), pp. 811-818. Cited 1 time.
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DOI: 10.1119/1.3596430
AFFILIATIONS: Franklin and Marshall College, Lancaster, PA 17604, United States
ABSTRACT: We discuss a challenge to the second law of thermodynamics in an optical setting, in which two black bodies at strategically chosen points inside a perfectly reflecting cavity of appropriate shape apparently transfer energy asymmetrically so that one body experiences a net gain of energy at the other's expense. We show how the finite sizes of the black bodies lead to a resolution of the apparent paradox. We describe a simulation that allows us to follow the paths of individual rays and show numerically that the second law requirement of energy balance is satisfied. We also demonstrate that the energy balance condition is satisfied in the more general situation where the cavity and black bodies are of arbitrary shape. © 2011 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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Falcioni, M., Villamaina, D., Vulpiani, A., Puglisi, A., Sarracino, A.
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DOI: 10.1119/1.3563046
AFFILIATIONS: Dipartimento di Fisica, Università La Sapienza, P. le Aldo Moro 2, 00185 Roma, Italy; ISC-CNR, Dipartimento di Fisica, Università La Sapienza, P. le Aldo Moro 2, 00185 Roma, Italy
ABSTRACT: The energy of a finite system thermally connected to a thermal reservoir may fluctuate, while the temperature is a constant representing a thermodynamic property of the reservoir. The finite system can also be used as a thermometer for the reservoir. From such a perspective, the temperature has an uncertainty, which can be treated within the framework of estimation theory. We review the main results of this theory and clarify some controversial issues regarding temperature fluctuations. We also offer a simple example of a thermometer with a small number of particles. We discuss the relevance of the total observation time, which must be much longer than the decorrelation time. © 2011 American Association of Physics Teachers.
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Versteegh, M.A.M., Dieks, D.
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The Gibbs paradox and the distinguishability of identical particles
(2011) American Journal of Physics, 79 (7), pp. 741-746. Cited 28 times.
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DOI: 10.1119/1.3584179
AFFILIATIONS: Institute for History and Foundations of Science, Utrecht University, P.O. Box 80 010, 3508 TA Utrecht, Netherlands;
Debye Institute for Nanomaterials Science, Princetonplein 1, 3584 CC Utrecht, Netherlands
ABSTRACT: Identical classical particles are distinguishable. This distinguishability affects the number of ways W a macrostate can be realized on the microlevel, and from the relation S=k ln W leads to a nonextensive expression for the entropy. This result is usually considered incorrect because of its inconsistency with thermodynamics. It is sometimes concluded from this inconsistency that identical particles are fundamentally indistinguishable and that quantum mechanics is indispensable for making sense of this inconsistency. In contrast, we argue that the classical statistics of distinguishable particles and the resulting nonextensive entropy function are perfectly acceptable from both a theoretical and an experimental perspective. The inconsistency with thermodynamics can be removed by taking into account that the entropy concept in statistical mechanics is not completely identical to the thermodynamical one. We observe that even identical quantum particles are in some cases distinguishable, and conclude that quantum mechanics is irrelevant to the Gibbs paradox. © 2011 American Association of Physics Teachers.
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Swendsen, R.H.
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How physicists disagree on the meaning of entropy
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DOI: 10.1119/1.3536633
AFFILIATIONS: Department of Physics, Carnegie Mellon University, Pittsburgh, PA 15213, United States
ABSTRACT: Discussions of the foundations of statistical mechanics, how they lead to thermodynamics, and the appropriate definition of entropy have occasioned many disagreements. I believe that some or all of these disagreements arise from differing, but unstated assumptions, which can make opposing opinions difficult to reconcile. To make these assumptions explicit, I discuss the principles that have guided my own thinking about the foundations of statistical mechanics, the microscopic origins of thermodynamics, and the definition of entropy. The purpose of this paper will be fulfilled if it paves the way to a final consensus, whether or not that consensus agrees with my point of view. © 2011 American Association of Physics Teachers.
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Denur, J.
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The apparent “super-Carnot” efficiency of hurricanes: Nature's steam engine versus the steam locomotive
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DOI: 10.1119/1.3534841
AFFILIATIONS: Electric & Gas Technology, 3233 West Kingsley Road, Garland, Texas 75041-2205, United States
ABSTRACT: The thermodynamics of the hurricane—Nature's steam engine—presents surprising contrasts with that of the steam locomotive. The hurricane rejects not only its waste heat at the lowest available temperature (as all heat engines must do to maximize efficiency), but also its work (that is, the kinetic energy of its winds) via frictional dissipation at the highest available temperature. We show how the hurricane's “super-Carnot” efficiency is consistent with the laws of thermodynamics.

We also show that even standard heat engines can achieve “super-Carnot” efficiency, albeit via a different mechanism and to a far inferior degree than the hurricane. 
DOCUMENT TYPE: Article
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Thermodynamics of heating a room
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DOI: 10.1119/1.3488987
AFFILIATIONS: Department of Physics and Atmospheric Science, Dalhousie University, Halifax, NS, B3H 3J5, Canada
ABSTRACT: A room is not heated by increasing its internal energy but by decreasing its entropy due to the fact that during heating, the volume and pressure remain constant and air is expelled. We first present a simple solution treating the air in the room as an ideal gas. We calculate the differential entropy change and heat transfer and give numbers for a typical room including estimates of heat loss through windows and walls. We also demonstrate the power of thermodynamics to derive the entropy and internal energy changes for any gas. © 2011 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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Moreno, A.J., Ferrari, H., Bekeris, V.
57206906182;57204341550;6603815767;
Cooling balloons with liquid nitrogen
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DOI: 10.1119/1.3473787
AFFILIATIONS: Departamento de Física, Laboratorio de Bajas Temperaturas, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Pabellón I, Ciudad Universitaria, C1428EGA Buenos Aires, Argentina;
CONICET, Av. Rivadavia 1917, C1033AAJ, Ciudad de Buenos Aires, Argentina
ABSTRACT: We present an undergraduate level experiment in which the radius of a rubber balloon is measured as it is cooled with liquid nitrogen. For balloons filled with simple gases that condense at liquid nitrogen temperatures, we found that the volume decreases linearly with time. We compared our measurements with a simplified model based on elementary kinetic theory and thermodynamics that explains this behavior. Students are encouraged to test the validity of the model by repeating the experiment using gas mixtures and gases that do not condense at liquid nitrogen temperatures. © 2010 American Association of Physics Teachers.
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Ruppeiner, G.
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Thermodynamic curvature measures interactions
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DOI: 10.1119/1.3459936
AFFILIATIONS: Division of Natural Sciences, New College of Florida, 5800 Bay Shore Road, Sarasota, FL 34243-2109, United States
ABSTRACT: Thermodynamic fluctuation theory originated with Einstein, who inverted the relation $S=k_B \ln \Omega$ to express the number of states in terms of entropy: $\Omega=\exp(S/k_B)$. The theory's Gaussian approximation is discussed in most statistical mechanics texts. I review work showing how to go beyond the Gaussian approximation by adding covariance, conservation, and consistency. This generalization leads to a fundamentally new object: The thermodynamic Riemannian curvature scalar R,

a thermodynamic invariant. I argue that {pipe}R{pipe} is related to the correlation length and suggest that the sign of R corresponds to whether the interparticle interactions are effectively attractive or repulsive. © 2010 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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Patrício, P., Tavares, J.M.
55231987600;35621140500;
Simple thermodynamics of jet engines
(2010) American Journal of Physics, 78 (8), art. no. 010006AJP, pp. 809-814. Cited 3 times.
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DOI: 10.1119/1.3373924
AFFILIATIONS: Instituto Superior de Engenharia de Lisboa, Rua Conselheiro Emídio Navarro 1, P-1949-014 Lisboa, Portugal;
Centro de Física Teórica e Computacional, Universidade de Lisboa, Avenida Professor Gama Pinto 2, P-1649-003 Lisboa Codex, Portugal
ABSTRACT: We use the first and second laws of thermodynamics to analyze the behavior of an ideal jet engine. Simple analytical expressions for the thermal efficiency, the overall efficiency, and the reduced thrust are derived. We show that the thermal efficiency depends only on the compression ratio r and on the velocity of the aircraft. The other two performance measures depend also on the ratio of the temperature at the turbine to the inlet temperature in the engine, T3/Ti. An analysis of these expressions shows that it is not possible to choose an optimal set of values of r and T3/Ti that maximize both the overall efficiency and thrust. We study how irreversibilities in the compressor and the turbine decrease the overall efficiency of jet engines and show that this effect is more pronounced for smaller T3/Ti. © 2010 American Association of Physics Teachers.
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Classical thermodynamics of particles in harmonic traps
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DOI: 10.1119/1.3417868
AFFILIATIONS: Department of Physics and Astronomy, Bucknell University, Lewisburg, PA 17837, United States
ABSTRACT: I develop simple thermodynamic relations for a system of noninteracting classical particles confined in an isotropic harmonic trap. The volume occupied by the particles in such a trap is not well defined the pressure varies with position, indicating that the thermodynamic relations should be expressed in terms of more appropriate variables. I use the effective spring constant of the trap as a state variable and show that the conjugate state variable is proportional to the ensemble average of the mean squared displacement of the particles from the center of the trap. Thermodynamic relations are derived in terms of these variables, including the pressure and thermal equations of state, the entropy the heat capacities. I also consider cyclic thermodynamic processes in a harmonically confined gas. © 2010 American Association of Physics Teachers.
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Bejan, A.
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The constructal-law origin of the wheel, size, and skeleton in animal design
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DOI: 10.1119/1.3431988
AFFILIATIONS: Department of Mechanical Engineering and Materials Science, Duke University, Durham, NC 27708-0300, United States

ABSTRACT: This paper shows that the emergence of body organs is predictable as an integral part of the design for moving animal mass more easily on Earth, in accord with the constructal law of design in nature: For a finite-size open system to persist in time (to live), it must evolve such that it provides easier access to the imposed (global) currents that flow through it. Every organ destroys useful energy in two ways: Internally by thermodynamic irreversibilities and by having to be carried. From the constructal law follows the necessity of characteristic-size organs and the emergence of solid columns (legs) to facilitate the flow of stresses. This natural "wheel" endows the body with rolling (falling-forward) locomotion, with predicted speeds that agree with the observed speeds in the body mass range of 10-6-103 kg. The constructal law also accounts for animal design features for changing speeds. Skeletons (bones and legs) are solid organs that emerge in accordance with the constructal-law design of moving animal mass: More and stronger material emerges along the lines of highest stresses. A connection between animal wheel movement and swimming, water waves, and tsunamis is also made. © 2010 American Association of Physics Teachers.
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Campisi, M., Kobe, D.H.
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Derivation of the Boltzmann principle
(2010) American Journal of Physics, 78 (6), art. no. 021003AJP, pp. 608-615. Cited 31 times.
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DOI: 10.1119/1.3298372
AFFILIATIONS: Institute of Physics, University of Augsburg, Universitätsstrasse 1, D-86135 Augsburg, Germany;
Department of Physics, University of North Texas, P.O. Box 311427, Denton, TX 76203-1427, United States
ABSTRACT: We derive the Boltzmann principle SB=kB ln W based on classical mechanical models of thermodynamics. The argument is based on the heat theorem and can be traced back to the second half of the 19th century in the works of Helmholtz and Boltzmann. Despite its simplicity, this argument has remained almost unknown. We present it in a contemporary, self-contained, and accessible form. The approach constitutes an important link between classical mechanics and statistical mechanics. © 2010 American Association of Physics Teachers.
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Lindsey, B.A., Heron, P.R.L., Shaffer, P.S.
35095516200;7003552695;7005100727;
Student ability to apply the concepts of work and energy to extended systems
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DOI: 10.1119/1.3183889
AFFILIATIONS: University of Washington, Seattle, WA 98195-1560, United States;
Department of Physics, Georgetown University, Washington, DC 20057, United States
ABSTRACT: We report results from an investigation of student ability to apply the concepts of work and energy to situations in which the internal structure of a system cannot be ignored, that is, the system cannot be treated as a particle. Students in introductory calculus-based physics courses were asked written and online questions after relevant instruction by lectures, textbook, and laboratory. Several difficulties were identified. Some related to student ability to calculate the work done on a system. Failure to associate work with the change in energy of a system was also widespread. The results have implications for instruction that aims for a rigorous treatment of energy concepts that is consistent with the first law of thermodynamics. The findings are guiding the development of two tutorials to supplement instruction. © 2009 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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Zia, R.K.P., Redish, E.F., McKay, S.R.
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Making sense of the Legendre transform

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DOI: 10.1119/1.3119512
AFFILIATIONS: Department of Physics, Virginia Polytechnic Institute, State University, Blacksburg, VA 24061, United States;
Department of Physics, University of Maryland, College Park, MD 20742, United States;
Department of Physics and Astronomy, University of Maine, Orono, ME 04469, United States
ABSTRACT: The Legendre transform is a powerful tool in theoretical physics and plays an important role in classical mechanics, statistical mechanics, and thermodynamics. In typical undergraduate and graduate courses the motivation and elegance of the method are often missing, unlike the treatments frequently enjoyed by Fourier transforms. We review and modify the presentation of Legendre transforms in a way that explicates the formal mathematics, resulting in manifestly symmetric equations, thereby clarifying the structure of the transform. We then discuss examples to motivate the transform as a way of choosing independent variables that are more easily controlled. We demonstrate how the Legendre transform arises naturally from statistical mechanics and show how the use of dimensionless thermodynamic potentials leads to more natural and symmetric relations. © 2009 American Association of Physics Teachers.
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Lindemuth, I.R., Siemon, R.E.
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The fundamental parameter space of controlled thermonuclear fusion
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DOI: 10.1119/1.3096646
AFFILIATIONS: Department of Physics, University of Nevada, Reno, NV 89557, United States
ABSTRACT: We apply a few simple first-principles equations to identify the parameter space in which controlled fusion might be possible. Fundamental physical parameters such as minimum size, energy, and power as well as cost are estimated. We explain why the fusion fuel density in inertial confinement fusion is more than 1011 times larger than the fuel density in magnetic confinement fusion. We introduce magnetized target fusion as one possible way of accessing a density regime that is intermediate between the two extremes of inertial confinement fusion and magnetic confinement fusion and is potentially lower cost than either of these two. © 2009 American Association of Physics Teachers.
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Gallo, E., Marolf, D.
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Resource letter BH-2: Black holes
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DOI: 10.1119/1.3056569
AFFILIATIONS: Massachusetts Institute of Technology, Kavli Institute for Astrophysics and Space Research, Building 37-685, 70 Vassar Street, Camdridge, MA 02139, United States;
Department of Physics, University of California Santa Barbara, Santa Barbara, CA 93106-9530, United States
ABSTRACT: This Resource Letter is designed to guide students, educators, and researchers through (some of) the literature on black holes. We discuss both the physics and astrophysics of black holes. We emphasize breadth over depth, and review articles over primary sources. We include resources ranging from nontechnical discussions appropriate for broad audiences to technical reviews of current research. Topics addressed include classification of stationary solutions, perturbations and stability of black holes, numerical simulations, collisions, the production of gravity waves, black-hole thermodynamics and Hawking radiation, quantum treatments of black holes, black holes in both higher and lower dimensions, and connections to nuclear and condensed-matter physics. On the astronomical end, we also cover the physics of gas accretion onto black holes, relativistic jets,

gravitationally redshifted emission lines, evidence for stellar-mass black holes in binary systems and supermassive black holes at the centers of galaxies, the quest for intermediate-mass black holes, the assembly and merging history of supermassive black holes through cosmic time, and their affects on the evolution of galaxies. © 2009 American Association of Physics Teachers.
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Morales, A.
7202369587;
The second law of classical thermodynamics stated in terms of twin systems
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DOI: 10.1119/1.3074300
AFFILIATIONS: Instituto de Ciencias Físicas, Universidad Nacional Autónoma de Ḿxico, P. O. Box 48-3, 62251 Cuernavaca, Morelos, Mexico
ABSTRACT: An alternative formulation of the second law of thermodynamics is presented in terms of twin systems in thermal equilibrium. This formulation allows a direct derivation of the thermodynamic variables of absolute temperature and entropy. The efficiency of Carnot cycles is also derived. Irreversible processes are defined in part two of the second law and the Kelvin-Planck and Clausius statements of the second law are derived. © 2009 American Association of Physics Teachers.
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Christensen, W.M., Meltzer, D.E., Ogilvie, C.A.
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Student ideas regarding entropy and the second law of thermodynamics in an introductory physics course
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DOI: 10.1119/1.3167357
AFFILIATIONS: Center for Science and Mathematics Education Research, University of Maine, Orono, Maine 04401, United States;
College of Teacher Education and Leadership, Arizona State University, Polytechnic Campus, Mesa, Arizona 85212, United States;
Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011, United States
ABSTRACT: We report on students' thinking regarding entropy in an introductory calculus-based physics course. We analyzed students' responses to a variety of questions on entropy changes of an arbitrarily defined system and its surroundings. In four offerings of the same course we found that before instruction, no more than 6% of all students could give completely correct responses to relevant questions posed in both general and concrete contexts. Nearly two-thirds of the students showed clear evidence of conservation-type reasoning regarding entropy. These outcomes were little changed even after instruction. Targeted instruction that guided students to recognize that entropy is not a conserved quantity appears to yield improved performance on qualitative questions related to this concept. 
DOCUMENT TYPE: Article
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DOI: 10.1119/1.3119513
AFFILIATIONS: Department of Physics, University of Richmond, Richmond, Virginia 23173, United States
ABSTRACT: Skeptics of biological evolution often claim that evolution requires a decrease in entropy, giving rise to a conflict with the second law of thermodynamics. This argument is fallacious because

it neglects the large increase in entropy provided by sunlight striking the Earth. A recent article provided a quantitative assessment of the entropies involved and showed explicitly that there is no conflict. That article rests on an unjustified assumption about the amount of entropy reduction involved in evolution. I present a refinement of the argument that does not rely on this assumption.

DOCUMENT TYPE: Note
PUBLICATION STAGE: Final
SOURCE: Scopus

De La Peña, L., Valdés-Hernández, A., Cetto, A.M.
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Statistical consequences of the zero-point energy of the harmonic oscillator
(2008) American Journal of Physics, 76 (10), pp. 947-955. Cited 16 times.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-56749183410&doi=10.1119%2f1.2948780&partnerID=40&md5=5c38a2e4a5ee9c22826936e73ac61f2f

DOI: 10.1119/1.2948780
AFFILIATIONS: Instituto de Física, Universidad Nacional Autónoma de México, Apartado postal 20-364, 01000 México, Mexico;
International Atomic Energy Agency, P.O. Box 200, A-1400 Vienna, Austria
ABSTRACT: In a recent thermodynamic analysis of the harmonic oscillator Boyer has shown, using an interpolation procedure, that the existence of a zero-point energy leads to Planck's law. We avoid the interpolation procedure by adding a statistical argument to arrive at Planck's law as a consequence of the existence of the zero-point energy. As in Boyer's argument, no explicit assumption of quantum mechanics is introduced. We discuss the relation of our results to the analysis of Planck and Einstein which led to the notion of the quantized radiation field. We then inquire into the discrete or continuous behavior of the energy and pinpoint the origin and meaning of the discontinuities. To include zero-point fluctuations (which are neglected in the thermodynamic analysis), we discuss the statistical (in contrast to the purely thermodynamic) description of the oscillator, which accounts for both the thermal and temperature-independent contributions to the dispersion of the energy. 
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DOI: 10.1119/1.2973046
AFFILIATIONS: Department of Physics and Astronomy, Oberlin College, Oberlin, OH 44074, United States
ABSTRACT: Quantitative estimates of the entropy involved in biological evolution demonstrate that there is no conflict between evolution and the second law of thermodynamics. The calculations are elementary and could be used to enliven the thermodynamics portion of a high school or introductory college physics course. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Uehara, M., Sakane, K.K., Bertolotti, S.A.
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Thermodynamics of the heart: Relation between cardiac output and oxygen consumption
(2008) American Journal of Physics, 76 (6), pp. 566-569. Cited 2 times.
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DOI: 10.1119/1.2825395
AFFILIATIONS: Universidade do Vale do Paraíba, Praça Cândida Dias Castejón, 26 apto 102, São José dos Campos, SP, 12245-720, Brazil
ABSTRACT: A thermodynamic approach is used to derive a relation between cardiac output and rate of oxygen consumption. As an example, the relation is used to calculate the cardiac output of a young woman exercising on a treadmill. The results can be understood by undergraduates without any previous

knowledge of human physiology. © 2008 American Association of Physics Teachers.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Coffey, T.S.
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Diet Coke and Mentos: What is really behind this physical reaction?
(2008) American Journal of Physics, 76 (6), pp. 551-557. Cited 30 times.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-45549089253&doi=10.1119%2f1.2888546&partnerID=40&md5=a69c7c799f660ae940a41580dc16381f

DOI: 10.1119/1.2888546
AFFILIATIONS: Department of Physics and Astronomy, Appalachian State University, Boone, NC 28608, United States
ABSTRACT: The Diet Coke and Mentos reaction is a fun demonstration in chemistry and physics classes of many important concepts in thermodynamics, fluid dynamics, surface science, and the physics of explosions. The reaction has been performed numerous times on television and the Internet, but has not been systematically studied. We report on an experimental study of the Diet Coke and Mentos reaction, and consider many aspects of the reaction, including the ingredients in the candy and soda, the roughness of the candy, the temperature of the soda, and the duration of the reaction. © 2008 American Association of Physics Teachers.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Sandnes, B.
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DOI: 10.1119/1.2830533
AFFILIATIONS: Department of Physics, University of Oslo, P.O. Box 1048, Blindern, NO-0316 Oslo, Norway
ABSTRACT: Flexing a metallic disk triggers the crystallization of the supercooled sodium acetate solution contained in commercial heat pads. Many mechanisms have been proposed to explain the apparent nucleation of crystalline material. In this paper a simple experiment is described that demonstrates that nucleation is triggered by preserving seed crystals clamped between opposing metal surfaces. An explanation for the retention of the crystalline particles is the elevated melting point caused by very high local pressures. A series of thermophysical properties of the sodium acetate solution is also measured, including the available enthalpy upon crystallization of the supercooled substance, and liquid and solid phase specific heat capacities. © 2008 American Association of Physics Teachers.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Lemons, D.S., Penner, M.K.
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Sadi Carnot's contribution to the second law of thermodynamics
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DOI: 10.1119/1.2794346
AFFILIATIONS: Bethel College, North Newton, KS 67117, United States
ABSTRACT: We identify an operative principle in Sadi Carnot's only publication that is closely related to a distinct version of the second law of thermodynamics. Although Carnot did not propose the second law of thermodynamics, he assumed its equivalent in proving Carnot's theorem. We show that, in the absence of the first law, Carnot's assumption is equivalent to Clausius' version of the second law. Both Carnot's assumption and Clausius' version, in the absence of the first law, are more restrictive than Kelvin's Statement of the second law. © 2008 American Association of Physics Teachers.

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Touchette, H.
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Simple spin models with non-concave entropies
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DOI: 10.1119/1.2794350
AFFILIATIONS: School of Mathematical Sciences, Queen Mary, University of London, London E1 4NS, United Kingdom
ABSTRACT: Two simple spin models are studied to show that the microcanonical entropy can be a non-concave function of the energy, and that the microcanonical and canonical ensembles can give non-equivalent descriptions of the same system in the thermodynamic limit. The two models are simple variations of the classical paramagnetic spin model of non-interacting spins and are solved as easily as the latter model. © 2008 American Association of Physics Teachers.
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Velasco, S., Fernández-Pineda, C.
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Thermodynamics of a pure substance at the triple point
(2007) American Journal of Physics, 75 (12), pp. 1086-1091. Cited 2 times.
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DOI: 10.1119/1.2779880
AFFILIATIONS: Departamento de Física Aplicada, Universidad de Salamanca, 37008 Salamanca, Spain; Departamento de Física Aplicada I (Termología), Universidad Complutense, 28040 Madrid, Spain
ABSTRACT: A thermodynamic study of a pure substance at the triple point is presented. In particular, we show that the mass fractions of the phases coexisting at the triple point obey lever rules in the specific entropy-specific volume diagram, and the relative changes in the mass fractions present in each phase along reversible isochoric and adiabatic processes of a pure substance at the triple point are governed by the relative sizes of the segments of the triple-point line in the pressure-specific volume diagram and in the temperature-specific entropy diagram. Applications to the ordinary triple point of water and to the triple point of Al2SiO5 polymorphs are presented. © 2007 American Association of Physics Teachers.
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Lachish, U.
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(2007) American Journal of Physics, 75 (11), pp. 997-998. Cited 24 times.
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DOI: 10.1119/1.2752822
AFFILIATIONS: Guma Science, Hanassi Harishon 40, Rehovot 76302, Israel
ABSTRACT: The van't Hoff formula for osmotic pressure, which is identical in form to the formula for ideal gas pressure, is a direct outcome of the second law of thermodynamics. The formula is derived by applying a closed cycle reversible and isothermal process, following an argument in Fermi's book on thermodynamics. © 2007 American Association of Physics Teachers.
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Nattermann, T.
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A heuristic approach to the weakly Interacting Bose gas

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DOI: 10.1119/1.2766934
AFFILIATIONS: Institut für Theoretische Physik, Universität zu Köln, Zülpicher Str. 77, 50937 Köln, Germany
ABSTRACT: Some of the thermodynamic properties of weakly interacting Bose systems are derived from dimensional and heuristic arguments and thermodynamic relations, without resorting to statistical mechanics. Our approach assumes only the existence of a branch of acoustic phonons in the interacting system. © 2007 American Association of Physics Teachers.
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Bormashenko, E., Shkorbatov, A., Gendelman, O.
57197741893;6507209507;6603740581;
The Carnot engine based on the small thermodynamic system: Its efficiency and the ergodic hypothesis
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DOI: 10.1119/1.2757626
AFFILIATIONS: College of Judea and Samaria, Research Institute, 44837 Ariel, Israel;
Institute for Low Temperature Physics and Engineering, Kharkov 61077, Ukraine;
Faculty of Mechanical Engineering, Technion, Technion City, 32000 Haifa, Israel
ABSTRACT: The operation of the minimal Carnot engine is discussed. It is demonstrated that its efficiency is given by the traditional Carnot expression when the motion of the gas particles is temporally averaged (instead of the usual spatial averaging). The impact of the heat capacity of the apparatus elements on the efficiency is considered, and the influence of temperature fluctuations on the engine operation is considered. The parameters of the minimal Carnot engine are calculated. © 2007 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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Chen, M., Rosendahl, L., Bach, I., Condra, T., Pedersen, J.
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Irreversible transfer processes of thermoelectric generators
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DOI: 10.1119/1.2750373
AFFILIATIONS: Institute of Energy Technology, Aalborg University, Pontoppidanstraede 101, DK-9220 Aalborg, Denmark
ABSTRACT: We discuss a novel tool based on heat flow diagrams for analyzing irreversible processes associated with thermoelectric devices and discuss some ambiguous descriptions and errors in related investigations. We consider thermoelectric generators as a paradigm of a heat engine cycle and determine the heat flow distribution by treating the one-dimensional heat transfer differential equation. Representative heat flow diagrams are used to study the influence of internal and external irreversible processes of heat conduction and Joule heat generation. © 2007 American Association of Physics Teachers.
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Gurarie, V.
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The equivalence between the canonical and microcanonical ensembles when applied to large systems
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DOI: 10.1119/1.2739571

AFFILIATIONS: Department of Physics, University of Colorado, Boulder, CO 80309
ABSTRACT: A straightforward technique is suggested that demonstrates that a microcanonical ensemble and canonical ensemble behave in exactly the same way in the thermodynamic limit. The canonical distribution is derived for a closed system, without the need to introduce a large reservoir that exchanges energy with the system. The derivation also clarifies the issue of the energy interval which arises when introducing the microcanonical ensemble. © 2007 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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Van Wezel, J., Van Den Brink, J.
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Spontaneous symmetry breaking in quantum mechanics
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DOI: 10.1119/1.2730839
AFFILIATIONS: Institute-Lorentz for Theoretical Physics, Universiteit Leiden, P. O. Box 9506, 2300 RA Leiden, Netherlands
ABSTRACT: We present a mathematically simple procedure to explain spontaneous symmetry breaking in quantum systems. The procedure is applicable to a wide range of models and can be easily used to explain the existence of a symmetry broken state in crystals, antiferromagnets, and even superconductors. It has the advantage that it automatically brings to the fore the main players in spontaneous symmetry breaking: the symmetry-breaking field, the thermodynamic limit, and the global excitations Of a "thin" spectrum. © 2007 American Association of Physics Teachers.
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Samiullah, M.
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What is a reversible process?
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DOI: 10.1119/1.2721588
AFFILIATIONS: Physics Department, Truman State University, 100 E. Normal Street, Kirksville, MO 63501, United States
ABSTRACT: The definitions of reversible processes given in introductory physics books are found to be vague and misleading. An operational definition suitable for introductory texts is presented that avoids these problems. It stresses that to properly describe reversible processes, the second law of thermodynamics must be used. The constancy of entropy, which defines a reversible process, also distinguishes reversible processes from quasi-static processes. © 2007 American Association of Physics Teachers.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Wang, X., Liu, Q.H., Dong, W.
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Dependence of the existence of thermal equilibrium on the number of particles at low temperatures
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DOI: 10.1119/1.2432128
AFFILIATIONS: School for Theoretical Physics, Department of Applied Physics, Hunan University, Changsha, 410082, China;
Laboratoire de Chimie, UMR 5182 CNRS, Ecole Normale Supéireure de Lyon, 46, Allée d'Italie, 69364 Lyon Cedex 07, France
ABSTRACT: A universal criterion for the existence of an equilibrium state at low temperatures is established based on the requirement that the temperature fluctuations be small and the third law of

thermodynamics. The criterion implies that at sufficiently low temperatures the minimum number of particles increases as the temperature decreases. The application of the criterion to the phonon gas, ideal Bose gas, and the ideal Fermi gas gives quantitative results that are compatible with recent results for nanoscale systems. © 2007 American Association of Physics Teachers.
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Bucher, M.
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Comment on "Development and assessment of research-based tutorials on heat engines and the second law of thermodynamics," by Matthew J. Cochran and Paula R. L. Heron [Am. J. Phys. 74 (8), 734-741 (2006)]
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DOI: 10.1119/1.2437748
AFFILIATIONS: Department of Physics, California State University Fresno, Fresno, CA 93740-8031, United States
DOCUMENT TYPE: Note
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Lavenda, B.H.
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DOI: 10.1119/1.2397094
AFFILIATIONS: Università degli Studi, Camerino 62032 (MC), Italy
ABSTRACT: It is shown that the Curzon-Ahlborn engine, a prototype of an endoreversible engine, has the same efficiency as that of an unequally heated body that produces maximum work when perfect thermodynamic engines equalize its temperature. Maximum power output and finite-time operations are completely illusory. © 2007 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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McGlynn, E.
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DOI: 10.1119/1.2210490
AFFILIATIONS: School of Physical Sciences/NCPST, Dublin City University, Glasnevin, Dublin 9, Ireland
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Lorenz, R.
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Finite-time thermodynamics of an instrumented drinking bird toy
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DOI: 10.1119/1.2190688
AFFILIATIONS: Lunar and Planetary Lab., University of Arizona, Tucson, AZ 85721, United States
ABSTRACT: The motion and temperature of a drinking bird toy is monitored by a variety of instruments to determine the quantitative history of its motion over long times and to determine the

thermodynamic and mechanical constraints on its performance. © 2006 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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Cochran, M.J., Heron, P.R.L.
7103277542;7003552695;
Development and assessment of research-based tutorials on heat engines and the second law of thermodynamics
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DOI: 10.1119/1.2198889
AFFILIATIONS: University of Washington, Seattle, WA 98195-1560, United States
ABSTRACT: We report on an investigation of student ability to apply the second law of thermodynamics to cyclic devices such as heat engines and refrigerators. Students enrolled in courses ranging from algebra-based introductory physics to a junior-level thermodynamics course were asked if certain specified processes could occur. Their responses revealed several conceptual difficulties, including the failure to recognize the relevance of the second law to various problems. These findings informed the development of two tutorials to supplement instruction in standard undergraduate courses. Student performance on examination questions indicates that both tutorials can help improve understanding. © 2006 American Association of Physics Teachers.
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Weiss, V.C.
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The uniqueness of Clausius' integrating factor
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DOI: 10.1119/1.2190685
AFFILIATIONS: School of Engineering and Science, International University Bremen, P. O. Box 750561, 28725 Bremen, Germany;
Eduard-Zintl-Institut für Anorganische und Physikalische Chemie, Technische Universität Darmstadt, Petersenstrasse 20, 64287 Darmstadt, Germany
ABSTRACT: For a closed system that contains an arbitrary pure substance, which can exchange energy as heat and as expansion/compression work, but no particles, with its surroundings, the inexact differential of the reversibly exchanged heat is a differential in two variables. This inexact differential can be turned into an exact one by an integrating factor that, in general, depends on both variables. We identify the general form of the integrating factor as the reciprocal temperature (Clausius' well-known 1/T), which is guaranteed to be a valid integrating factor by the second law of thermodynamics, multiplied by an arbitrary function of the implicit adiabat equation $\xi(T,V)$ =constant or $\xi(T,P)$=constant. In general, we cannot expect that two different equations of state (corresponding to two different substances) predict identical equations for the adiabats. The requirement of having a universal integrating factor thus eliminates the volume-dependent or pressure-dependent integrating factors and leaves only a function of temperature alone: Clausius' integrating factor 1/T. The existence of other integrating factors is rarely mentioned in textbooks; instead, the integrating factor 1/T is usually taken for granted relying on the second law or, occasionally, one finds it "derived" incorrectly from the first law of thermodynamics alone. © 2006 American Association of Physics Teachers.
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Astumian, R.D.
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The unreasonable effectiveness of equilibrium theory for interpreting nonequilibrium experiments
(2006) American Journal of Physics, 74 (8), pp. 683-688. Cited 63 times.
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DOI: 10.1119/1.2205883
AFFILIATIONS: Department of Physics and Astronomy, University of Maine, Orono, ME 04469-5709, United States
ABSTRACT: There has been much interest in applying the results of statistical mechanics to single molecule experiments. Recent work has highlighted nonequilibrium work-energy relations and fluctuation theorems that have an equilibriumlike (time independent) form. I give a simple heuristic example where an equilibrium result (the barometric law for colloidal particles in water) can be derived using the thermodynamically nonequilibrium behavior of a single colloidal particle falling through the water due to gravity. This description is possible because the particle, even while falling, is in mechanical equilibrium (the gravitational force equals the viscous drag force) at every instant. The results are generalized using Onsager's thermodynamic action approach for stochastic processes to derive time independent equations that hold for thermodynamically nonequilibrium (and even nonstationary) systems. These relations offer great possibilities for the rapid determination of thermodynamic parameters from single molecule experiments. © 2006 American Association of Physics Teachers.
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De Gregorio, A.
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Radioactivity induced by neutrons: Enrico Fermi and a thermodynamic approach to radiative capture (2006) American Journal of Physics, 74 (7), pp. 614-620. Cited 1 time.
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DOI: 10.1119/1.2198884
AFFILIATIONS: Department of Physics, University of Rome La Sapienza, P. le A. Moro, 2, 00185 - Rome, Italy
ABSTRACT: When Fermi learned that slow neutrons are much more effective than fast ones in inducing radioactivity, he explained this phenomenon by mentioning the well-known scattering cross section between neutrons and protons. At this early stage, he did not refer to the capture cross section by target nuclei. At the same time a thermodynamic approach to neutron-proton capture was being discussed by physicists: neutron capture was interpretated as the reverse of deuteron photodissociation and detailed balance among neutrons, protons, deuterons, and radiation was invoked. This thermodynamic approach might underlie Fermi's early explanation of the great efficiency of slow neutrons. Fermi repeatedly used a thermodynamic approach that had been used in describing some of the physical properties of conductors by Richardson and had been influential in Fermi's youth. © 2006 American Association of Physics Teachers.
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Determination of the Kelvin equation in the presence of an arbitrary gravitational/inertial field (2006) American Journal of Physics, 74 (7), pp. 565-568. Cited 5 times.
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DOI: 10.1119/1.2186336
AFFILIATIONS: Department of Materials Engineering and Industrial Technologies, University of Trento, Mesiano di Povo 38050 Povo, Trento, Italy
ABSTRACT: The validity of the Kelvin equation in the presence of an arbitrary stationary field due to gravity or an accelerated reference frame is determined by a fluid-dynamical argument. In this approach capillary rise and the Kelvin effect appear to be different aspects of the same phenomenon. A general form of the Kelvin equation is obtained that does not depend on the applied field. A higher-order approximation than the usual Kelvin equation is derived by using Lagrange's expansion method. The fluid-dynamical approach is proved to be equivalent to a purely thermodynamical approach provided that the surface free energy in the presence of the external field is appropriately defined. Both the fluid-dynamical and the thermodynamic approach lead to the conclusion that the generalized form of Kelvin equation does not depend on the applied field. © 2006 American Association of Physics Teachers.
DOCUMENT TYPE: Article

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DOI: 10.1119/1.2174034
AFFILIATIONS: Istituto Nationale di Ricerca Metrologica (INRIM), Strada delle Cacce, 91-10135 Torino, Italy
ABSTRACT: Shot noise and Johnson noise in electrical circuits are usually introduced by referring to completely separate physical models and derivations. We derive Johnson and shot noise expressions from the same physical model, an ideal tunnel junction, to show the deep connection between the two types of noise. The derivation uses concepts of quantum mechanics, thermodynamics, and signal processing. © 2006 American Association of Physics Teachers.
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DOI: 10.1119/1.2173273
AFFILIATIONS: Department of Physics, College of Sciences, Shiraz University, Shiraz 71454, Iran
ABSTRACT: There are two independent critical exponents that describe the behavior of systems near their critical point. However, at the critical point only the exponent η, which describes the decay of the correlation function, is usually discussed. We emphasize that there is a second independent exponent η′ that describes the decay of the fourth-order correlation function. The exponent η′ is related to the exponents determining the behavior of thermodynamic functions near criticality via a fluctuation-response equation for the specific heat. We also discuss a scaling law for η′. © 2006 American Association of Physics Teachers.
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DOI: 10.1119/1.2174962
AFFILIATIONS: Physics Department, Carnegie Mellon University, Pittsburgh, PA 15213, United States
ABSTRACT: The Boltzmann entropy as traditionally presented in statistical mechanics textbooks is only a special case and not Boltzmann's fundamental definition. The difference becomes important when the traditional expression for the entropy is applied to colloids, for which it makes incorrect predictions. Boltzmann's original definition of the entropy in terms of the probabilities of states of composite systems leads to consistent and correct statistical mechanics and thermodynamics. © 2000 American Association of Physics Teachers.
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DOI: 10.1119/1.2121755
AFFILIATIONS: H. H. Wills Physics Laboratory, University of Bristol, Tyndall Avenue, Bristol BS8 ITL, United Kingdom
ABSTRACT: Thermodynamics centers on the fact that work and heat are not functions of state. However, the natural formalism to capture this fact was not incorporated into thermodynamics because it was formulated before the development of vector field notation. One reason for reexamining this omission is provided by the work of Sadi Carnot that initiated thermodynamics. His results, which he derived from his grand principle, were not obtained by what is now called the 2 nd law of thermodynamics or by the 1st law of thermodynamics. Instead they were obtained by a (co)vector formula, albeit expressed in words not symbols. Carnot's formula allowed him to obtain several standard results of thermodynamics, including the Clausius-Clapeyron equation. The formula also implies the Maxwell relations. © 2006 American Association of Physics Teachers.
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DOI: 10.1119/1.2162547
AFFILIATIONS: Department of Physics and Astronomy, Dickinson College, Carlisle, PA 17013, United States
ABSTRACT: Glass syringes have precision fit low-friction pistons and are relatively inexpensive, which makes them an ideal tool for studying the thermal behavior of gases. The glass syringe is used to construct a thermometer, a miniature hydraulic press, and a working heat engine. Concepts illuminated by these experiments include temperature, pressure, the ideal gas law, work, internal energy, and the first law of thermodynamics. © 2006 American Association of Physics Teachers.
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DOI: 10.1119/1.2117127
AFFILIATIONS: Research Group on Materials Science and Thermodynamics, Department of Physics, University of Girona, Edif. PII, Campus Montilivi, E17071-Girona, Catalonia, Spain
ABSTRACT: The fundamental laws governing the mechanical equilibrium of solid-fluid systems were formulated in 1805 and 1806. They are Laplace's law, which describes the pressure drop across an interface, and Young's equation for the contact angle. At that time, these laws were justified on purely mechanical grounds. In 1880 Gibbs used thermodynamics to show that these laws were necessary conditions for the equilibrium of heterogeneous systems. We revisit Gibbs' derivation and simplify it for possible use at the undergraduate level. In addition, we present derivations of Young's and Laplace's equations, which involve energy balance on a volume element located at the surface. In particular, it is shown that the derivations are simpler, allow the analysis of nonequilibrium situations, and give a natural identification of the surface energy with the surface tension of the liquid-vapor interface. © 2005 American Association of Physics Teachers.
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DOI: 10.1119/1.1904623
AFFILIATIONS: Abteilung für Didaktik der Physik, Universität Karlsruhe, D-76128 Karlsruhe, Germany; Institut für Angewandte Physik, Universität Karlsruhe, D-76128 Karlsruhe, Germany
ABSTRACT: Thermodynamic states and processes involving light are discussed in which the chemical potential of light is nonzero. Light with nonzero chemical potential is produced in photochemical reactions, for example, in a light emitting diode. The chemical potential of black-body radiation becomes negative upon a Joule expansion. The isothermal diffusion of light, which is a common phenomenon, is driven by the gradient in the chemical potential. These and other examples support the idea that light can be interpreted as a gas of photons, with properties similar to a material gas. © 2005 American Association of Physics Teachers.
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DOI: 10.1119/1.1848116
AFFILIATIONS: Inst. für Theoretische Physik, Universität zu Köln, 50937 Köln, Germany
ABSTRACT: The thermodynamic properties of ideal quantum gases are derived solely from dimensional arguments, the Pauli principle, and thermodynamic relations, without resorting to statistical mechanics. ©2005 American Association of Physics Teachers.
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Falcon, E., Castaing, B.
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DOI: 10.1119/1.1848114
AFFILIATIONS: Laboratoire de Physique, Ecl. Normale Sup. de Lyon, UMR 5672, 46, allée d'Italie, 69 007 Lyon, France
ABSTRACT: We show how a simple laboratory experiment can illustrate certain electrical transport properties of metallic granular media. At a low critical external voltage, a transition from an insulating to a conductive state is observed. This transition comes from an electro-thermal coupling in the vicinity of the microcontacts between grains where microwelding occurs. Our apparatus allows us to obtain an implicit determination of the microcontact temperature, which is analogous to the use of a resistive thermometer. The experiment also helps us explain an old problem, Branly's coherer effect, which was used as a radio wave detector for the first wireless radio transmission, and is based on the sensitivity of the conductivity of metal filings to an electromagnetic wave. © 2005 American Association of Physics Teachers.
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DOI: 10.1119/1.1842732
AFFILIATIONS: Department of Physics, U.S. Naval Academy, Annapolis, MD 21402-5040, United States
ABSTRACT: Laser cooling of bulk matter uses thermally assisted fluorescence to convert heat into light and can be interpreted as an optically pumped laser running in reverse. Optical pumping in such devices drives the level populations out of equilibrium. Nonthermal radiative energy transfers are thereby central to the operation of both lasers and luminescent coolers. A thermodynamic treatment of their limiting efficiencies requires a careful development of the entropy and effective temperatures of radiation, valid for the entire range of light from the blackbody to the ideal laser limiting cases. In particular, the distinct meaning and utility of the brightness and flux temperatures should be borne in mind. Numerical examples help illustrate these concepts at a level suitable for undergraduate physics majors. © 2005 American Association of Physics Teachers.
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DOI: 10.1119/1.1783899
AFFILIATIONS: Department of Physics, B5, University of Liège, B-4000, Sart-Tilman, Belgium; Department of Chemistry, University of Missouri-Rolla, Rolla, MO 65409-0010, United States
ABSTRACT: The Einstein model of a solid usually lacks a clear illustration in introductory solid-state physics courses because most solids are much better described by the Debye model. Filled antimony skutterudites, materials that have recently attracted much attention because of their potential for thermoelectric applications, provide a canonical illustration of the Einstein model. The filling atoms are loosely bound in the atomic cage formed by their neighbors, and hence their description as independent harmonic oscillators is adequate. Simple models for the heat capacity and thermal conductivity of a solid are introduced, with emphasis on the density of vibrational states. These models are used in conjunction with experimental results obtained from heat capacity and inelastic neutron scattering measurements to demonstrate the applicability of the concept of the Einstein oscillator to the filling guests in antimony skutterudites. The importance of these Einstein oscillators for impeding thermal transport is discussed and some simple problems involving the heat capacity, thermal conductivity, and inelastic neutron scattering are proposed. © 2005 American Association of Physics Teachers.
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Hadley, S.W., Kelly, R., Lam, K.
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DOI: 10.1120/jacmp.v6i1.1957
AFFILIATIONS: Department of Radiation Oncology Physics, The University of Michigan, 1500 E. Medical Center Drive, Box 0010, Ann Arbor, Michigan 48109, United States
ABSTRACT: This work investigates the increase in surface dose caused by thermoplastic masks used for patient positioning and immobilization. A thermoplastic mask is custom fit by stretching a heated mask over the patient at the time of treatment simulation. This mask is then used at treatment to increase the reproducibility of the patient position. The skin sparing effect of mega-voltage X-ray beams can be reduced when the patient's skin surface is under the mask material. The sheet of thermoplastic mask has holes to reduce this effect and is available from one manufacturer with two different sizes of holes, one larger than the other. This work investigates the increase in surface dose caused by the mask material and quantifies the difference between the two samples of masks available. The change in the dose buildup was measured using an Attix parallel plate chamber by measuring tissue maximum ratios (TMRs) using solid water. Measurements were made with and without the mask material on the surface of the solid water for 6-MV and 15-MV X-ray beams. The effective thickness of equivalent water was estimated from the TMR curves, and the increase in surface dose was

estimated. The buildup effect was measured to be equivalent to 2.2 mm to 0.6 mm for masks that have been stretched by different amounts. The surface dose was estimated to change from 16% and 12% for 6 MV and 15 MV, respectively, to 27% to 61% for 6 MV and 18% to 40% for 15 MV with the mask samples.
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DOI: 10.1120/jacmp.v6i1.2051
AFFILIATIONS: Department of Radiation Medicine, University of Kentucky Medical Center, 800 Rose Street, Lexington, Kentucky  40536, United States
ABSTRACT: The high spatial resolution of radiochromic film makes it ideal for dosimetric measurements and dose distributions in regions of high dose gradient. Intensity-modulated radiation therapy, intravascular brachytherapy, and eye-plaque radiation therapy demand precise spatial dosimetric calculations. Such precision is not possible with conventional dosimeters, such as thermoluminescent dosimeters and ionization chambers. Recently, new GAFCHROMIC XR type T and type R films have been developed for radiation dosimetry, specifically in interventional radiology procedures. Dosimetric characteristics (i.e., linearity, post-exposure density growth, energy dependence, dose-rate dependence, and UV light sensitivity) of these new films were investigated. To evaluate the clinical applications of these films, their characteristics were compared with other commercially available film models. GAFCHROMIC XR type T and type R films were found to be more sensitive to low-energy doses as compared with GAFCHROMIC MD-55 films.
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DOI: 10.1119/1.1794753
AFFILIATIONS: Department of Physics, Texas A and M University, College Station, TX 77843, United States;
Department of Theoretical Physics, Palacký University, 17. listopadu 50, 77200 Olomouc, Czech Republic
ABSTRACT: In a maser, a state selector sends excited molecules or atoms to a resonant cavity, while ground-level particles are not allowed to enter the resonator. The excited particles radiate their energy in the form of coherent electromagnetic oscillation. In this way the thermal energy of the atoms is transformed into useful work. Is this transformation equivalent to the Maxwell demon violating the second law? We explain the thermodynamics of an idealized maser system which works as a reversible heat engine and show how the second law reveals its validity during the conversion of heat into coherent radiation and mechanical work. We discuss different working regimes of the system. In particular, the ideal engine can either work with two heat reservoirs and convert heat into maser radiation with the Carnot efficiency, or, if working with a single heat reservoir, the engine can convert mechanical work entirely into maser radiation. © 2005 American Association of Physics Teachers.
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Investigation of students' reasoning regarding heat, work, and the first law of thermodynamics in an introductory calculus-based general physics course
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DOI: 10.1119/1.1789161
AFFILIATIONS: Department of Physics and Astronomy, Iowa State University, Ames, IA 50011, United States
ABSTRACT: Students in an introductory university physics course were found to share many substantial difficulties related to learning fundamental topics in thermal physics. Responses to written questions by 653 students in three separate courses were consistent with the results of detailed individual interviews with 32 students in a fourth course. Although most students seemed to acquire a reasonable grasp of the state-function concept, it was found that there was a widespread and persistent tendency to improperly over-generalize this concept to apply to both work and heat. A large majority of interviewed students thought that net work done or net heat absorbed by a system undergoing a cyclic process must be zero, and only 20% or fewer were able to make effective use of the first law of thermodynamics even after instruction. Students' difficulties seemed to stem in part from the fact that heat, work, and internal energy share the same units. The results were consistent with those of previously published studies of students in the U.S. and Europe, but portray a pervasiveness of confusion regarding process-dependent quantities that has been previously unreported. Significant enhancements of current standard instruction may be required for students to master, basic thermodynamic concepts. © 2004 American Association of Physics Teachers.
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DOI: 10.1119/1.1773577
AFFILIATIONS: Laboratoire Ondes et Acoustique, ESPCI, Université Paris VII, 10 rue Vauquelin, 75231 Paris Cedex 05, France
ABSTRACT: Acoustic time-reversal is a well-established technique that focuses an ultrasonic wave on the location of its source. It is based on the time-reversal invariance of the wave equation and is usually implemented using time-reversal mirrors made up of a hundred of piezoelectric transducers. However, a time-reversal experiment can be performed in a closed cavity (a water-filled beaker) with only one transducer as a pulse-echo system. This easy-to-build and low cost experiment involves students in the general concept of the time-reversal invariance of the wave equation. We show that it also can be adapted to become an ultrasonic time-reversal thermometer. A careful study of the focal point shows a dependence of its position as a function of temperature variations. © 2004 American Association of Physics Teachers.
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Landau, D.P., Tsai, S.-H., Exler, M.
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DOI: 10.1119/1.1707017
AFFILIATIONS: Center for Simulational Physics, University of Georgia, Athens, GA 30602, United States;
Fachbereich Physik, Universität Osnabrück, D-49069 Osnabrück, Germany
ABSTRACT: We describe a Monte Carlo algorithm for doing simulations in classical statistical physics in a different way. Instead of sampling the probability distribution at a fixed temperature, a random walk is performed in energy space to extract an estimate for the density of states. The probability can be computed at any temperature by weighting the density of states by the appropriate Boltzmann factor. Thermodynamic properties can be determined from suitable derivatives of the partition function and, unlike "standard" methods, the free energy and entropy can also be computed directly. To demonstrate the simplicity and power of the algorithm, we apply it to models exhibiting first-

order or second-order phase transitions. ©2004 American Association of Physics Teachers.
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DOI: 10.1119/1.1737395
AFFILIATIONS: Department of Physics, University of Wisconsin-Madison, Madison, WI 53706, United States
ABSTRACT: I show how the pressure in Fermi and Bose systems, identified in standard discussions of quantum statistical mechanics by the use of thermodynamic analogies, can be derived directly in terms of the flux of momentum across a surface by using the quantum mechanical stress tensor. In this approach, which is analogous to classical kinetic theory, the pressure is naturally defined locally. The approach leads to a simple interpretation of the pressure in terms of the momentum flow encoded in the wave functions. The stress-tensor and thermodynamic approaches are related by an interesting application of boundary perturbation theory for quantum systems. I investigate the properties of quasi-continuous systems, the relations for Fermi and Bose pressures, shape-dependent effects and anisotropies, and the treatment of particles in external fields, and note several interesting problems for graduate courses in statistical mechanics. © 2004 American Association of Physics Teachers.
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DOI: 10.1119/1.1703547
AFFILIATIONS: Department of Physics, Oberlin College, Oberlin, OH 44074, United States
DOCUMENT TYPE: Erratum
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DOI: 10.1119/1.1703544
AFFILIATIONS: Theoretical Division, Los Alamos National Laboratory, Los Alamos, NM 87545, United States
ABSTRACT: The calculation of the structure of white dwarf and neutron stars is a suitable topic for an undergraduate thesis or an advanced special topics or independent study course. The subject is rich in many different areas of physics, ranging from thermodynamics to quantum statistics to nuclear physics to special and general relativity. The computations for solving the coupled structure differential equations (both Newtonian and general relativistic) can be done using a symbolic computational package. In doing so, students will develop computational skills and learn how to deal with units. Along the way they also will learn some of the physics of equations of state and of degenerate Stars. ©2004 American Association of Physics Teachers.
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DOI: 10.1119/1.1648327
AFFILIATIONS: Department of Physics, Washington and Jefferson College, Washington, PA 15301, United States
ABSTRACT: I describe subtle calculus ideas that are essential for thermodynamics, but are typically not encountered by students in calculus or prior physics classes. I argue that these previously unencountered subtleties are a substantial cause of the difficulty that many students encounter in learning thermodynamics and that thermodynamics can be taught more effectively by introducing the subtleties within an environment with which students are familiar rather than insisting that students learn them at the same time that they encounter new physics concepts such as entropy and thermodynamic potentials. I show how Legendre transforms can be used to illustrate the important calculus concepts and the nature of thermodynamics calculations. An added advantage of this approach is that it provides a coherent picture of the thermodynamic potentials. © 2004 American Association of Physics Teachers.
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DOI: 10.1119/1.1624116
AFFILIATIONS: Institute de Física, Univ. Federal do Rio Grande do Sul, Caixa Postal 15051, 91501-970-Porto Alegre, RS, Brazil
ABSTRACT: We discuss the main features of noncommutative quantum mechanics, a version of nonrelativistic quantum mechanics that involves noncommuting coordinates. After finding a representation for the algebra obeyed by the coordinates and momenta, we analyze the changes due to the noncommutative nature of the coordinates. The noncommutative two-dimensional harmonic oscillator is discussed in detail. Under certain restrictions, the effect of the noncommutativity is found to be equivalent to a Landau interaction. The modifications produced by the noncommutativity on the thermodynamic functions of the oscillator also are studied. © 2004 American Association of Physics Teachers.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Domínguez-Adame, F., Malyshev, V.A.
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A simple approach to Anderson localization in one-dimensional disordered lattices
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DOI: 10.1119/1.1593660
AFFILIATIONS: GISC, Depto. de Fís. de Materiales, Universidad Complutense, E-28040 Madrid, Spain; S. I. Vavilov Stt. Optical Institute, Saint-Petersburg, Russian Federation
ABSTRACT: We present a simple approach to Anderson localization in one-dimensional disordered lattices. We introduce the tight-binding model in which one orbital and a single random energy are assigned to each lattice site, and the hopping integrals are constant and restricted to nearest-neighbor sites. The localization of eigenstates is explained by two-parameter scaling arguments. We compare the size scaling of the level spacing in the bare energy spectrum of the quasi-particle (in the ideal lattice) with the size scaling of the renormalized disorder seen by the quasi-particle. The former decreases faster than the latter with increasing system size, giving rise to mixing and to the localization of the bare quasi-particle wave functions in the thermodynamic limit. We also provide a self-consistent calculation of the localization length and show how this length can be obtained from

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DOI: 10.1119/1.1794761
AFFILIATIONS: Laboratory of Physical Chemistry, Department of Chemistry, University of Athens, Panepistimiopolis, Athens, GR-15771, Greece
DOCUMENT TYPE: Letter
PUBLICATION STAGE: Final
SOURCE: Scopus

Yokoyama, S., Roberson, P.L., Litzenberg, D.W., Moran, J.M., Fraass, B.A.
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Surface buildup dose dependence on photon field delivery technique for IMRT.
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DOI: 10.1120/jacmp.v5i2.1966
AFFILIATIONS: Department of Radiation Oncology, University of Michigan Medical Center, Ann Arbor, Michigan  48109-0010, United States
ABSTRACT: The more complex delivery techniques required for implementation of intensity-modulated radiotherapy (IMRT) based on inverse planning optimization have changed the relationship between dose at depth and dose at buildup regions near the surface. Surface buildup dose is dependent on electron contamination primarily from the unblocked view of the flattening filter and secondarily from air and collimation systems. To evaluate the impact of beam segmentation on buildup dose, measurements were performed with 10 x 10 cm2 fields, which were delivered with 3 static 3.5 x 10 cm2 or 3 x 10 cm2 strips, 5 static 2 x 10 cm2 strips, 10 static 1 x 10 cm2 strips, and 1.1 x 10 cm2 dynamic delivery, compared with a 10 x 10 cm2 open field. Measurements were performed in water and Solid Water using parallel plate chambers, a stereotactic diode, and thermoluminescent dosimeters (TLDs) for a 6 MV X-ray beam. Depth doses at 2 mm depth (relative to dose at 10 cm depth) were lower by 6%, 7%, 11%, and 10% for the above field delivery techniques, respectively, compared to the open field. These differences are most influenced by differences in multileaf collimator (MLC) transmission contributing to the useful beam. An example IMRT field was also studied to assess variations due to delivery technique (static vs. dynamic) and intensity level. Buildup dose is weakly dependent on the multileaf delivery technique for efficient IMRT fields.
DOCUMENT TYPE: Article
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Hui, S.K., Das, R.K., Thomadsen, B., Henderson, D.
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CT-based analysis of dose homogeneity in total body irradiation using lateral beam.
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DOI: 10.1120/jacmp.v5i4.1980
AFFILIATIONS: Department of Human Oncology, University of Wisconsin-Madison, 600 Highland Avenue, Madison, Wisconsin  53792, United States
ABSTRACT: A computed tomography (CT) based treatment planning system for total body irradiation (TBI) is presented and compared with the commonly practiced lateral treatment delivery. The TBI regimen has been proved to be an essential conditional regimen for patients undergoing bone marrow transplantation. The advantage of the TBI regimen with bone marrow transplantation (BMT) in

hematological malignancies can be offset by toxicities arising from TBI in posttransplant complications. With the increasing survival rates, the evaluation of long-term side effects and quality of life has become an important area of research interest. There have been several treatment techniques developed over the decades designed to achieve accurate dose delivery and dose homogeneity. This paper reports on the verification of the dose delivery for a basic lateral technique using thermoluminescent dosimeters (TLDs) placed in an anthropomorphic phantom and its correlation with CT-based treatment planning. CT-based treatment plans on several patients were used to evaluate the doses delivered to the whole body and critical organs. A large variation in doses delivered to the whole body was demonstrated, with some parts of the bone marrow failing to receive the prescribed dose and some critical organs, such as the lungs, receiving excessive doses. Placing the arms at the sides only partially compensates for the increased transmission of the lungs because the arms only shadow part of the lung. This study shows that CT-based treatment planning for TBI provides precise and accurate dose calculations and allows for the correlation of clinical outcomes with the doses actually delivered to various organs.
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1768556
AFFILIATIONS: Department of Physics, Royal Institute of Technology, AlbaNova University Center, SE-106 91 Stockholm, Sweden
AUTHOR KEYWORDS: 01.55;  05.20
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DOI: 10.1119/1.1621028
AFFILIATIONS: Department of Physics, Oberlin College, Oberlin, OH 44074, United States
ABSTRACT: Statistical mechanics applies to large systems: technically, its results are exact only for infinitely large systems in "the thermodynamic limit." The importance of this proviso is often minimized in undergraduate courses. This paper presents six paradoxes in statistical mechanics that can be resolved only by acknowledging the thermodynamic limit. For example, it demonstrates that the widely used microcanonical "thin phase space limit" must be taken after taking the thermodynamic limit. © 2004 American Association of Physics Teachers.
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Garrett, S.L.
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Resource letter: TA-1: Thermoacoustic engines and refrigerators
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DOI: 10.1119/1.1621034
AFFILIATIONS: Graduate Program in Acoustics, Penn State University, State College, PA 16804, United States
ABSTRACT: This Resource Letter provides an annotated guide to some of the literature pertaining to the understanding of thermoacoustic engines and refrigerators. These devices incorporate acoustical components and networks to produce mechanical power or to pump heat, or both, without the use of

traditional mechanical contrivances such as pistons, linkages, and valves. To bring some order to this research and the variety of thermoacoustic engines and refrigerators produced over the past two decades, these devices also are classified as stack-based and regenerator-based. The background and motivation for this organizational structure is provided in the introduction. © 2004 American Association of Physics Teachers.
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Thermodynamics of black holes in a finite box
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DOI: 10.1119/1.1590656
AFFILIATIONS: Inst. Astron., Geofis./Cie. A., Rua do Matão, 1226, 05508-900 São Paulo SP, Brazil
ABSTRACT: We analyze the thermodynamic behavior of black holes in a finite closed box. The evolution of the black hole mass is analyzed, with and without radiation initially. We deduce a minimal volume above which one black hole can lose all of its mass to the box, a result that agrees with a previous analysis by Page. The equilibrium times and masses are evaluated and their behavior is discussed. We show that N black holes achieve the same equilibrium masses even though the initial masses were different. The total entropy of the system is used to derive the functional dependence of the equilibrium mass on the box volume, the number of black holes, and the temperature of the radiation. A set of problems devised to reinforce the concepts is also presented. © 2003 American Association of Physics Teachers.
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DOI: 10.1119/1.1593658
AFFILIATIONS: Department of Physics, Center for Molecular Electronics, University of Missouri, St. Louis, St. Louis, MO 63121, United States;
Department of Physics, Washington University, St. Louis, MO 63130, United States
ABSTRACT: The temperature T may be expressed as the rate of energy increase per unit increase in the state uncertainty under no-work conditions. The consequences of such a choice for heat capacities are explored. I show that the ratio of the total thermal energy E to k T is the multiplicity exponent (log-log derivative of the multiplicity) with respect to energy, as well as the number of base-b units of mutual information that is lost about the state of the system per b-fold increase in the thermal energy. Similarly, the no-work heat capacity CV is the multiplicity exponent for temperature, making C V independent of the choice of the intensive parameter associated with energy (for example, kT vs 1/kT) to within a constant, and explaining why its usefulness may go beyond the detection of thermodynamic phase changes and quadratic modes. © 2003 American Association of Physics Teachers.
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DOI: 10.1119/1.1566782
AFFILIATIONS: Department of Physics, City College, City University of New York, New York, NY 10031, United States

ABSTRACT: A thermodynamic analysis of the harmonic oscillator is presented. The motivation is provided by the blackbody radiation spectrum, because radiation modes take the harmonic-oscillator form. We use the behavior of a thermal harmonic oscillator system under a quasistatic change of oscillator frequency w to show that the thermodynamic functions can all be derived from a single function of ω/T, analogous to Wien's displacement theorem. The high- and low-frequency limits yield asymptotic forms involving the temperature T alone or frequency ω alone, corresponding to energy equipartition and zero-point energy. We suggest a natural interpolation between the limiting forms. The Planck spectrum with zero-point energy corresponds to the function satisfying the Wien displacement result which provides the smoothest possible interpolation between energy equipartition at low frequency and zero-point energy at high frequency. © 2003 American Association of Physics Teachers.
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DOI: 10.1119/1.1571833
AFFILIATIONS: Department of Mathematical Sciences, Ball State University, Muncie, IN 47306, United States
ABSTRACT: One of the first mathematical models that students encounter is that of the cooling of a cup of coffee. A related, but more complicated, problem is how the temperature in a thermos full of ice-cold water changes as a function of both time and position in the thermos. We use the approach developed by Fourier for the heating of an insulated rod to establish a model for a thermos. We verify the model by comparing it to data recorded with a calculator-based laboratory. © 2003 American Association of Physics Teachers.
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Jeromen, A.
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DOI: 10.1119/1.1524163
AFFILIATIONS: Inst. of Math., Phys. and Mechanics, University of Ljubljana, P.O. Box 2964, SI-1000 Ljubljana, Slovenia
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Craig Wheeler, J., Stuewer, R.H.
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DOI: 10.1119/1.1523076
AFFILIATIONS: Department of Astronomy, University of Texas at Austin, 1 University Station, Austin, TX 78712-0259, United States;
School of Physics and Astronomy, University of Minnesota, 116 Church Street SE, Minneapolis, MN 55455, United States
ABSTRACT: This Resource Letter provides a guide to the literature on the observations of supernovae and the theory of their explosion mechanisms. Journal articles and books are cited for the following topics: observations of the spectra, spectropolarimetry, and light curves of supernovae of various types, theory of thermonuclear explosions, core collapse, and radioactive decay, applications to

cosmology, and possible connections to gamma-ray bursts. © 2003 American Association of Physics Teachers.
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DOI: 10.1119/1.1456070
AFFILIATIONS: Department of Mechanical Engineering, University of California, Berkeley, CA 94720, United States
ABSTRACT: The propagation speed c of an infinitesimal pressure step is obtained as a compatibility condition on the system of equations derived from the thermal equation of state and balances of mass, momentum, and total energy. Because the entropy is not introduced during the derivation, c is given initially in terms of the pressure, volume v per unit mass, and derivatives of the internal energy. An identity using only the first law of thermodynamics is then used to show that $c = \sqrt{\gamma v K_T}$, where γ is the specific heat ratio, and $K_T$ is the isothermal bulk modulus. This derivation differs from existing ones as the entropy is not used to obtain the result for c, but only to interpret it. © 2002 American Association of Physics Teachers.
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DOI: 10.1119/1.1479743
AFFILIATIONS: Department of Physics, California State Polytechnic University, Pomona, 3801 West Temple Avenue, Pomona, CA 91768, United States
ABSTRACT: The ideal gas is often the only thermodynamic system for which equations of state are studied in introductory physics. The photon gas can be a rich supplement to the ideal gas, and a vehicle for introducing 20th century physics concepts. © 2002 American Association of Physics Teachers.
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Pellicer, J., García-Morales, V., Guanter, L., Hernández, M.J., Dolz, M.
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DOI: 10.1119/1.1477431
AFFILIATIONS: Departament de Tennodinàmica, Universitat de València, E-46100 Burjassot, Spain
ABSTRACT: A thermodynamic study of one component liquid-vapor planar interfaces and the temperature dependence of some relevant thermodynamic quantities is presented. A critical review of data for the surface tension of water found in some textbooks is given. More accurate measurements show a qualitative change in the temperature dependence of the surface tension, from the almost linear dependence of the old data to nonlinear behavior and the occurrence of an inflection point in the more accurate, more recent data. © 2002 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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Zia, R.K.P., Praestgaard, E.L., Mouritsen, O.G.
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DOI: 10.1119/1.1427088
AFFILIATIONS: Department of Physics, Virginia Polytechnic Institute, State University, Blacksburg, VA 24061-0435, United States;
Fachbereich Physik, Universität Essen, D-45117 Essen, Germany;
Department of Life Sciences and Chemistry, Roskilde University, 4000, Roskilde, Denmark;
Department of Physics, University of Southern Denmark-Odense, Campusvej 55, DK-5230 Odense M, Denmark
ABSTRACT: For students familiar with equilibrium statistical mechanics, the notion of a positive specific heat, being intimately related to the idea of stability, is both intuitively reasonable and mathematically provable. However, for systems in nonequilibrium stationary states, coupled to more than one energy reservoir, a negative specific heat is entirely possible. We present a minimal system that displays this phenomenon. For a system in contact with two thermal baths at different temperatures, the (internal) energy may increase when a thermostat is turned down. In another context, a similar phenomenon is negative conductivity, where a current may increase by decreasing the drive (for example, an external electric field). The counter-intuitive behavior in both processes may be described as getting more from pushing less. The crucial ingredients for this phenomenon and the elements needed for a minimal system are also presented. © 2002 American Association of Physics Teachers.
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Loverude, M.E., Kautz, C.H., Heron, P.R.L.
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Student understanding of the first law of thermodynamics: Relating work to the adiabatic compression of an ideal gas
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DOI: 10.1119/1.1417532
AFFILIATIONS: Department of Physics, Box 351560, University of Washington, Seattle, WA 98195-1560, United States;
Department of Physics, California State University Fullerton, Fullerton, CA 92834, United States;
Department of Physics, Syracuse University, Syracuse, NY 13210, United States
ABSTRACT: We report on an investigation of student understanding of the first law of thermodynamics. The students involved were drawn from first-year university physics courses and a second-year thermal physics course. The emphasis was on the ability of the students to relate the first law to the adiabatic compression of an ideal gas. Although they had studied the first law, few students recognized its relevance. Fewer still were able to apply the concept of work to account for a change in temperature in an adiabatic process. Instead most of the students based their predictions and explanations on a misinterpretation of the ideal gas law. Even when ideas of energy and work were suggested, many students were unable to give a correct analysis. They frequently failed to differentiate the concepts of heat, temperature, work, and internal energy. Some of the difficulties that students had in applying the concept of work in a thermal process seemed to be related to difficulties with mechanics. Our findings also suggest that a misinterpretation of simple microscopic models may interfere with student ability to understand macroscopic phenomena. Implications for instruction in thermal physics and in mechanics are discussed. © 2002 American Association of Physics Teachers.
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Russell, D.A., Weibull, P.
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DOI: 10.1119/1.1485720
AFFILIATIONS: Science and Mathematics Department, Kettering University, Flint, MI 48504, United States;
TXU Energy Trading, Dallas, TX 75201, United States
ABSTRACT: An inexpensive (less than $25) tabletop thermoacoustic refrigerator for demonstration purposes was built from a boxed loudspeaker, acrylic tubing and sheet, a roll of 35 mm film, fishing line, an aluminum plug, and two homemade thermocouples. Temperature differences of more than 15 °C were achieved after running the cooler for several minutes. While nowhere near the efficiency of devices described in the literature, this demonstration model effectively illustrates the behavior of a thermoacoustic refrigerator. © 2002 American Association of Physics Teachers.
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DOI: 10.1119/1.1512658
AFFILIATIONS: Departamento de Física, Centro de Ciências e Tecnologia, Universidade Federal de Campina Grande, 58109-970 Campina Grande-PB, Brazil;
Departamento de Engenharia Elétrica, Centro de Ciências e Tecnologia, Universidade Federal de Campina Grande, 58109-970 Campina Grande-PB, Brazil
ABSTRACT: Semiconductor diodes, in conjunction with a constant current source, are sometimes used as thermometers. It has been observed experimentally that, within a certain temperature range, the relation between temperature and voltage is almost linear. We show that this linearity is a direct consequence of the constancy of the current flowing through the diode, and that the parameters resulting from a least-squares fit to the experimental data can be used to determine the band gap energy of the semiconductor. We test the validity of our model by comparing our results to measurements on diodes made of germanium and silicon. If we take into account the simplifications used in our model, the results agree well with known values of the energy gaps. © 2002 American Association of Physics Teachers.
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Rebhan, E.
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DOI: 10.1119/1.1501116
AFFILIATIONS: Institut fur Theoretische Physik, Heinrich-Heine-Universität, D-40225 Düsseldorf, Germany
ABSTRACT: In nonideal thermodynamic engines the efficiency is well below the Carnot efficiency η=1-t1/T2. In 1975 an expression for the efficiency of a nonideal Carnot engine with heat losses was derived, yielding η=1 - √T1/T2 at maximum power output. In this paper, a corresponding relation is obtained for more general nonideal Carnot engines. If there are friction losses only, the result is η = (1 - T1/T2)/2. If friction and heat losses are both included, the efficiency at maximum power depends on a dimensionless parameter λ* that takes into account the effects of friction and heat conduction, and can vary between the values obtained for friction and heat losses separately, (1 - T1/T2)/2< ηpmax< 1 - √T1/T2. A general relation between efficiency and power output is established, and it is shown that an appreciable gain in efficiency can be obtained at a power output only slightly below its maximum. © 2002 American Association of Physics Teachers.
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Gifford, K.A., Followill, D.S., Liu, H.H., Starkschall, G.
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DOI: 10.1120/jacmp.v3i1.2589
AFFILIATIONS: Department of Radiation Physics, The University of Texas M. D. Anderson Cancer Center, Houston, Texas, United States
ABSTRACT: An extensive set of measured data was developed for the purpose of verifying the accuracy of a photon dose-calculation algorithm. Dose distributions from a linear accelerator were measured using an ion chamber in a water phantom and thermoluminescent dosimeters in a heterogeneous anthropomorphic phantom. Test cases included square fields, rectangular fields, fields having different source-to-surface distances, wedged fields, irregular fields, obliquely incident fields, asymmetrically collimated fields with wedges, multileaf collimator-shaped fields, and two heterogeneous density cases. The data set was used to validate the photon dose-calculation algorithm in a commercial radiation treatment planning system. The treatment planning system calculated photon doses to within the American Association of Physicists in Medicine (AAPM) Task Group 53 (TG-53) criteria for 99% of points in the buildup region, 90% of points in the inner region, 88% of points in the outer region, and 93% of points in the penumbra. For the heterogeneous phantoms, calculations agreed with actual measurements to within +/-3%. The monitor unit tests revealed that the 18-MV open square fields, oblique incidence, oblique incidence with wedge, and mantle field test cases did not meet the TG-53 criteria but were within +/-2.5% of measurements. It was concluded that (i) the photon dose calculation algorithm used by the treatment planning system did not meet the TG-53 criteria 100% of the time; (ii) some of the TG-53 criteria may need to be modified, and (iii) the generally stated goal of accuracy in dose delivery of within 5% cannot be met in all situations using this beam model in the treatment planning system.
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DOI: 10.1120/jacmp.v3i4.2558
AFFILIATIONS: Department of Radiology, Martin Luther King/Drew Medical Center, 12021 South Wilmington Boulevard, Los Angeles, California  90059, United States
ABSTRACT: Two specially designed plastic/aluminum phantoms positioned thermoluminescent dosimeters (TLDs) at the right and left breast location of an anthrophomorophic chest torso. Imaging was performed on a spiral CT for a Volume of the chest phantom through the breast area for a noncontiguous (pitch 1.5) helical chest scan. Conventional pencil beam ionization chamber measurements were made at the same operating parameters. The doses ranged from approximately 1 to 3 cGy. For both breast phantoms, the doses were highest for the medial inner quadrants near the mediastinum. The doses were lowest for the outer quadrants (lateral aspects) of both breasts.
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AFFILIATIONS: Faculty of Mathematical Studies, University of Southampton Southampton SO17 1BJ, United Kingdom
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DOI: 10.1119/1.1410957
AFFILIATIONS: Physics Department, California State Polytechnic University, Pomona, 3801 West Temple Avenue, Pomona, California 91768, United States
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DOI: 10.1119/1.1410956
AFFILIATIONS: Computing Division Fermi National Accelerator Laboratory Batavia, Illinois 60510-0500, United States
AUTHOR KEYWORDS: 0.5;  05.70
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DOI: 10.1119/1.1410958
AFFILIATIONS: Department of Economics Santa Clara University Santa Clara, California 95053, United States
AUTHOR KEYWORDS: 0.5;  05.70
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DOI: 10.1119/1.1410959
AFFILIATIONS: Laboratory of Atomic and Solid State Physics Cornell, University Ithaca, New York 14853, United States
AUTHOR KEYWORDS: 0.5;  05.70
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DOI: 10.1119/1.1412643
AFFILIATIONS: Universität Osnabrück, Fachbereich Physik, Barbarastrasse 7, 49069 Osnabrück, Germany
ABSTRACT: We find a close correspondence between the partition functions of ideal quantum gases and certain symmetric polynomials. From this correspondence, it can be shown that a number of thermodynamic identities that have recently been considered in the literature are essentially of combinatorial origin and have been known for a long time as theorems on symmetric polynomials. For example, a recurrence relation for partition functions in the textbook by P. Landsberg is Newton's identity in disguised form. Conversely, a theorem on symmetric polynomials translates into a new and unexpected relation between fermion and boson partition functions, which can be used to express the former by means of the latter and vice versa. © 2002 American Association of Physics Teachers.
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DOI: 10.1119/1.1397456
AFFILIATIONS: Departamento de Física Aplicada I, Facultad de Físicas, Universidad Complutense, 28040 Madrid, Spain;
Departamento de Física Aplicada, Facultad de Ciencias, Universidad de Salamanca, 37008 Salamanca, Spain
ABSTRACT: A simple system is used to illustrate the application of different extremum principles in thermodynamics. The system consists of an ideal gas contained in an adiabatically isolated cylinder interacting with a constant-pressure work device through an adiabatic movable piston. A kinetic model is also used to analyze the time evolution of the system toward the final equilibrium state. © 2001 American Association of Physics Teachers.
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DOI: 10.1120/jacmp.v2i2.2616
AFFILIATIONS: Department of Radiation Physics, The University of Texas M. D. Anderson Cancer Center, 1515 Holcombe Boulevard, Houston, Texas  77030, United States
ABSTRACT: The accuracy of the photon convolution/superposition dose algorithm employed in a commercial radiation treatment planning system was evaluated for conditions simulating tangential breast treatment. A breast phantom was fabricated from machineable wax and placed on the chest wall of an anthropomorphic phantom. Radiographic film was used to measure the dose distribution at the axial midplane of the breast phantom. Subsequently, thermoluminescent dosimeters (TLDs) were used to measure the dose at four points within the midplane to validate the accuracy of the film dosimetry. Film measurements were compared with calculations performed using the treatment planning system for four types of treatment: optimized wedged beams at 6 and 18 MV and two-dimensional compensated beams at 6 and 18 MV. Both the film- and TLD-measured doses had a precision of approximately 0.6%. The

film-measured doses were approximately 1.5% lower than the TLD-measured doses, ranging from 0-3% at 6 MV and 0.5-1% at 18 MV. Such results placed a high level of confidence in the accuracy and precision of the film data. The measured and calculated doses agreed to within +/-3% for both the film and TLD measurements throughout the midplane exclusive of areas not having charged particle equilibrium. Good agreement was not expected within these regions due to the limitations in both film dosimetry and the dose-calculation algorithm. These results indicated that the treatment planning system calculates doses at the midplane with clinically acceptable accuracy in conditions simulating tangential breast treatment.
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DOI: 10.1119/1.1352718
AFFILIATIONS: Laboratory of Atomic and Solid State Physics Cornell University, Ithaca, New York 14853, United States
AUTHOR KEYWORDS: 0.5;  05.70
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DOI: 10.1119/1.1371917
AFFILIATIONS: Department of Physics and Astronomy, University of Georgia, Athens 30602-2451, United States
ABSTRACT: The Carnot cycle for a photon gas provides a useful means to illustrate the thermodynamic laws. It is particularly useful in showing the path dependence of thermodynamic functions. Thermodynamic relationships to a neutrino gas are also drawn. © 2001, American Association of Physics Teachers. All rights reserved.
AUTHOR KEYWORDS: 05.20;  05.70;  90
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DOI: 10.1119/1.1287719
AFFILIATIONS: Department of Physics, Center for Theoretical Physics, Seoul National University, Seoul, 151-742, South Korea
ABSTRACT: We report on several simulation programs (available through http://phys.snu.ac.kr/howto/ or http:// phya.snu.ac.kr/~kclee/howto/) which can be used to teach the statistical foundations of thermal physics in introductory college physics courses. These programs are simple applications of a technique for generating random configurations of many dice with a fixed total value. By merely simulating dice throwing we can demonstrate all the important principles of classical thermodynamics. © 2001 American Association of Physics Teachers.
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Ma, L., Chin, L., Sarfaraz, M., Shepard, D., Yu, C.
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DOI: 10.1120/jacmp.v1i4.2632
AFFILIATIONS: Department of Radiation Oncology, University of Maryland School of Medicine, Baltimore, MD 21201, United States
ABSTRACT: Stereotactic Gamma Knife radiosurgery has been widely used for treating trigeminal neuralgia (TN). A single large fractional dose of 7000 to 9000 cGy is commonly prescribed as the maximum dose for these treatments. For this reason, if a small percentage of the prescribed dose such as 2-3% scattered to the eye, it could reach or even exceed the tolerance dose of the lens. For several TN cases, we found that the Leksell Gamma Plan system calculates the lens dose about 0.5-2% of the maximum dose independent of the use of eye shielding. These dose values are significantly high and it motivated us to investigate the lens dose for the TN patients treated with stereotactic Gamma Knife radiosurgery. Phantom studies and in vivo dosimetry measurements were carried out for six patients treated at our institution. The average dose to the lens ipsilateral to the treated nerve was measured to be 7.7+/-0.6 cGy. Based on the biological model of Lyman and Emami [Int. J. Radiat. Oncol. Biol. Phys. 21, 109-122 (1991)], the probability of the lens complication (cataract) was determined to be 0.1%. Our findings suggest that few TN patients would develop cataracts after receiving Gamma Knife radiosurgery.
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DOI: 10.1119/1.1302719
AFFILIATIONS: Mechanical Engineering Department, Purdue University, 1288 Mechanical Engineering Building, West Lafayette, 47907-1288, United States
AUTHOR KEYWORDS: 05.70
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DOI: 10.1119/1.19478
AFFILIATIONS: California Stt. Polytech. University, Physics Department, 3801 West Temple Avenue, Pomona, CA 91768, United States
ABSTRACT: The Boltzmann reservoir (BR) is a model constant-temperature environment that exhibits highly atypical thermodynamic behavior. Its microcanonical ensemble entropy is a linear, nonconcave function of its internal energy U, and its zero-work heat capacity is infinite. Its canonical partition function diverges because all possible energies are equally likely, so the microcanonical and canonical ensembles are not equivalent. If two BRs with the same temperature TB are put in thermal contact, either can have any fraction of the total energy; i.e., there is no unique equilibrium state. If two BRs with different temperatures are in thermal contact, the higher temperature BR gives all its energy to the other. A BR's temperature cannot be changed by a heat process but, in principle, can be altered by a work process. These and other properties that challenge conventional wisdom provide thought-provoking examples for thermal physics courses. © 2000 American Association of Physics Teachers.

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DOI: 10.1119/1.19383
AFFILIATIONS: Department of Physics and Astronomy, University of Massachusetts, Amherst, MA 01003, United States
ABSTRACT: We examine Bose-Einstein condensation (BEC) for particles trapped in a harmonic potential by considering it as a transition in the length of permutation cycles that arise from wave-function symmetry. This "loop-gas" approach was originally developed by Feynman in his path-integral study of BEC for a homogeneous gas in a box. For the harmonic oscillator potential it is possible to treat the ideal gas exactly so that one can easily see how standard approximations become more accurate in the thermodynamic limit (TDL). One clearly sees that the condensate is made up of very long permutation loops whose length fluctuates ever more widely as the number of particles increases. In the TDL, the Wentzel-Kramers-Brillouin approximation, equivalent to the standard approach to BEC, becomes precise for the noncondensate; however, this approximation neglects completely the long cycles that make up the condensate. We examine the exact form for the density matrix for the system and show how it describes the condensate and behaves in the TDL. © 2000 American Association of Physics Teachers.
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Mafé, S., Manzanares, J.A., De La Rubia, J.
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DOI: 10.1119/1.1285849
AFFILIATIONS: Department of Thermodynamics, Faculty of Physics, University of Valencia, E-46100 Burjasot, Spain
ABSTRACT: The statistical definition of entropy is often used to justify Planck's form of the third law of thermodynamics in a very graphic form. Statements like for a nondegenerate ground state system at 0 K, the system should be in its lowest energy (ground) state and then S=O according to the statistical definition of entropy are commonplace in many textbooks. These statements are useful, but might as well be supplemented with more empirical views concerning the physical limits of low temperatures in thermodynamics and the high number of states still accessible for a macroscopic system when the entropy takes small values. The purpose of this note is to emphasize the above points making use of four model systems: the Fermi ideal gas, the confined Bose ideal gas, the photon gas, and the noninteracting particles in a two-level system. Each of these physical systems has a characteristic temperature related to the nature and organization of its microscopic constituents and the third law should perhaps be expressed in terms of the behavior of the system when it approaches this temperature rather than the presumed behavior at exactly T=0 K. © 2000 American Association of Physics Teachers.
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DOI: 10.1119/1.19375

AFFILIATIONS: Institute for Theoretical Physics, University of California, Santa Barbara, CA 93106, United States;
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ABSTRACT: Density functional theory (DFT) is one of the most widely used methods for ab initio calculations of the structure of atoms, molecules, crystals, surfaces, and their interactions. Unfortunately, the customary introduction to DFT is often considered too lengthy to be included in various curricula. An alternative introduction to DFT is presented here, drawing on ideas which are well-known from thermodynamics, especially the idea of switching between different independent variables. The central theme of DFT, i.e., the notion that it is possible and beneficial to replace the dependence on the external potential v(r) by a dependence on the density distribution n(r), is presented as a straightforward generalization of the familiar Legendre transform from the chemical potential μ to the number of particles N. This approach is used here to introduce the Hohenberg-Kohn energy functional and to obtain the corresponding theorems, using classical nonuniform fluids as simple examples. The energy functional for electronic systems is considered next, and the Kohn-Sham equations are derived. The exchange-correlation part of this functional is discussed, including both the local density approximation to it, and its formally exact expression in terms of the exchange-correlation hole. A very brief survey of various applications and extensions is included. © 2000 American Association of Physics Teachers.
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DOI: 10.1119/1.1302732
AFFILIATIONS: Observ. Midi Pyrénées, Université Paul Sabatier, Toulouse, France
ABSTRACT: We point out a thermodynamic interpretation of the variational Maxwell theorem relative to dc circuits, based on the minimum of the entropy production. We thus complete the interesting pedagogical analysis of D. A. Van Baak in a recent paper concerning the use of variational methods on dc circuits. © 2000 American Association of Physics Teachers.
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DOI: 10.1119/1.1286116
AFFILIATIONS: Inst. für Theoretische Physik, Universität Göttingen, Bunsenstrasse 9, Göttingen, Germany
ABSTRACT: Exact results for the thermodynamic properties and mean occupation numbers of a system of noninteracting fermions with equidistant level spacing are presented for an arbitrary number of particles. It is discussed quantitatively how the results converge to the corresponding ones in the grand canonical ensemble when the thermodynamic limit is reached. From the simple calculations it also follows that the thermodynamics of an infinite two-dimensional electron gas is identical to that of a one-dimensional harmonic chain with linearized dispersion. The results generalize and simplify previous approaches to this model published in this journal. © 2000 American Association of Physics Teachers.
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DOI: 10.1119/1.19357
AFFILIATIONS: Department of Physics and Geophysical Research Center, New Mexico Institute of Mining and Technology, NewSocorro, Mexico 87801, United States
ABSTRACT: During their thermodynamics courses, students learn that the temperature of an ideal gas will drop during an adiabatic reversible expansion. They also usually learn that no change of temperature occurs as a result of a certain free expansion. These results often become intuitively connected with gas expansion. However when air expands freely into an evacuated chamber from a constant pressure atmosphere, its temperature increases. This can be easily demonstrated using only simple equipment and makes for a memorable lesson on the importance of identifying what exactly is the system and then simply applying the first law of thermodynamics. © 1999, American Association of Physics Teachers. All rights reserved.
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DOI: 10.1119/1.19240
AFFILIATIONS: Physics Department, University of Manchester, Institute of Science & Technology, P.O. Box 88, Manchester M60 1QD, United Kingdom
AUTHOR KEYWORDS: 0.5;  05.70
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Thermodynamics at work: The pressure derivative of the specific heat
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DOI: 10.1119/1.19090
AFFILIATIONS: Depto. de Física Aplicada, Universidad de Cantabria, E-39005 Santander, Spain; Departamento de Física, Ctro. de Física Computational, Universidade de Coimbra, P-3000 Coimbra, Portugal
ABSTRACT: Thermodynamics relates measurable quantities such as thermal coefficients and specific heats. The first law, which implies that the enthalpy is a function of state, yields a relation for the pressure derivative of the specific heat cP. The second law gives a simpler and well-known relation for this pressure derivative. We compare the values of the pressure derivative of cP obtained from the first and second laws to the values obtained from measurements for water at different pressures. The comparison illustrates the scope and methodology of thermodynamics. © 1999 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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Thermodynamics of mixtures: Functions of mixing and excess functions
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DOI: 10.1119/1.19089
ABSTRACT: Applying thermodynamics to realistic systems requires a knowledge of the thermodynamic

properties of mixtures. Functions of mixing and excess functions provide a useful approach. The concepts are simple and their application straightforward, but students often fail to apply them correctly when they are given only a theoretical explanation. We discuss some typical mistakes and some problems we have found useful for overcoming them. © 1999 American Association of Physics Teachers.
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DOI: 10.1119/1.19332
AFFILIATIONS: Department of Philosophy, University of Wisconsin, Madison, WI 53706, United States; Luther College, Decorah, IA 52101, United States
ABSTRACT: Magnetic work takes two forms in the thermodynamics of a paramagnet as developed in many textbooks. We observe that in the case when the lattice energy is excluded, the form $\delta W = BdM$ cannot be used in a fundamental thermodynamic equation. This shows that there are thermodynamic systems with no fundamental thermodynamic equation. © 1999 American Association of Physics Teachers.
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DOI: 10.1119/1.19107
AFFILIATIONS: Dept. Biochem., Molec. Biol., B., University of Minnesota, 1479 Gortner Avenue, St. Paul, MN 55108, United States
ABSTRACT: Helical conformations, such as the α-helix in polypeptides and the double helix in DNA, are common structural elements in biopolymers. As the temperature is raised or the pH is changed to extremes of acidity or alkalinity, the helix becomes disordered into a random coil state. The helix-coil transition has been extensively studied, both experimentally and theoretically, as a model for conformational transitions in biopolymers and as a way to obtain information about the intermolecular forces which stabilize biopolymer structure. We develop three theoretical treatments that describe the helix-coil transition with increasing degrees of detail and rigor: the all-or-none model, the zipper model, which allows initiation of the helix only once along the polymer chain, and the matrix model, which places no restrictions on helix-coil junctions. The matrix model is mathematically similar to the familiar one-dimensional Ising model. © 1999 American Association of Physics Teachers.
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DOI: 10.1119/1.19091
AFFILIATIONS: Bethel College, North Newton, KS 67117, United States; Los Alamos National Laboratory, Los Alamos, NM 87545, United States
ABSTRACT: We construct a set of equations of state for condensed matter at temperatures well above the Debye temperature. These equations incorporate the Mie-Gruneisen equation of state and generic properties of high temperature solids. They are simple enough to provide an alternative to the ideal gas and the van der Waals equations of state for illustrating thermodynamic concepts. © 1999 American

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DOI: 10.1119/1.19088
AFFILIATIONS: Department of Physics, Oberlin College, Oberlin, OH 44074, United States
ABSTRACT: All too often, courses in thermodynamics and statistical mechanics barrage their students with numerous equations that are left unexamined and uninvestigated. This note explains how to pause, examine a thermodynamic equation, and render it more meaningful. Three techniques are discussed: (1) design two experiments that would measure the quantities on either side of the equality; (2) examine special cases; (3) consider the consequences if the equality failed to hold. © 1999 American Association of Physics Teachers.
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DOI: 10.1119/1.19110
AFFILIATIONS: Department of Physics, Texas A and M University, College Station, TX 77840, United States
ABSTRACT: We develop analogies between economic systems and thermodynamics, and show how economic quantities can characterize the state of an economic system in equilibrium. We argue that just as a physical system in thermodynamic equilibrium requires a nonmechanical variable (the temperature T) to specify its state, so does an economic system. In addition, both systems must have a corresponding conjugate quantity, the entropy S. We also develop economic analogies to the free energy, Maxwell relations, and the Gibbs-Duhem relationship. Assuming that economic utility can be measured, we develop an operational definition of an economic temperature scale. We also develop an analogy to statistical mechanics, which leads to Gaussian fluctuations. © 1999 American Association of Physics Teachers.
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DOI: 10.1119/1.19181
AFFILIATIONS: Center for Innovation in Learning, Department of Physics, Carnegie Mellon University, Pittsburgh, PA 15213, United States
ABSTRACT: Heat and thermodynamics are traditionally taught in the introductory physics course from a predominantly macroscopic point of view. However, it is advantageous to adopt a more modern approach that systematically builds on students' knowledge of the atomic structure of matter and of elementary mechanics. By focusing on the essential physics without requiring more than elementary classical mechanics, this approach can be made sufficiently simple to be readily teachable during five or six weeks of an ordinary calculus-based introductory physics course. This approach can be highly unified, using atomic considerations to infer the properties of macroscopic systems while also enabling

thermodynamic analyses independent of specific atomic models. Furthermore, this integrated point of view provides a deeper physical understanding of basic concepts (such as internal energy, heat, entropy, and absolute temperature) and of important phenomena (such as equilibrium, fluctuations, and irreversibility). © 1999 American Association of Physics Teachers.
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DOI: 10.1119/1.19094
AFFILIATIONS: Physics Department, California Stt. Polytech. University, 3801 West Temple Avenue, Pomona, CA 91768, United States
ABSTRACT: One of entropy's puzzling aspects is its dimensions of energy/temperature. A review of thermodynamics and statistical mechanics leads to six conclusions: (1) Entropy's dimensions are linked to the definition of the Kelvin temperature scale. (2) Entropy can be defined to be dimensionless when temperature T is defined as an energy (dubbed tempergy). (3) Dimensionless entropy per particle typically is between 0 and ~80. Its value facilitates comparisons among materials and estimates of the number of accessible states. (4) Using dimensionless entropy and tempergy, Boltzmann's constant k is unnecessary. (5) Tempergy, kT, does not generally represent a stored system energy. (6) When the (extensive) heat capacity C ≫ k, tempergy is the energy transfer required to increase the dimensionless entropy by unity. © 1999 American Association of Physics Teachers.
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DOI: 10.1119/1.19087
AFFILIATIONS: Departamento de Física, Universidad de Los Andes, Apartado Aéreo 4976, Bogotá, Colombia
ABSTRACT: The chaotic volume-preserving standard map is used to illustrate the invertibility paradox, which is related to the reversibility paradox of the microscopic foundations of thermodynamics. The new paradox, whose resolution relies exclusively on phase-space arguments, gives insight into Boltzmann's original resolution of the reversibility paradox. © 1999 American Association of Physics Teachers.
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DOI: 10.1119/1.19093
AFFILIATIONS: Department of Physics, New Mexico State University, Las Cruces, NM 88003, United States
ABSTRACT: The "thermodynamic cube," a mnemonic device for learning and recalling thermodynamic relations, is introduced. The cube is an extension of the familiar "thermodynamic square" seen in many textbooks. The cube reproduces the functions of the usual thermodynamic squares and incorporates the Euler relations which are not as well known. © 1999 American Association of Physics Teachers.
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DOI: 10.1119/1.19182
AFFILIATIONS: Department of Physics, University of Washington, Seattle, WA 98195, United States
ABSTRACT: The work-energy theorem, derived from Newton's second law, applies to the displacement of a particle or the center of mass of an extended body treated as a particle. Because work, as a quantity of energy transferred in accordance with the First Law of Thermodynamics, cannot be calculated in general as an applied force times the displacement of center of mass, the work-energy theorem is not a valid statement about energy transformations when work is done against a frictional force or actions on or by deformable bodies. To use work in conservation of energy calculations, work must be calculated as the sum of the products of forces and their corresponding displacements at locations where the forces are applied at the periphery of the system under consideration. Failure to make this conceptual distinction results in various errors and misleading statements widely prevalent in textbooks, thus reinforcing confusion about energy transformations associated with the action in everyday experience of zero-work forces such as those present in walking, running, jumping, or accelerating a car. Without a thermodynamically valid definition of work, it is also impossible to give a correct description of the connection between mechanical and thermal energy changes and of dissipative effects. The situation can be simply corrected and student understanding of the energy concepts greatly enhanced by introducing and using the concept of internal energy, that is, articulating the First Law of Thermodynamics in a simple, phenomenological form without unnecessary mathematical encumbrances. 
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DOI: 10.1119/1.19105
AFFILIATIONS: SPhT, CEA/Saclay, Orme des Merisiers, F-91191 Gif-sur-Yvette Cedex, France
ABSTRACT: The physics of stars, their workings and their evolution, is a goldmine of problems in statistical mechanics and thermodynamics. We discuss many examples that illustrate the possibility of deepening student's knowledge of statistical mechanics by an introductory study of stars. The matter constituting the various stellar objects provides examples of equations of state for classical or quantal and relativistic or non-relativistic gases. Maximum entropy can be used to characterize thermodynamic and gravitational equilibrium which determines the structure of stars and predicts their instability above a certain mass. Contraction accompanying radiation induces either heating or cooling, which explains the formation of stars above a minimum mass. The characteristics of the emitted light are understood from blackbody radiation and more precisely from the Boltzmann-Lorentz kinetic equation for photons. The luminosity is governed by the transport of heat by photons from the center to the surface. Heat production by thermonuclear fusion is determined by microscopic balance equations. The stability of the steady state of stars is controlled by the interplay of thermodynamics and gravitation. 
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DOI: 10.1119/1.19086

AFFILIATIONS: Service de Physique Théorique, CE-Saclay, F-91191 Gif-sur-Yvette Cedex, France
ABSTRACT: Statistical mechanics relies on the complete although probabilistic description of a system in terms of all its microscopic variables. Its object is to derive from this microscopic description the static and dynamic properties for some reduced set of variables. The elimination of the irrelevant variables is guided by the maximum entropy criterion, which produces the least biased probability law consistent with the available information about the relevant variables. This approach defines relevant entropies which measure the missing information associated with the variables retained in the incomplete description. The relevant entropies depend not only on the state, but also on the coarseness of the reduced description of the system. Their use sheds light on questions such as the second law, both in equilibrium and in irreversible thermodynamics, the projection operator method of statistical mechanics, Boltzmann's H-theorem, and spin-echo experiments. © 1999 American Association of Physics Teachers.
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DOI: 10.1119/1.18982
AFFILIATIONS: Depto. de Física Aplicada, Universidad de Salamanca, 37008 Salamanca, Spain
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DOI: 10.1119/1.19048
AFFILIATIONS: Department of Physics, University of Waterloo, Waterloo, Ont. N2L 3G1, Canada
ABSTRACT: The role of finite-size effects in determining the thermodynamic behavior of an ideal gas is critically examined. While classical statistics do not produce any perceptible effects, quantum statistics do yield results that play a crucial role in determining the low-temperature behavior of the given system. For illustration, we carry out an exact analysis of the ideal Bose gas in one dimension and show that at least in this case (i) the bulk term (customarily obtained by replacing the summation-over-states by an integration) yields results that are, at best, misleading, whereas (ii) the correct behavior of the system is determined almost entirely by terms representing finite-size effects. The subtle, yet distinctive, role played by the boundary conditions imposed on the system is also explored. © 1998 American Association of Physics Teachers.
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DOI: 10.1119/1.18644
AFFILIATIONS: Facultad de Física, P. Univ. Católica de Chile, Casilla 306, Santiago 22, Chile
ABSTRACT: Thermodynamic quantities of an ideal gas enclosed in a finite container are examined. We use an asymptotic expansion for high temperatures to obtain the partition function of an ideal gas, both in two and three dimensions, showing the leading corrections to the internal energy due to a finite container. In the three-dimensional case, the first correction term depends only on the area-volume ratio, but higher order terms depend also on other geometric properties of the container.

However, according to recent results, we show that the answer to the question posed in the title is negative. © 1997 American Association of Physics Teachers.
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AFFILIATIONS: Physics Department, University of Memphis, Memphis, TN 38152, United States
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AFFILIATIONS: Ctro. Bras. de Pesq. Fisicas/CNPq, R. Xavier Sigaud 150, CEP 22290-180, Rio de Janeiro, Brazil;
Department of Physics, University of Pretoria, Pretoria 0002, South Africa;
Physics Department, National University la Plata, Casilla de Correo 727, 7900 La Plata, Argentina;
Fac. Cie. Astronomicas y Geofisicas, Universidad Nacional de la Plata, Paseo del Bosque s/n, 1900 La Plata, Argentina
ABSTRACT: Jensen's inequality is obtained from thermodynamic arguments applied to two physical processes: temperature equalization in a set of N bodies, and height equalization of an incompressible fluid in a system of connected standpipes. © 1997 American Association of Physics Teachers.
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DOI: 10.1119/1.18561
AFFILIATIONS: University of Virginia, Aerospace Research Laboratory, 570 Edgemont Road, Charlottesville, VA 22903, United States
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DOI: 10.1119/1.18371
AFFILIATIONS: Depto. de Fis. e Informática, Inst. de Fis. de S. Carlos-USP, Av. dr. Carlos Botelho, 1465-cep 13560-004, S. Carlos, S.P., Brazil;

Faculdade de Filosofia, Cie. e Letras de Ribeirao Preto-USP, Avenida Bandeirantes, 3900-cep 14040-901, R. Preto, S.P., Brazil
ABSTRACT: Using the long-range Ising model, we present modern Monte Carlo techniques - single and multiple histogram and entropic sampling - which permit increasing the amount of information obtained from a simulation. Numerical results for the density of states, mean energy and specific heat are compared with exact calculations, easily handled in this case. As a consequence of the simplicity of the model, the ability of those methods to generate continuous plots of thermodynamical quantities can be appreciated even by students taking basic courses of statistical physics. © 1996 American Association of Physics Teachers.
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Mañosa, L., Bou, M., Calles, C., Cirera, A.
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DOI: 10.1119/1.18216
AFFILIATIONS: Dept. d'Estructura i Constituents M., Universitat de Barcelona, Facultat de Física, Diagonal 647, E-08028 Barcelona, Catalonia, Spain
ABSTRACT: We present a simple and inexpensive calorimetric system that has been implemented in the undergraduate students laboratory of thermodynamics at the Physics Faculty of the University of Barcelona. It is shown that, after proper calibration, the system enables measurement of the relevant thermodynamic quantities at a first-order phase transition. As an example, the solid-liquid phase transition of water can be studied: Students find that both the change in specific heat and the latent heat (and its temperature dependence) coincide within the experimental scatter with the values given in the literature. © 1996 American Association of Physics Teachers.
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Thomsen, J.S., Bers, H.C.
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DOI: 10.1119/1.18158
AFFILIATIONS: Henry A. Rowland Dept. Phys. Astron., Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218, United States;
3618 Courtleigh Drive, Randallstown, MD 21133, United States
ABSTRACT: After the concept of entropy has been introduced in the classical approach to thermodynamics, the definition of a reversible process may be refined in a mathematical way. If a given process can be modified by appropriate adjustment of the thermodynamic force involved so that it approaches a limit of zero entropy production, defining a limit process, and if the reverse process can be similarly modified, defining the same limit process in reverse, then we say that the process is reversible in this limit. Two examples are given, one dealing with the heating of a system and the second involving the adiabatic expansion of a viscous ideal gas. © 1996 American Association of Physics Teachers.
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DOI: 10.1119/1.18163

AFFILIATIONS: Dipartimento di Fisica, Università dell'Aquila, 67010 L'Aquila, Italy; Department of Electrical Engineering, Princeton Materials Institute (PMI), Princeton University, Princeton, NJ 08544, United States
ABSTRACT: The problem of prediction of the equilibrium state in an isolated composite system with an adiabatic internal wall is a delicate problem, whose solution is easily seen to be not entirely determined in the frame of elementary thermodynamics. We show how this indeterminacy can be removed by introducing a suitable kinetic model, in which the influence of the finite velocity of the wall on the change of momentum of the gas molecules impinging on it plays a relevant role. An interesting feature of the entropy behavior of the system is discussed. © 1996 American Association of Physics Teachers.
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DOI: 10.1119/1.18414
AFFILIATIONS: Dept. of Physics and Applied Physics, University of Massachusetts - Lowell, Lowell, MA 01854-2881, United States
ABSTRACT: Pedagogic niceties in the treatment of unconventional thermodynamic cycles, especially those involving (negatively sloping) diagonal linear transitions in a P/V state diagram and/or those implying supposedly superefficient heat-engine operation, are discussed as a means of stimulating student interest and comprehension, as well as promoting fresh insights, correcting erroneous notions, and provoking further enquiry. In particular, a novel (ostensibly all-adiabatic) engine using two ideal gases of mutually differing atomicities as working substance is analyzed qualitatively and quantitatively. Emphasis is placed on the crucial role of the second law of thermodynamics in a determination of heat-engine operation. © 1996 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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Leff, H.S.
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Thermodynamic entropy: The spreading and sharing of energy
(1996) American Journal of Physics, 64 (10), pp. 1261-1271. Cited 59 times.
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DOI: 10.1119/1.18389
AFFILIATIONS: Physics Department, California Stt. Polytech. Univ., P., Pomona, CA 91768, United States
ABSTRACT: A new approach to thermodynamic entropy is proposed to supplement traditional coverage at the junior-senior level. It entails a model for which: (i) energy spreads throughout macroscopic matter and is shared among microscopic storage modes; (ii) the amount and/or nature of energy spreading and sharing changes in a thermodynamic process; and (iii) the degree of energy spreading and sharing is maximal at thermodynamic equilibrium. A function S that represents the degree of energy spreading and sharing is defined through a set of reasonable properties. These imply that S is identical with Clausius' thermodynamic entropy, and the principle of entropy increase is interpreted as nature's tendency toward maximal spreading and sharing of energy. Microscopic considerations help clarify these ideas and, reciprocally, these ideas shed light on statistical entropy. © 1996 American Association of Physics Teachers.
DOCUMENT TYPE: Article
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DOI: 10.1119/1.15783
AFFILIATIONS: Applied Solar Calculations Unit, Jacob Blaustein Institute for Desert Research, Ben-Gurion University of the Negev, Sede Boqer Campus84993, Israel
ABSTRACT: An upper bound on annual average energy in the Earth's winds is calculated via the formalism of finite-time thermodynamics. The Earth's atmosphere is viewed as the working fluid of a heat engine where the heat input is solar radiation, the heat rejection is to the surrounding universe, and the work output is the energy in the Earth's winds. The upper bound for the annual average power in the Earth's winds is found to be 17 W/m2, which can be contrasted with the actual estimated annual average wind power of 7 W/m2. Our thermodynamic model also predicts the average extreme temperatures of the Earth's atmosphere and can be applied to wind systems on other planets. © 1989 American Association of Physics Teachers.
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DOI: 10.1119/1.14959
AFFILIATIONS: Department of Chemistry, University of Odense, DK-5230 Odense M, Denmark
ABSTRACT: The fact that metallic gadolinium is ferromagnetic with a Curie temperature of 294 K is used in the constuction of an inexpensive and simple thermomagnetic engine, which can be driven by an electric lamp or by sunlight. The apparatus can be used as a simple demonstration of the Carnot principle. © 1987, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Fox, J.N., Gaggini, N.W., Wangsani, R.
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Measurement of the thermal conductivity of liquids using a transient hot wire technique
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DOI: 10.1119/1.15177
AFFILIATIONS: Department of Physics, Indiana University of Pennsylvania, Indiana, Pennsylvania 15705, United States
ABSTRACT: The thermal conductivity of a liquid is measured using a transient hot wire technique. This technique employs a very thin wire that is used both as a heating element and thermometer. The data are collected before the onset of convection currents in the liquid. Results are presented for several liquids. © 1987, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
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Fuchs, H.U.
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DOI: 10.1119/1.15216
AFFILIATIONS: Winterthur Polytechnic, School of Engineering, 8401 Winterthur, Switzerland
ABSTRACT: An elementary physics course on thermodynamics is presented. It uses entropy and temperature as fundamental, undefined objects. Suggestions on how to do this can be traced back to H. L. Callendar [Proc. Phys. Soc. (London) 23, 153 (1911)]. © 1987, American Association of Physics

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DOI: 10.1119/1.14975
AFFILIATIONS: Physics and Theoretical Physics, Faculty of Science, Australian National University, Canberra, A.C.T.2601, Australia
ABSTRACT: Classical thermodynamics as usually formulated is remarkable for the total absence of any variational principles. It is shown here that as far as its implications for quasistatic transitions are concerned the Second Law can be formulated as a variational principle which guarantees the existence of an empirical entropy function. © 1987, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Massa, C.
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Erratum: On the thermodynamics of Planck’s radiation [Am. J. Phys. 54, 754 (1986)]
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DOI: 10.1119/1.15329
AFFILIATIONS: Via Fratelli Manfredi 55, 42100, Reggio Emilia, Italy
DOCUMENT TYPE: Erratum
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DOI: 10.1119/1.15064
AFFILIATIONS: Department of Physical Chemistry, Hebrew University, 91904 Israel, Jerusalem, Israel
ABSTRACT: Mixing processes exist with positive entropy change and negative free energy change. However, the idea that the irreversibility of the mixing processes is responsible for the so-called free energy and entropy of mixing is faulty. The mixing, as well as the demixing processes may be associated with either reversible or irreversible phenomena, depending on the particular conditions. For ideal gases, the word “mixing”in the terms “mixing entropy” and “mixing free energy” may sometimes be used descriptively but never causatively. The quantity − Σ Ni R ln Xi, usually referred to as “mixing entropy,” has nothing to do with the mixing phenomenon. Therefore the terms“mixing entropy” and “mixing free energy” are essentially misconceptions. In fact, it is shown that the process of mixing of ideal gases has, by itself, no relevance to any thermodynamic quantity. Therefore, in a thermodynamical sense, it is a nonprocess. The concepts of assimilation and deassimilation are introduced. It is shown that the “deassimilation process is essentially irreversible.” This should replace the traditional principle that “the mixing process is essentially irreversible.”. © 1987, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
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Cropper, W.H.
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DOI: 10.1119/1.15255
AFFILIATIONS: Chemistry Department, St. Lawrence University, Canton, New York 13617, United States
ABSTRACT: This paper traces an important chapter in the evolution of the temperature concept in classical thermodynamics. The centerpiece in the story is the temperature function discovered by Carnot, and gradually developed over a period of 30 yr by Clapeyron, Holtzmann, Helmholtz, Joule, Rankine, Thomson (Kelvin), and Clausius. In Thomson's final resolution of the problem, Carnot's function simply determined the thermodynamic temperature scale. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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DOI: 10.1119/1.15278
AFFILIATIONS: Department of Physical Chemistry, The Hebrew University of Jerusalem, Jerusalem 91904, Israel
ABSTRACT: The concepts of “mixing” and “assimilation,” as previously discussed for ideal gases, are applied to systems of interacting particles. Some common misconceptions frequently found in the literature on solution thermodynamics are noted. These are traced to originate from a faulty interpretation of the thermodynamics of mixing processes. 
AUTHOR KEYWORDS: CHEMICAL POTENTIAL; FREE ENERGY; MIXING; PARTICLES; THERMODYNAMICS
DOCUMENT TYPE: Article
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DOI: 10.1119/1.15171
AFFILIATIONS: Physics Department, University of Puget Sound, Tacoma, Washington 98416, United States
ABSTRACT: The problem of Maxwell’s sorting demon traditionally has been studied for the case in which the hot and cold regions differ very little in temperature. In this article a solution is presented for the case in which the temperature difference is great so that the total entropy is lower. Calculations indicate that in this case the demon must use a large number of photons to observe the proper kinds of particles. This causes an increase in entropy which more than offsets the decrease caused by an exchange of particles. 
AUTHOR KEYWORDS: ENTROPY; PHOTONS; THERMODYNAMICS; VELOCITY DISTRIBUTION
DOCUMENT TYPE: Article
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DOI: 10.1119/1.14489
AFFILIATIONS: Center for Design of Educational Computing, Physics, Carnegie-Mellon University, Pennsylvania 15213, Pittsburgh, United States;
Physics, Louisiana Tech University, Louisiana 71272, Ruston, United States
DOCUMENT TYPE: Letter
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DOI: 10.1119/1.14487
AFFILIATIONS: The College of Staten Island, New York 10301, United States
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DOI: 10.1119/1.14864
AUTHOR KEYWORDS: BENCH-SCALE EXPERIMENTS; COLD EFFLUENTS; MIRRORS; REFLECTION; THERMOMETERS
DOCUMENT TYPE: Letter
PUBLICATION STAGE: Final
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DOI: 10.1119/1.14563
AFFILIATIONS: Wright State University, Dayton, Ohio 45435, United States
ABSTRACT: When an object is cooled by immersion in a liquid, there is an unexpected increase in the violence of boiling just before the boiling stops. Most people seem fascinated by this phenomenon yet few are acquainted with its explanation in terms of a change in the heat-transfer mechanism from film boiling to nucleate boiling. We have developed two variations of an intermediate level undergraduate laboratory experiment to measure the heat-transfer rate after a sample is immersed in liquid nitrogen. The temperature of the sample, as measured by a thermocouple, is recorded as a function of time using either a potentiometer strip-chart recorder or a digital voltmeter–microcomputer combination. The heat-transfer rate as a function of sample temperature is computed from these results, and the reason for the effect is clearly seen. 
AUTHOR KEYWORDS: BENCH-SCALE EXPERIMENTS; COOLING; FILM BOILING; HEAT TRANSFER; NITROGEN; NUCLEATE BOILING; TEMPERATURE DEPENDENCE; TIME DEPENDENCE
DOCUMENT TYPE: Article
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DOI: 10.1119/1.14509
AFFILIATIONS: Academy of the New Church College, Bryn Athyn, Pennsylvania 19009, United States
ABSTRACT: One of the most interesting and enduring problems of physics is the reconciliation of time-reversal invariance in mechanics and the time directionality property of the second law of thermodynamics. In this paper a very simple model of a many-body system is given which may be used to illustrate the trend toward equilibrium both in terms of populations, Boltzmann's H theorem, and fluctuations.
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DOI: 10.1119/1.14743
AFFILIATIONS: Center for Integrated Electronics and Physics Department, Rensselaer Polytechnic Institute, Troy, New York 12181, United States
ABSTRACT: The thermodynamic properties of the classical ideal gas are well known and documented. The departure of real gases from ideal behavior requires modification of the ideal equation of state. We derive an exact solution for an “excluded volume” system in which the constituent particles have nonzero volume and only one particle may occupy a specific region in space. To incorporate this volume exclusion, we propose a lattice gas model and find a simple combinatorial solution to this model. We construct the partition function, equation of state, and several other thermodynamic quantities. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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DOI: 10.1119/1.14475
AFFILIATIONS: Via Fratelli Manfredi 55, 42100, Reggio Emilia, Italy
DOCUMENT TYPE: Letter
PUBLICATION STAGE: Final
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DOI: 10.1119/1.14622
AFFILIATIONS: Department of Space Physics and Astronomy, Rice University, Houston, Texas 77251, United States
ABSTRACT: We derive succinctly the equations of solar structure. We first present models of objects in hydrostatic equilibrium that fail as models of the sun in order to illustrate important physical requirements. Then by arguing physically that the pressure gradient can be matched to the simple function dP/dr=−kre−(r/a)2, we derive a complete analytic representation of the solar interior in terms of a one-parameter family of models. Two different conditions are then used to select the appropriate value of the parameter specifying the best model within the family: (1) the solar luminosity is equated to the thermonuclear power generated near the center and/or (2) the solar luminosity is equated to the radiative diffusion of energy from a central region. The two methods of selecting the parameter agree to within a few percent. The central conditions of the sun are well

calculated by these analytic formulas, all without aid of a computer. This is an original treatment, yielding much the best description of the solar center to be found by methods of differential and integral calculus, rendering it an excellent laboratory for applied calculus. 
AUTHOR KEYWORDS: LUMINOSITY; MATHEMATICAL MODELS; NUCLEAR REACTIONS; PRESSURE GRADIENTS; SUN
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Fuchs, H.U.
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DOI: 10.1119/1.14787
AFFILIATIONS: Winterthur Polytechnic (School of Engineering), 8401 Winterthur, Switzerland
ABSTRACT: Using thermodynamics as an analogy, an “electricity machine” is constructed and analyzed. This machine runs through a “Carnot” cycle. The analysis leads to the construction of a “new” quantity called “reduced electricity” (charge). The example shows what life in electrodynamics would be without the substancelike quantity which we call electrical charge. (This state of affairs is accepted in thermodynamics.) Imagine the development of the theory of electricity had fallen into the hands of the thermodynamicists. As fairy and other tales go, they have an air of surrealism surrounding them. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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DOI: 10.1119/1.14431
AFFILIATIONS: Department of Physics, California State University, Fresno, California 93740, United States
AUTHOR KEYWORDS: CARNOT CYCLE; DIAGRAMS; ENTROPY; HEAT FLOW; THERMODYNAMICS
DOCUMENT TYPE: Letter
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DOI: 10.1119/1.14393
AUTHOR KEYWORDS: coordinates; energy; thermodynamics
DOCUMENT TYPE: Letter
PUBLICATION STAGE: Final
SOURCE: Scopus

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DOI: 10.1119/1.14044

AFFILIATIONS: Physics Department, Northern Illinois University, DeKalb, Illinois 60115, United States
AUTHOR KEYWORDS: CONSERVATION LAWS; ENERGY TRANSFER; HEAT ENGINES; THERMODYNAMIC PROPERTIES
DOCUMENT TYPE: Letter
PUBLICATION STAGE: Final
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Seligmann, P., Spencer, C.D.
16532909300;7201518343;
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DOI: 10.1119/1.14163
AFFILIATIONS: Department of Physics, Ithaca College, Ithaca, New York 14850, United States
ABSTRACT: This article describes two one-credit freshman courses intended to familiarize students with the laboratory use of computers. The courses provide an introduction to programming in a high level language (BASIC) and in assembly language and to the design and construction of simple digital circuits. A final project requires students to interface an electronic thermometer to an S-100 Bus machine. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Alonso, M.
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DOI: 10.1119/1.14185
AUTHOR KEYWORDS: coordinates; energy; thermodynamics
DOCUMENT TYPE: Letter
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SOURCE: Scopus

Guy, A.G.
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DOI: 10.1119/1.14162
AFFILIATIONS: Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, Florida 32901, United States
ABSTRACT: Recent publications by the author have employed classical physics (especially electromagnetic theory and phenomenological thermodynamics) to analyze quantitatively the behavior of conduction electrons in metals and semiconductors. The topics discussed here include enthalpy of electrons, electronic heat capacity, departure from Ohm’s law for semiconductors, implications for junction theory, and an extension of Maxwell’s equations. These applications suggest that complex electronic devices can be analyzed more effectively by (nonmechanistic) classical physics than by present electron theories based on quantum mechanics. 
AUTHOR KEYWORDS: CHEMICAL POTENTIAL; CONTACT POTENTIAL; ELECTRIC CONDUCTIVITY; ELECTRONIC EQUIPMENT; ELECTRONIC SPECIFIC HEAT; ELECTRONS; MAXWELL EQUATIONS; OHM LAW; SEEBECK EFFECT; SEMICONDUCTOR JUNCTIONS; SEMICONDUCTOR MATERIALS
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thermodynamics in the presence of a magnetic field
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DOI: 10.1119/1.14413
AFFILIATIONS: Department of Physics and Mathematics, Oranim—School of Education of the Kibbutz Movement, Tivon 36910, United States
ABSTRACT: The equivalence between the second principle of thermodynamics and the Lambert cosine law, which has for a long time been noticed for particles moving in straight trajectories, is shown to hold as well in the presence of a magnetic field. As a corollary, the cosine law is a necessary condition under which the absence of diamagnetism in classical statistics holds. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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DOI: 10.1119/1.14100
AFFILIATIONS: Condensed Matter and Thermal Physics Group MS K764, Los Alamos National Laboratory, Los Alamos, New Mexico 87545, United States
ABSTRACT: Thermoacoustical phenomena have a long history and are frequently characterized by great complexity. In the present paper, we describe how, by the use of suitable acoustical structures, the phenomena can both be simplified and readily demonstrated. A heuristic discussion is emphasized, which we hope will be useful in teaching the principles. The qualities of certain model apparatus that demonstrate acoustically stimulated entropy flow, a thermally driven acoustic oscillator, and an acoustically driven refrigerator are also presented in semiquantitative detail. 
AUTHOR KEYWORDS: ACOUSTICS; ENTROPY; HEAT ENGINES; OSCILLATORS; REFRIGERATORS; SOUND WAVES; TEMPERATURE EFFECTS
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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DOI: 10.1119/1.14040
AFFILIATIONS: Department of Physics and Astronomy, Northwestern University, Evanston, Illinois, United States
ABSTRACT: The relation between Kelvin’s Heat Death and Carnot’s prohibition of perpetual motion machines is traced. The link between them is that Carnot’s proposition implies a perpetual destruction machine, whereas Kelvin’s implies a perpetual degradation machine, the one historically evolving into the other. 
AUTHOR KEYWORDS: CARNOT CYCLE; EFFICIENCY; HEAT ENGINES; HEAT LOSSES; HISTORY; THERMODYNAMICS
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Kemp, H.R.
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Internal work: A thermodynamic treatment
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DOI: 10.1119/1.13990
AFFILIATIONS: Royal Australian Naval College, Jervis Bay, 2540, Australia
ABSTRACT: In a recent note, W. H. Bernard1 discussed misinterpretations of the concept of internal work by two textbooks. Bernard showed that where no external work is done on a system there is no necessary relation between internal work and change in kinetic energy. For example, a man on roller skates pushes off from a wall. The difficulties that arise in the use of internal work can be avoided if the analysis is done by way of thermodynamics rather than by dynamics alone. © 1985 American Association of Physics Teachers
DOCUMENT TYPE: Letter
PUBLICATION STAGE: Final
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Albano, A.M., Abraham, N.B., Chyba, D.E., Martelli, M.
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Bifurcations, propagating solutions, and phase transitions in a nonlinear chemical reaction with diffusion
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DOI: 10.1119/1.13729
AFFILIATIONS: Department of Physics, Bryn Mawr College, Bryn Mawr, Pennsylvania 19010, United States; Mathematics, Bryn Mawr College, Bryn Mawr, Pennsylvania 19010, United States
ABSTRACT: The Schlögl model of a nonlinear chemical reaction with diffusion is presented as an example of a reaction-diffusion system displaying a nonequilibrium phase transition. It is described by a scalar diffusion equation with a cubic nonlinearity and is used here to show such features of nonlinear systems as bifurcations and spatial dissipative structures, as well as to illustrate some of the simpler mathematical techniques used in their analysis. The model contains analogs of the critical isotherm and of Maxwell's construction. It shows hysteresis and a limiting behavior interpretable in terms of the thermodynamic limit. More importantly, it provides a description of the dynamics of a phase transition, showing a fluctuation-induced nucleation process and the evolution of a phase transition by the motion of phase boundaries. 
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DOI: 10.1119/1.13893
AFFILIATIONS: Universidad de Magallanes, Casilla 113-D, Punta Arenas, Chile
ABSTRACT: In order to prove the general validity of the second law of thermodynamics, several instances of the Stirling cycle are studied, especially in relation to their efficiency. 
AUTHOR KEYWORDS: efficiency; heat transfer; isotherm; stirling cycle; thermodynamics; virial equation
DOCUMENT TYPE: Article
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DOI: 10.1119/1.13701
AFFILIATIONS: Laboratoire de Physique Nucléaire, Département de Physique, Université de Montréal,

Montréal, Québec, Canada
AUTHOR KEYWORDS: blackbody radiation; energy density; energy transfer; gases; temperature dependence; thermodynamics
DOCUMENT TYPE: Letter
PUBLICATION STAGE: Final
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Mandal, G.
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DOI: 10.1119/1.13633
AFFILIATIONS: Department of Physics, Presidency College, Calcutta 700073, India
AUTHOR KEYWORDS: boltzmann-vlasov equation; gases; irreversible processes; phase space; t invariance; thermodynamics
DOCUMENT TYPE: Letter
PUBLICATION STAGE: Final
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DOI: 10.1119/1.13562
AFFILIATIONS: 1174 Bucknell Drive, Monroeville, Pennsylvania 15146, United States
ABSTRACT: From Planck’s statement of the second law of thermodynamics it is generally inferred that it is impossible to construct an engine which produces work at the expense only of heat taken from the air or the ocean. The experiment described in this paper demonstrates that when the air and the ocean are combined as a nonhomogeneous reservoir of uniform temperature, it is possible to construct an engine which produces work by extracting heat from the said reservoir. This does not constitute a violation of the second law of thermodynamics, rather that the “reservoir” in the Planck’s statement must be clearly stated as being in equilibrium. 
AUTHOR KEYWORDS: air; equilibrium; heat engines; heat transfer; seas; thermodynamic cycles
DOCUMENT TYPE: Article
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Response to “Comments on ‘Ideal gas and the second law of thermodynamics’-”
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DOI: 10.1119/1.13634
AFFILIATIONS: School of Physics, Georgia Tech, Atlanta, Georgia 30332, United States
AUTHOR KEYWORDS: boltzmann-vlasov equation; gases; irreversible processes; phase space; t invariance; thermodynamics
DOCUMENT TYPE: Letter
PUBLICATION STAGE: Final
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Tsatis, D.E.
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DOI: 10.1119/1.13604
AFFILIATIONS: Physics Department, University of Patras, Patras, Greece
AUTHOR KEYWORDS: measuring methods; thermal conductivity; thermal diffusivity; thermocouples; thermoelectric properties
DOCUMENT TYPE: Letter
PUBLICATION STAGE: Final
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DOI: 10.1119/1.13540
AFFILIATIONS: Magnetism Theory Division, Institute of Physics, A. Mickiewicz University, Poznań, Poland
ABSTRACT: Using one and the same simple variational principle for average energy, a new equation is obtained equivalent to the set of two equations: the time-independent Schrödinger equation and that describing canonical Gibbs distribution. © 1984, American Association of Physics Teachers. All rights reserved.
AUTHOR KEYWORDS: canonical ensemble; energy; hamiltonians; quantum mechanics; schroedinger equation; statistical mechanics; thermodynamics; variational methods
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Gupta, V.K., Shanker, G., Saraf, B., Sharma, N.K.
57209148413;7003342318;22990071100;57208678667;
Experiment to verify the second law of thermodynamics using a thermoelectric device
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DOI: 10.1119/1.13582
AFFILIATIONS: Centre for Development of Physics Education, University of Rajasthan, Jaipur 302004, India
ABSTRACT: An experiment to verify the second law of thermodynamics using a thermoelectric device is described. The response of the device when it is used as a Seeback-effect heat engine after filtering out the contributions of the associated irreversible parts is studied as a function of the temperatures of the hot and cold junctions. Likewise its response as a Peltier-effect heat pump is also investigated. The experimental results are in close agreement with the predictions of the second law of thermodynamics. © 1984, American Association of Physics Teachers. All rights reserved.
AUTHOR KEYWORDS: heat engines; heat pumps; peltier effect; seebeck effect; temperature dependence; thermocouples; thermodynamics; thermoelectricity
DOCUMENT TYPE: Article
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Erlichson, H.
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DOI: 10.1119/1.13601
AFFILIATIONS: Department of Applied Sciences, The College of Staten Island, Staten Island, New York 10301, United States
ABSTRACT: The definition of the internal energy of a thermodynamic system in most introductory texts usually states or implies that the c.m. kinetic energy of the system is not part of the internal energy. This is inconsistent with their statement of the first law of thermodynamics as $\Delta U=Q-W$. If the c.m. kinetic energy is not considered part of U, the first law should be stated as $\Delta U+\Delta K_{c.m.}=Q-W$.

Several examples are given. Clarification of this point is needed in many widely used texts. 
AUTHOR KEYWORDS: center-of-mass system; energy; heat transfer; kinetic energy; thermodynamics
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Work and heat transfer in the presence of sliding friction
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DOI: 10.1119/1.13775
AFFILIATIONS: Computer-based Education Research Laboratory, Physics and Linguistics, University of Illinois at Urbana-Champaign, Urbana, Illinois 61801, United States;
Physics, Louisiana Tech University, Ruston, Louisiana 71272, United States
ABSTRACT: The work done by frictional forces has usually been calculated incorrectly. The key to a correct treatment lies in making a careful distinction between a purely mechanical integral of Newton's second law on the one hand and the first law of thermodynamics on the other. These two equations are the same for point particles but differ for deformable systems, which include systems subject to sliding friction. A model-independent calculation is supplemented by applications to current models for friction. Heat transfer is treated in detail for the case of lubricated friction. Rotational friction is analyzed. An invariant form of the energy equation is presented. © 1984 American Association of Physics Teachers
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DOI: 10.1119/1.13583
AFFILIATIONS: Department of Chemistry, The University of Michigan, Ann Arbor, Michigan 48109, United States
ABSTRACT: The usual treatment of temperature fluctuations in thermometry is based on an analysis of fluctuations in a mechanical variable in a system of constant temperature. This calculation is here inverted to discuss the uncertainty in the temperature for a system whose mechanical variables have been measured. The inversion is accomplished by introducing a new statistical-mechanical ensemble, the polythermal ensemble, which is obtained as an extension of the canonical ensemble. It is shown that temperature fluctuations in very small systems are larger than is sometimes believed. This is a sense in which $\beta=(kBT)-1$ is a more fundamental variable than is the temperature T. 
AUTHOR KEYWORDS: ensemble; fluctuations; statistical mechanics; temperature noise; thermometers
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Thomsen, J.S.
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Comment on “The concept of temperature and its dependence on the laws of thermodynamics”
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DOI: 10.1119/1.13239
AFFILIATIONS: Physics, Johns Hopkins University, Baltimore, Maryland 21218, United States
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Bartlett, A.A., Braun, T.J.
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DOI: 10.1119/1.13466
AFFILIATIONS: Physics, University of Colorado, Box 390, Boulder, Colorado 80309, United States; Memorial Sloan-Kettering Cancer Center, New York, New York 10021, United States
ABSTRACT: High environmental temperature and/or vigorous physical work will tend to cause a person's body temperature to rise. In an attempt to maintain a normal body temperature of 37C the body then increases its rate of dissipation of heat by mechanisms that involve large increases in the blood flow to the skin. When there is an increase in the fraction of the blood that flows to the skin, the fraction available to other organs will decrease. A decreased flow to the brain can cause unconsciousness or death. The basic elements of this competition can be represented in terms of a simple dc circuit. Here is an example where the elements of dc circuit theory can be coupled with basic concepts of thermodynamics to help demonstrate the complimentarity of different branches of physics and to help students in elementary physics courses to gain an improved understanding of an important physiological situation. Examples of this type seem to be absent from many of our texts for introductory courses in physics. © 1983 American Association of Physics Teachers
DOCUMENT TYPE: Article
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DOI: 10.1119/1.13224
AFFILIATIONS: Center for Theoretical Physics, The University of Texas at Austin, Austin, Texas 78712, United States
ABSTRACT: The belief is expressed that particles, fields of force, spacetime, and “initial conditions” are only intermediate entities in the building of physics, that at bottom there is no “law,” that everything is built higgledy-piggledy on the unpredictable outcomes of billions upon billions of elementary quantum phenomena, and that the laws and initial conditions of physics arise out of this chaos by the action of a regulating principle, the discovery and proper formulation of which is the number one task of the coming third era of physics. What a regulating principle means and how it works is illustrated in the far more modest content of (1) Boltzmann's law for the distribution of energy among molecules, (2) universality of exponents near thermodynamic critical points, (3) Wigner's “semicircle law” for the distribution of characteristic frequencies of a randomly coupled system, and (4) a new “physicist's version” of the problem of the traveling salesman. The regulating principles to be seen in these simple examples fall far short in scope and simplicity of the sought-for regulating principle. The search for it lies in the new domain of “recognition physics,” being explored today on four fronts and at least half a dozen centers of investigation. © 1983 American Association of Physics Teachers
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DOI: 10.1119/1.13157
AFFILIATIONS: Department of Physics & Atmospheric Science, Drexel University, Philadelphia,

Pennsylvania 19104, United States
ABSTRACT: Le Châtelier’s principle is discussed carefully in terms of two sets of simple thermodynamic examples. The principle is then formulated quantitatively for general thermodynamic systems. The formulation is in terms of a perturbation-response matrix, the Le Châtelier matrix [L]. Le Châtelier’s principle is contained in the diagonal elements of this matrix, all of which exceed one. These matrix elements describe the response of a system to a perturbation of either its extensive or intensive variables. These response ratios are inverses of each other. The Le Châtelier matrix is symmetric, so that a new set of thermodynamic reciprocal relations is derived. This quantitative formulation is illustrated by a single simple example which includes the original examples and shows the reciprocities among them. The assumptions underlying this new quantitative formulation of Le Châtelier’s principle are general and applicable to a wide variety of nonthermodynamic systems. Le Châtelier’s principle is formulated quantitatively for mechanical systems in static equilibrium, and mechanical examples of this formulation are given. 
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PUBLICATION STAGE: Final
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Sherwood, B.A.
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DOI: 10.1119/1.13173
AFFILIATIONS: Computer-based Education Research Laboratory, Department of Physics and Department of Linguistics, University of Illinois at Urbana–Champaign, 252 Eng. Res. Lab. 103 S. Mathews, Urbana, Illinois 61801, United States
ABSTRACT: In teaching mechanics, we should more clearly distinguish between an integral of Newton’s second law and the energy equation. This leads to greater clarity in the notions of system, work, and energy. A reorientation of the treatment of work and energy would not only provide benefits in the mechanics course but would also produce better connections between the mechanics and thermodynamics courses. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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DOI: 10.1119/1.13433
AFFILIATIONS: Faculty of Mechanical Engineering, Technion-Israel Institute of Technology, Haifa 32000, United States
ABSTRACT: The definitions of work and heat and the relation between these quantities and energy is reviewed. Three expositions are considered and their validity for thermodynamical nonequilibrium processes is examined by applying them to hypothetical experiments where light is made to interact with absorbing systems. The Carathéodory exposition in contrast to the other expositions properly classifies laser interaction with absorbing matter as a work interaction. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Landsberg, P.T.
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The Born Centenary: Remarks about classical thermodynamics
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DOI: 10.1119/1.13131
AFFILIATIONS: Department of Electrical Engineering, University of Florida, Gainesville, Florida 32611, United States
ABSTRACT: Max Born (1882–1970) advocated Carathéodory's approach to thermodynamics in 1921 and 1949, and it was expounded by various authors in the intervening years, but it did not come into general use. Some historical remarks are made concerning the discussions between Born and Carathéodory. Although the Carathéodory approach continues to be regarded as "difficult," it is here noted that his principle (as contrasted with what is called his theorem) is really straightforward in concept. It is here emphasized that there was a need to push Carathéodory's approach further since it did not cover the third law of thermodynamics, and that set theory and simple topological concepts provided the ideal tools to achieve this aim. This led to a more complete geometrization of thermodynamics. Although specialized and mathematical work on the axiomatization of thermodynamics continued in the 1960s and 1970s, there also emerged a reasonably simple way of combining elements of the geometrical approach and the approach via thermodynamic cycles, as it is here recalled. When Born died in 1970 this work was essentially complete. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Numark, N.J., Bartlett, A.A.
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Energy waste in a university building
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DOI: 10.1119/1.12854
AFFILIATIONS: Department of Physics, University of Colorado, Box 390, Boulder, Colorado 80309, United States
ABSTRACT: Interesting physics problems that can be used as examples in introductory physics courses relating to the waste of thermal energy can be found in the mechanical systems of campus buildings. The design of these wasteful systems may represent the "state of the art" as it existed just a few years ago, so such examples are probably abundant. Our Student Recreation Center was opened in 1973. It has an ice skating rink with the associated large refrigeration system. Simple calculations using elementary thermodynamics applied to this system show that the heat rejected by the system is roughly a quarter of a megawatt, which is approximately the average thermal power needed to heat water for the showers in the building. An outcome of this student project is the recommendation that the rejected heat be used to heat (or preheat) the shower water at an estimated annual saving of $40 000 in current energy costs. 
DOCUMENT TYPE: Article
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Didactic remarks on the Sears-Kestin statement of the second law of thermodynamics
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DOI: 10.1119/1.13048
AFFILIATIONS: Mechanical Engineering, University of Nebraska-Lincoln, Lincoln, Nebraska 68588, United States

ABSTRACT: Examples, counterexamples, clarifying remarks, and developmental background are presented in relation to the following new statement of the second law: As a result of an irreversible (or reversible)process, a system will always have a larger (or same) final internal energy than (or as) the initial if(i) the system is adiabatic, (ii) the process returns all the generalized displacements to their initial values, (hi) the system exhibits one temperature whenever in equilibrium, and (iv) the process connects equilibrium end states. 
DOCUMENT TYPE: Article
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Parametric solution of the van der Waals liquid-vapor coexistence curve
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DOI: 10.1119/1.12877
AFFILIATIONS: Physics Department, Victoria University, Wellington, New Zealand
ABSTRACT: The van der Waals equation of state together with Maxwell's equal area rule, leads to a transcendental equation linking the densities of the two coexisting phases. Gibbs solved this in parametric form. We show that the parameter can be chosen to be the difference As between the entropy per molecule in the vapour and the entropy per molecule in the liquid. The parametric solution gives, for an arbitrary positive value of As, the thermodynamic properties of the two coexisting phases as functions of As. The van der Waals coexistence curves are compared with pressure-temperature-density data on He4, Xe, and H2O. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Fox, R.F.
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DOI: 10.1119/1.13101
AFFILIATIONS: School of Physics, Georgia Tech, Atlanta, Georgia 30332, United States
ABSTRACT: Explicit solutions are used to show that the second law of thermodynamics is not in conflict with the time-reversal invariance of Liouville's equation. The solutions are generated for a contracted, exact description of an ideal gas. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Woolsey, G.A., Sulaiman, M.Y., Mokhsin, M.
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Correlation of changes in laser tube temperature, cavity length, and beam polarization for an internal-mirror helium-neon laser
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DOI: 10.1119/1.13017
AFFILIATIONS: Physics, University of New England, Armidale, N. S. W. 2351, Australia; Jabatan Fizik, Universiti Pertanian Malaysia, Serdang, Selangor, United States
ABSTRACT: This experiment involves a study of those changes which occur in an internal-mirror helium-neon laser, during the warm-up period after switch-on. Increase in the tube temperature is measured using an array of thermocouples. Longitudinal expansion of the laser cavity is measured using one or two Michelson interferometers. Switching between axial modes is analyzed by measuring the laser output after transmission through a polarizer. The data from the three sets of measurements are compared by using them to calculate changes in tube length, and good correlation results. 

American Association of Physics Teachers
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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DOI: 10.1119/1.12468
AFFILIATIONS: Department of Physics, Michigan State University, East Lansing, Michigan, 48824, United States
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DOI: 10.1119/1.12678
AFFILIATIONS: Department of Physics, University Queensland, Brisbane 4067, Australia
DOCUMENT TYPE: Letter
PUBLICATION STAGE: Final
SOURCE: Scopus

Herlihy, J., Michelson, C., Prieto, M., Ruth, J., Barker, W.A.
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Maxwell's relations for a van der waals gas and a nuclear paramagnetic system
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DOI: 10.1119/1.12693
AFFILIATIONS: Physics Department, University of Santa Clara, Santa Clara, California 95053, United States
ABSTRACT: Appropriate partition functions for the van der Waals gas and the nuclear paramagnetic system are used to obtain the entropy expressions and the equations of state. The particular form for each of the four Maxwell's relations is evaluated for these two systems, establishing internal consistency with the first two laws of thermodynamics. The well-known limiting expressions for the ideal gas and Curie law paramagnetism readily follow. Maxwell's relations are important in analyzing the throttling process for a nonideal gas and adiabatic demagnetization for a nuclear spin system. The van der Waals equations are of classical orgin, they have a limited temperature range of validity, and they do not describe real gases at low temperature after they have condensed. The low-temperature predictions of the equations describing the nuclear paramagnetic system are consistent with the third law of thermodynamics because the partition function takes quantum effects into account. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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DOI: 10.1119/1.12416

AFFILIATIONS: Physics Department, University of Mississippi, University, Mississippi, 38677, United States
ABSTRACT: The thermodynamics of homogeneous, isotropic, unpolarized electromagnetic radiation in a cavity with volume and temperature controllable as the independent variables is analyzed. Internal energy, pressure, chemical potential, enthalpy, Gibbs free energy, heat capacities, expansivity, and compressibility are all derived from the Helmholtz free energy. Topics treated are the third law, isothermal, adiabatic, and free expansion, throttling process, phase equilibrium, stability, and the Carnot cycle. © 1981, American Association of Physics Teachers
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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DOI: 10.1119/1.12448
AFFILIATIONS: Department of Philosophy, Committee on History and Philosophy of Science, University of Maryland, College Park, Maryland 20740, United States
ABSTRACT: It is argued that the temperature concept has a richer theoretical basis than is generally appreciated. The importance of an absolute comparative concept of temperature is emphasized. A set of necessary and sufficient conditions for the existence and metricization of the temperature quantity is examined. It is shown that these conditions are all consequences of the laws of thermodynamics together with a number of ancillary thermodynamic assumptions. The absolute comparative concept of temperature as well as the absolute scale are introduced without employing the concept of a thermometer. The general notion of a thermometer is introduced as an addendum to thermodynamics. © 1981, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
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Milonni, P.W.
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Quantum mechanics of the Einstein-Hopf model
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DOI: 10.1119/1.12552
AFFILIATIONS: Electro-Optical Division, The Perkin-Elmer Corporation, 100 Wooster Heights Rd., Danbury, Connecticut, 06810, United States
ABSTRACT: The Einstein-Hopf model for the thermodynamic equilibrium between the electromagnetic field and dipole oscillators is considered within the framework of quantum mechanics. Essential to the consistency of the theory is the fluctuation-dissipation theorem connecting the radiation reaction with the zero-point electromagnetic field. The well-known “particle” term in the Einstein fluctuation formula is shown to be acorisequence of the quantum-mechanical zero-point oscillations of the field and the dipole radiators. Both the wave and particle aspects of the fluctuation formula are interpreted in terms of the fundamental absorption and emission processes. © 1981, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
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Fluitman, J.
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Energy considerations concerning current loops and magnetic objects
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DOI: 10.1119/1.12062
AFFILIATIONS: Department of Electronic Engineering, Twente University of Technology, Enschede,

Netherlands
ABSTRACT: In the thermodynamics of compound magnetic systems there is an ambiguity in defining the free energies connected to the constituent parts or subsystems. It is argued that the choice, usually made in defining the energy of a magnetized body, leads to an expression for the energy of a current loop or coil of the form U = (1/2)Li2 +iφa, where i and 4φa (an externally aplied flux, coupled to the loop) are considered as independent variables. With this expression a convention to decompose compound magnetic systems into subsystems can be given, which fits to the rules applied for nonmagnetic systems. Analogous to the case of a coil, an expression for the energy of a charged particle in a magnetic field can be derived which results in an expression for the Hamiltonian, which is generally applicable. 
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Neumann, R.M.
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DOI: 10.1119/1.12058
AFFILIATIONS: Polymer Science and Engineering Department, University of Massachusetts, Amherst, Massachusetts, 01003, United States
ABSTRACT: From Boltzmann's equation, S = k lnω, an expression for the orientational entropy, S of a rigid rod (electric dipole) is derived. The free energy of the dipole in an electric field is then calculated as a function of both the dipole's average orientation and the field strength. Application of the equilibrium criterion to the free energy yields the field dependence of the entropy of the dipole. Irreversible thermodynamics is used to derive the general form of the equation of motion of the dipole's average orientation. Subsequent application of Newton's second law of motion produces Debye's classical expression for the relaxation of an electric dipole in a viscous medium. 
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Sobel, M.I.
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DOI: 10.1119/1.12279
AFFILIATIONS: Department of Physics, Brooklyn College, Brooklyn, New York 11210, United States
ABSTRACT: We show how the adiabatic law for ideal gases can be derived from the assumption of a Maxwell-Boltzmann (or any other) distribution of velocities—in contrast to the usual derivation from thermodynamics alone. We also discuss the higher-order effect that leads to one-body viscosity. We give a more elementary derivation of the adiabatic law suitable for introductory classes. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Lurié, D., Wagensberg, J.
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DOI: 10.1119/1.12277
AFFILIATIONS: Departamento de Física Teórica, Universidad de Barcelona, Barcelona, Spain; Departamento de Termología, Universidad de Barcelona, Barcelona, Spain
ABSTRACT: Examples of thermodynamic evolutions toward stationary states are exhibited in a one-

dimensional heat conduction problem. A computer simulation technique is employed to solve the Fourier partial differential equation and compute the evolution of the three terms in the entropy balance equation. Some concepts of linear nonequilibrium thermodynamics are analyzed in the framework of the model: the meaning of the entropy balance equation, the disticntion between free and fixed forces, the role of the Onsager's relations, and the relationship between the structural adaptation of a linear system to the externally imposed constraints and the entropic concept of “order”. 
DOCUMENT TYPE: Article
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DOI: 10.1119/1.12002
AFFILIATIONS: Department of Physics, Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio, 45433, United States
ABSTRACT: The condition of equilibrium molecular dissociation is investigated without using thermodynamic reasoning explicitly. The approach of “phase-space maximization” illuminates the basic principles of statistical mechanics while providing an understanding of an equation which is useful in many applications. © 1980 American Association of Physics Teachers
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Weinstock, H.
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Thermodynamics of cooling a (live) human body
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DOI: 10.1119/1.12092
AFFILIATIONS: Physics Department, Illinois Institute of Technology, Chicago, Illinois, 60616, United States
ABSTRACT: Students in a junior-level thermodynamics course were presented a practical problem in which a human body must maintain its normal interior temperature of 37°C while the surface is at 15°C. Suggested solutions to this problem are offered along with details of heat flow in the body. © 1980 American Association of Physics Teachers
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Walsh, P.J., Gallo, C.F.
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Thermodynamic laws of neutrino and photon emission
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DOI: 10.1119/1.12327
AFFILIATIONS: Fairleigh Dickinson University, Teaneck, New Jersey, 07666, United States; 51 Coachman Drive, Penfield, New York, 14526, United States
ABSTRACT: From the analogous properties of neutrinos and photons as quantized energy waves, the generalized “blackbody” radiation law for the total power radiated Rv per unit area per unit frequency v is derived as Rv=(2πk3/c2h2) × T3{(hv/kT)3/ [exp(hv/kT) - 1] +3{hv/kT)3 / [exp(hv/kT)+ 1]}, where c is the speed of light, h is Planck’s constant, k is Boltzmann’s constant, and T is the absolute temperature. The first term in the brackets is the usual Planck radiation law for photon emission. The second term is the corresponding expression describing blackbody neutrino and antineutrino emission, which contains a factor of 3 because three different types of neutrinos are presently suspected. Otherwise the photon and neutrino terms only differ in the sign of the unity

term due to the different spin statistics of photons compared with neutrinos. For photons, the spin = ħ and Bose-Einstein statistics apply, while for neutrinos the spin = ħ/2 and Fermi-Dirac statistics are appropriate. The wavelength (λm) at which the maximum energy is radiated is λmT = 2.898 p kK for photons and λmT - 2.859 λ kK for neutrinos, while the total power radiated per unit area is R =T4 (σp+σn), where σp =5.67 W/cm2(kK)4for photons and σn = 14.88 W/cm2(kK)4for three types of neutrinos. Note that kK represents kilo degrees Kelvin. As is well known, the form of the blackbody law for photons demands the possibility of stimulated emission by light flux, thus allowing light to be amplified. On the other hand, the neutrino blackbody law demands that neutrino radiating transitions are suppressed in the presence of a neutrino flux. There are applications of these neutrino concepts in particle physics and astrophysics. It appears that neutrino blackbodies or graybodies may exist in nature associated with black holes, the formation of neutron stars, and the formation of the universe itself. 
DOCUMENT TYPE: Article
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Parker, B.R., McLeod, R.J.
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Black hole thermodynamics in an undergraduate thermodynamics course
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DOI: 10.1119/1.12288
AFFILIATIONS: Physics Department, Idaho State University, Pocatello, Idaho, 83209, United States
ABSTRACT: An analogy has been drawn between black hole physics and thermodynamics. In this paper the analogy is mathematically broadened. Equations similar to the standard partial differential relations of thermodynamics are found for black holes. The results can be used to supplement an undergraduate thermodynamics course. 
DOCUMENT TYPE: Article
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Neumann, R.M.
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DOI: 10.1119/1.12095
AFFILIATIONS: Polymer Science and Engineering Program and Materials Research Laboratory, University of Massachusetts, Amherst, Massachusetts, 01003, United States
ABSTRACT: A diffusional driving force, called the radial force, which is responsible for the increase with time of the scalar separation between a fixed point and a particle undergoing three-dimensional Brownian motion, is derived using Boltzmann’s equation. The radial force is used to derive several results from the classical theory of Brownian motion, namely Einstein’s <x2> = 2Dt equation and the expression for the one-dimensional harmonic oscillator. The radial force concept is then extended to establish a thermodynamic criterion for the occurrence of a melting transition in a liquid whose particles attract one another by means of centrally symmetric forces. The theory, when applied to the alkali halide and alkaline-earth oxide molten salts, accurately predicts the observed melting temperatures. The definition of the dielectric constant used in the ionic salt fusion theory also provides a basis for understanding molten salt surface tensions. Finally, the radial force is used to demonstrate that an ideal rubber network is not prone to collapse into a state having zero volume. 
DOCUMENT TYPE: Article
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Stoeckly, B.
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Thermodynamic derivation of the equilibrium distribution functions of statistical mechanics
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DOI: 10.1119/1.11789
AFFILIATIONS: Department of Mechanical and environmental Engineering, University of California, Santa Barbara, United States
ABSTRACT: A simplified derivation of the equilibrium distribution functions is presented. The derivation proceeds from the change in the Helmholtz free energy when a particle is added to a system of fixed temperature, volume, and chemical potential. Besides its simplicity, this form of the derivation offers a clear view of the relationship between statistical mechanics and macroscopic thermodynamics. 
DOCUMENT TYPE: Article
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DOI: 10.1119/1.11981
AFFILIATIONS: Department of Physics, Oberlin College, Oberlin, Ohio 44074, United States
DOCUMENT TYPE: Letter
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DOI: 10.1119/1.11563
AFFILIATIONS: Department of Physics and Astronomy, California State University, 90840, Long Beach, California, United States
ABSTRACT: Basic macroscopic relations involving the concept of available energy are derived from the local equations of nonequilibrium thermodynamics. The available energy is that part of a system’s energy which can be converted into useful work. The model used describes a mixture of heat conducting compressible inviscid chemically reacting fluids in a gravitational field. Integration of the local equations yields instructive derivations of basic available energy relations for closed systems, continuous flow arrangements, and for diffusive mixing or separation processes. 
DOCUMENT TYPE: Article
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DOI: 10.1119/1.11566
AFFILIATIONS: Department of Physics, Harvard University, Cambridge, Massachusetts 02138, United States
DOCUMENT TYPE: Letter
PUBLICATION STAGE: Final
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Weichman, F.L., Austen, D.J.
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Black liquid solar collector demonstrator
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DOI: 10.1119/1.11747
AFFILIATIONS: Department of Physics, University of Alberta, Edmonton, Alberta T6G 2J1, Canada
ABSTRACT: A solar collector, suitable for an undergraduate laboratory project or lecture demonstration has been built and the details of the construction and the way in which it can be used by students in elementary or advanced courses is described. A simple and efficient system results from using a black liquid to absorb the energy and from using the thermosyphon effect to drive the liquid through the collector. A floodlamp is used as a surrogate sun. The collector is of considerable current interest in the field of solar energy. 
DOCUMENT TYPE: Article
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Hoover, W.G., Moran, B.
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DOI: 10.1119/1.11628
AFFILIATIONS: Department of Applied Science, University of California Davis-Livermore, University of California Lawrence Livermore Laboratory, Livermore, California 94550, United States
ABSTRACT: We present two exercises involving rapid compression and expansion of ideal gases. The exercises are useful teaching tools and illustrate the first and second laws of thermodynamics. The first problem involves the conversion of gravitational energy into heat through mechanical work. The second involves the mutual interaction of two gases through an adiabatic piston. Both local and global versions of the second law can be applied to this second exercise. Both problems are also treated by numerical fluid dynamics. 
DOCUMENT TYPE: Article
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Peterson, M.A.
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Analogy between thermodynamics and mechanics
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DOI: 10.1119/1.11788
AFFILIATIONS: Department of Physics, Amherst College, Amherst, United States
ABSTRACT: We note that equations of state—by which we mean identical relations among the thermodynamic variables characterizing a system—are actually first-order partial differential equations for a function which defines the thermodynamics of the system. Like the Hamilton-Jacobi equation, such equations can be solved along trajectories given by Hamilton's equations, the trajectories being quasistatic processes which obey the given equation of state. This gives rise to the notion of thermodynamic functions as infinitesimal generators of quasistatic processes, with a natural Poisson bracket formulation. This formulation of thermodynamic transformations is invariant under canonical coordinate transformations, just as classical mechanics is, which is to say that thermodynamics and classical mechanics have the same formal structure, namely a symplectic structure. 
DOCUMENT TYPE: Article
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Masut, R., Mullin, W.J.
57196692838;7005249099;
Spatial bose-einstein condensation
(1979) American Journal of Physics, 47 (6), pp. 493-497. Cited 21 times.
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0000891750&doi=10.1119%2f1.11790&partnerID=40&md5=44bd57143be07848d7570459d7d099c8

DOI: 10.1119/1.11790
AFFILIATIONS: Department 0f Physics and Astronomy, University of Massachusetts, Amherst, United States
ABSTRACT: Three examples of spatial Bose-Einstein condensations in which the particles macroscopically occupy the lowest localized state of an inhomogeneous external potential are analyzed. The three cases are (a) a small potential well in a large box which causes a spectrum with a gap, (b) a harmonic oscillator potential, and (c) randomly sized trapping potentials caused by &impurities.& All three cases are two dimensional so that no Bose condensation occurs without the inhomogeneous potentials. An attempt is made to keep the treatments as mathematically simple as possible. A review of much of the literature of spatial Bose condensations is provided. The special problem of the form of the thermodynamic limit in an inhomogeneous potential is discussed for case (b). Numerical examples applying to monolayer4He adsorbed on a surface are treated. 
DOCUMENT TYPE: Article
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Chang, K.N., Cook, M.S., Hamlyn, K.M., Chaplin, R.L.
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DOI: 10.1119/1.11502
AFFILIATIONS: Department of Physics, Astronomy, Clemson University, Clemson, South Carolina, 29631, United States
ABSTRACT: A special thermocouple circuit has been used to measure the Joule heating as well as the Peltier heating and cooling for a copper-Constantan metallic junction. It isshown how the Seebeck effect from a thermocouple can successfully monitor the temperature condition of a junction with regard to input power and Peltier effect. By comparisonof theoretical and experimental results, it is found that the experimental evaluation of the thermocouple response is 18% of the actual value of the Peltier coefficient. 
DOCUMENT TYPE: Article
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Edmonds, J.D.
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DOI: 10.1119/1.11140
AFFILIATIONS: Department of Physics, Bucknell University, Lewisburg, Pennsylvania 17837, United States
ABSTRACT: The harmonic oscillator is examined as an example of a thermodynamic system with properties analogous to the ideal gas at high temperatures, but better behaved as T—>0° K. The concept of PdV work is examined in the generalized context of the oscillator “pressure. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Bowers, R.G., McKerrell, A.
7101863320;6602323496;
The information-theoretic statistical mechanics of a system in contact with a heat reservoir
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https://www.scopus.com/inward/record.uri?eid=2-s2.0-84935608240&doi=10.1119%2f1.11373&partnerID=40&md5=0680286abbf1c5f1afdabbbffe3725a2

DOI: 10.1119/1.11373

AFFILIATIONS: Department of Applied Mathematics and Theoretical Physics, University of Liverpoo, L69 3BX, United Kingdom
ABSTRACT: The subject of this paper is the information-theoretic statistical mechanics of a system in contact with a heat reservoir. The fundamental extremum principle of Jaynes is introduced, and a new essentially thermodynamic characterization of a heat reservoir is established. This allows a new extremum principle—involving a generalization of the Helmholtz free energy of thermodynamics—to be derived. This new extremum principle is used to find that probability distribution which, roughly speaking, best represents a system at fixed temperature. Not unexpectedly, the canonical distribution of Gibbs results. Some consequences of the analysis are discussed. An example of other applications of the new extremum principle is given. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Kittel, P., Hackleman, W.R., Donnelly, R.J.
7004191214;23041815500;24572753800;
Undergraduate experiment on noise thermometry
(1978) American Journal of Physics, 46 (1), pp. 94-100. Cited 12 times.
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DOI: 10.1119/1.11171
AFFILIATIONS: Department of Physics, University of Oregon, Eugene, Oregon 97403, United States
ABSTRACT: An absolute temperature scale noise thermometer is described and Boltzmann’s constant is measured. The apparatus involves an easily constructed temperature probe and standard electronic instruments. The design considerations for the experiment are a useful introduction to low noise electronics. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Baierlein, R.
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Teaching the approach to thermodynamic equilibrium: Some pictures that help
(1978) American Journal of Physics, 46 (10), pp. 1042-1045. Cited 6 times.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-33744686720&doi=10.1119%2f1.11424&partnerID=40&md5=324e0c7dfaa61646afb18a8acb96e439

DOI: 10.1119/1.11424
AFFILIATIONS: Department of Physics, Wesleyan University, Middletown, Connecticut 06457, United States
ABSTRACT: Although the approach to thermodynamic equilibrium is a subtle issue, one can capture the essence even in an introductory physics course. Here I share a method of pictorial, intuitive presentation that has evolved during a dozen years of teaching the topic. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Tykodi, R.J.
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Quasi-Carnot cycles, negative Kelvin temperatures, and the laws of thermodynamics
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DOI: 10.1119/1.11310
AFFILIATIONS: Department of Chemistry, Southeastern Massachusetts University, North Dartmouth, Massachusetts 02747, United States
ABSTRACT: It is maintained that the impossibility of moving a thermodynamic system adiabatically and reversibly (isentropically) from the domain of positive Kelvin temperatures to the domain of negative Kelvin temperatures (and vice versa) is a consequence of (an extended form of) the Third Law of thermodynamics and not of the Second Law alone; it is further maintained that Schopfs s apparent proof to the contrary is inconclusive. In the course of the discussion the properties of a quasi-

Carnot cycle (two adiabatic steps coupled with two steps involving floating temperature heat reservoirs) are explored. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Guénault, A.M., Lawson, N.S., Veazey, S.D.
7004164828;7102396608;16528152700;
Measurement of thermoelectric effects at low temperaure
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DOI: 10.1119/1.11332
AFFILIATIONS: Department of Physics, University of Lancaster, Lancaster LA1 4YB, United Kingdom; Department of Science(Physics), College of Higher Education, Park Square, Luton LU1 3JU, Bedfordshire, United Kingdom
ABSTRACT: A method, suitable for an advanced undergraduate project laboratory, is described whereby the existence of the Seebeck, Peltier, and Thomson effects may be demonstrated in a single experimental setup using a Cu-0.01%Fe sample. Experimental results for the Peltier and Thomson coefficients are obtained which are consistent with the Kelvin relations. The experiment provides the student with a convenient introduction to the use of liquid helium as well as to the procedural and measuring techniques employed at low temperatures. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Canagaratna, S.G.
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Critique of the treatment of work
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https://www.scopus.com/inward/record.uri?eid=2-s2.0-17444422109&doi=10.1119%2f1.11386&partnerID=40&md5=a51eac84a332940a65ee6b1ef6378f6c

DOI: 10.1119/1.11386
AFFILIATIONS: Department of Chemistry, University of Ceylon, Peradeniya, Sri Lanka
ABSTRACT: The difficulties in the treatment of work are discussed. It is shown that it is useful to distinguish between the work done by the work source and the work received by the system. The former is in general greater than the latter. This inequality should be carefully distinguished from the inequality that compares the work received by the system in a change carried out quasistatically with the corresponding quantity for the same change carried out nonstatically. The conditions under which these two quantities may be compared are carefully examined. It is shown that in the general nonstatic case the work cannot be calculated in mechanical terms alone; we have to use the first law of thermodynamics. 
DOCUMENT TYPE: Article
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Leff, H.S., Teeters, W.D.
36854071400;24532382900;
EER, COP, and the second law efficiency for air conditioners
(1978) American Journal of Physics, 46 (1), pp. 19-22. Cited 63 times.
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DOI: 10.1119/1.11174
AFFILIATIONS: Department of Physical Sciences, Chicago State University, Chicago, Illinois 60628, United States
ABSTRACT: It is pointed out that there is a close relationship between the energy efficiency ratio (EER) of an air conditioner unit and the coefficient of performance (COP) of its refrigeration cycle. This connection helps to bridge the gap between pure thermodynamics and practical energy-related problems. In this spirit, two other efficiency parameters, the total COP and total EER, measured relative to the energy extracted by a primary energy source (e.g., a fossil fuel), are defined. A comparison of the actual total COP (or total EER) relative to its maximum allowed value, consistent

with the second law of thermodynamics, leads to an estimate for air conditioners of the recently proposed second law efficiency. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Marshall, T.W.
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A simplified version of Caratheodory thermodynamics
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DOI: 10.1119/1.11372
AFFILIATIONS: Department of Mathematics, Manchester University, Manchester M13, 9PL, United Kingdom
ABSTRACT: Starting from the existence of adiabiatic surfaces for a thermodynamic system, we show, by coupling it to a perfect gas, that the absolute temperature is an integrating factor of the reversible heat input. The proof makes no use of the general theory of Pfaffians. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Leff, H.S.
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Multisystem temperature equilibration and the second law
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DOI: 10.1119/1.11002
AFFILIATIONS: Department of Physical Sciences, Chicago State University, Chicago, Illinois 60628, United States
ABSTRACT: The entropy change during the temperature equilibration of an isolated collection of systems which may exchange heat (but not work) energy is shown to be positive. The proof holds when the constant volume heat capacity of each system is a non-negative function of the temperature. If the collection is allowed to exchange heat A Q with its environment during the equilibration, its entropy change AS is shown to satisfy the inequality Δs≥ Δq/tf, where Tfis the final equilibrium temperature. For infinitesimal equilibration transformations, this inequality reduces to a generalized statement of the second law of thermodynamics, showing that the internal portion of the entropy production during equilibration is nonnegative. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Harker, G.G., III, Eshelman, D.M., Schmidt, R.L.
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Millidegree temperature thermostat for optical studies
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DOI: 10.1119/1.10624
AFFILIATIONS: Department of Chemistry, University of New Orleans, New Orleans, Louisiana 70122, United States
ABSTRACT: This department in collaboration with the Committee on Apparatus of the AAPT will welcome the submission of brief communications reporting new equipment, techniques, or materials of interest to teachers of physics. Notes on new applications of older apparatus, measurements supplementing data supplied by manufacturers, information which, while not new, is not generally known, procurement information, and news about apparatus under development are suitable for publication in this section. Neither the American Journal of Physics nor the Editors assume responsibility for the correctness of the information presented. Submit materials to: Bruce G. Eaton, Department of Physics, University of Minnesota, 116 Church St. SE, Minneapolis, MN 55455. 

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PUBLICATION STAGE: Final
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Arrott, A.S.
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DOI: 10.1119/1.10809
AFFILIATIONS: Department of Physics, Simon Fraser University, Burnaby, British Columbia V5A 1S6, Canada
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Home, D.
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Concept of temperature without the zeroth law
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DOI: 10.1119/1.10701
AFFILIATIONS: Physics Department, Presidency College, Calcutta, India
ABSTRACT: The present article consists of two parts: (1) criticism of the zeroth law, and (2) development of thermodynamics dispensing with the zeroth law. Two main criticisms of the zeroth law are (a) it is not an independent law of thermodynamics, and (b) it does not furnish even a qualitative objective definition of temperature. It is, therefore, asserted that the concept of temperature must not be introduced before the second law. How the second law can be used to give a complete objective definition of temperature consistent with the zeroth law is then discussed. © 1977, American Association of Physics Teachers. All rights Reserved.
DOCUMENT TYPE: Article
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de Heer, J.
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Some comments on the “axiomatic” formulation of the first law of thermodynamics
(1977) American Journal of Physics, 45 (12), pp. 1225-1226. Cited 2 times.
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DOI: 10.1119/1.10687
AFFILIATIONS: Chemistry Department, University of Colorado, Boulder, Colorado 80309, United States
DOCUMENT TYPE: Letter
PUBLICATION STAGE: Final
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Schwartz, H.M.
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Einstein's comprehensive 1907 essay on relativity, part II
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DOI: 10.1119/1.11053
AFFILIATIONS: Department of Physics, University of Arkansas, Arizona, 72701, United States
ABSTRACT: This continuation of the English rendition of Einstein’s 1907 essay on relativity, of which the first part appeared in the June 1977 issue of this Journal, is devoted to Parts II-IV of the essay, dealing with the relativistic treatments of electrodynamics, optics, mechanics, and thermodynamics. The original text of these parts covers 27 printed pages. However, owing to the

nature of the subject matter and the character of the original exposition, it was possible to reproduce here the essential content of the original text intact in terms of a free rendition, using modern notation, and retaining all the original formulas with their numbering, and also including direct translations of all passages of possible historical interest. Mathematical amplifications of a few of the key derivations in the original text are presented in added footnotes. 
DOCUMENT TYPE: Article
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Hajj, F.Y.
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On fundamental equations for thermodynamic systems
(1976) American Journal of Physics, 44 (11), pp. 1116-1118.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-84956038824&doi=10.1119%2f1.10573&partnerID=40&md5=13735f6b5c7846990818b118984e7b21

DOI: 10.1119/1.10573
AFFILIATIONS: National Council for Scientific Research, Beirut, Lebanon
ABSTRACT: The principle of maximum entropy and the principle of minimum energy lead to inequalities which are useful in testing the validity of fundamental equations. It can be seen that these principles are actually conditions on the curvature of functions containing the variables S, U, V, and n. Several theorems illustrating the nature of these functions are proved by simple methods. The condition for the equivalence of the two principles is shown. © 1976, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
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Dowling Jr, J., Swartz, P.
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The thermostat—turn it down
(1976) American Journal of Physics, 44 (10), pp. 950-952.
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DOI: 10.1119/1.10238
AFFILIATIONS: Department of Environmental and Applied Physics, Mansfield State College, Mansfield, Pennsylvania 16933, United States
ABSTRACT: The energy saved in turning the thermostat down overnight is examined. The model for the house is a 1500-ml water-filled beaker. The beaker is in an ice-water bath. The energy required to maintain the beaker at TH(20 °C), TL(15 °C), and to raise the temperature from tl to this determined. Times to cool and heat are noted. The data are extrapolated to fit typical house situations, and resultant energy savings are shown. © 1976, American Association of Physics Teachers.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Bartlett, A.A.
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Introductory experiment to determine the thermodynamic efficiency of a household refrigerator
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DOI: 10.1119/1.10361
AFFILIATIONS: Department of Physics and Astrophysics, University of Colorado, Boulder, United States
ABSTRACT: An experiment is described in which students in an introductory laboratory can determine all of the relevant energy flows (and hence the coefficient of performance) of an ordinary household refrigerator and can compare their measured results with the coefficient for an ideal Carnot refrigerator operating between the same two temperatures. The analysis of the data makes use of the first and second laws of thermodynamics and the relationship for thermal conductivity. The experiment has relevance in the world of the energy crisis. © 1991, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article

PUBLICATION STAGE: Final
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Smith, R., Haley, S.B.
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Nonequilibrium thermodynamic properties of dilute Maxwellian gases
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DOI: 10.1119/1.10197
AFFILIATIONS: Department of Physics, Florida Technological University, Orlando, Florida, 32816, United States
ABSTRACT: The Boltzmann equation is solved analytically for a physically reasonable model of dilute neutral gas transport through a prism containing randomly located hard sphere scattering centers. The role of boundary and bulk scattering in establishing local equilibrium is clearly illustrated. Asymptotically exact expressions are given for the particle density, pressure, and temperature distributions in the limits of large and small mean free path. The particle flux and the heat flux are calculated exactly for all values of the mean free path. © 1976, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
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Barford, N.C.
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Derivation of classical and quantum statistical distributions
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DOI: 10.1119/1.10236
AFFILIATIONS: Department of Physics, Imperial College, London, SW7 2BZ, United Kingdom
ABSTRACT: An elementary method is described for deriving the Boltzmann, Fermi-Dirac, and Bose-Einstein distributions that neither uses Lagrange undetermined multipliers nor requires a knowledge of Stirling’s approximation for ln(n!). Apart from giving a more direct account of the optimal properties of these distributions, which may be useful when first introducing statistical thermodynamics, the method also shows clearly how the validity of the distributions depends upon the size of the system. Extensions of the method demonstrate the statistical origin of temperature and the dominance of the most probable macrostate. © 1976, American Association of Physics Teachers.
DOCUMENT TYPE: Article
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Ioriatti, L.C., Jr., Rosa, S.G., Jr., Hipolito, O.
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Bose–Einstein condensation in a one-dimensional system due to an attractive-δ impurity center
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DOI: 10.1119/1.10123
AFFILIATIONS: Departamento de Fisica e Ciencia dos Materiais, Instituto de Fisica e Quimica de Sao Carlos, Universidade de Sao Paulo, 13560, Sao Carlos, Sao Paulo, Brasil, Brazil
ABSTRACT: The thermodynamic behavior of the one-dimensional Bose-gas-attractive-δ impurity system is studied in this paper. The system is shown to undergo the Bose-Einstein condensation and the cause of the phase transition is attributed to the bound state introduced by the impurity in the free-particle energy spectrum. The condensed phase is composed of particles captured by the impurity, forming a drop of particles well localized in space. This gives to the Bose-Einstein condensation in this system the appearance of the ordinary vapor-liquid phase transition. The expression for the pressure is obtained and is plotted as a function of the temperature and the system length. The shapes of the isothermal curves reinforce the interpretation of a vapor-liquid transition. The evaluation of the heat capacity at constant length shows the existence of a finite discontinuity at the transition temperature. © 1991, American Association of Physics Teachers. All rights reserved.
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Mullen, J.G.
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An attempt at a personalized course in thermodynamics
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DOI: 10.1119/1.9853
AFFILIATIONS: Physics Department, Purdue University, West Lafayette, Indiana, 47907, United States
ABSTRACT: A personalized course in thermodynamics is described which organizes learning about moderately difficult projects designed to bring a sense of continuity and relevance to student studies. The approach minimizes formal lecturing and tries to encourage discovery and enjoyment in learning. Student lecturing, laboratory visits, and demonstrations, along with class discussions of projects, are used as a replacement for most, but not all formal classroom lecturing. Student comments are used as a basis for evaluating the approach. © 1975, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Buchdahl, H.A., Simpson, M.A.
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Remark on the equilibrium of moving systems
(1975) American Journal of Physics, 43 (12), pp. 1041-1045. Cited 3 times.
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DOI: 10.1119/1.10035
AFFILIATIONS: The Australian National University, Canberra, 2600, Australia
ABSTRACT: The most general motion of an isolated thermodynamic system K in equilibrium is determined by Landau and Lifshitz through an appeal to the equilibrium condition 8S = 0. It is argued that this work actually amounts to a demonstration of the internal consistency of the thermodynamic formalism in this case since the problem is soluble by an appeal to prior criteria. We use these to determine all motions consistent with equilibrium in the more general case of a system K which is not isolated. Although the temperature would of necessity be uniform if K were at rest, this is no longer obviously the case when it is moving. To emphasize this point, we first determine the possible relativistic motions of K, restricted to be translations in a fixed direction, and then determine explicitly the distribution of absolute temperature within it. It turns out to be nonuniform only when K is accelerated, and then it varies in a manner consistent with the principle of equivalence. © 1975, American Association of Physics Teachers.
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16413882600;22975904500;57068916400;
Thermodynamics of a simple rubber-band heat engine
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DOI: 10.1119/1.9852
AFFILIATIONS: Physics Department, Purdue University, West Lafayette, Indiana, 47907, United States
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Guyon, E.
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Second-order phase transitions: Models and analogies
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DOI: 10.1119/1.9970
AFFILIATIONS: Department of Physics, University of California, Los Angeles, California, 90024, United States
ABSTRACT: We present models of second-order phase transitions, using elementary equipment, which reproduce the static behavior above a mean field phase transition and the thermodynamic slowing down on each side of it, The model is compared to continuum physics examples involving side effects in liquid crystals (Freedericksz transition) and in superconductors (proximity effect). © 1975, American Association of Physics Teachers. All rights reserved.
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Leff, H.S.
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Irreversibility, entropy production, and thermal efficiency
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DOI: 10.1119/1.10032
AFFILIATIONS: Dpruirtment of Physical Sciences, Chicago State University, Chicago, Illinois, 60628, United States;
Department of Physics, University of Notre Dame, Notre Dame, Indiana, 46556, United States
ABSTRACT: The relationships between the entropy production per cycle and the thermal efficiency are investigated for a class of irreversible cyclic processes. Examples are given that pinpoint specific sources of irreversibility and their thermodynamic consequences. It is found that an increase (decrease) in an irreversible cycle's thermal efficiency does not necessarily lead to a decrease (increase) in its entropy production even if the work done per cycle is held constant. Only for the case of a reversible Carnot cycle is it guaranteed that a change (negative for this case) in the efficiency is met by an entropy production change of opposite algebraic sign. Sufficiency conditions are found for which the entropy production and the efficiency η are inversely related for more general cyclic processes. For a given set of heat reservoirs and specified values of the work output W, the absolute minimum and maximum entropy productions are determined and are shown to be monotonically decreasing functions of η for fixed W. It is shown also that for an irreversible cycle with maximum and minimum temperatures T+ and T_, respectively, η≤(1 -T-T+)(1 +T__S/W)_1, where _S is the entropy production per cycle. The equality holds only for a cycle employing two reservoirs. The potential relevance of these results to environmental and technological problems is mentioned. © 1975, American Association of Physics Teachers. All rights reserved.
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Harper, C.
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DOI: 10.1119/1.1987708
AFFILIATIONS: Lawrence Berkeley Laboratory, University of California, 94720, Berkeley, United States
ABSTRACT: A simplified derivation of Wigner's quantum-mechanical correction for thermodynamic equilibrium is presented. The analysis is restricted to the quantum statistics of systems with classical analogs. © 1974, American Association of Physics Teachers. All rights reserved.
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AFFILIATIONS: Avco Everett Research Laboratory Inc., Everett, Massachusetts, 02149, United States
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DOI: 10.1119/1.1987755
AFFILIATIONS: Theoretical Physics Institute, University of Alberta, Edmonton, Alberta, Canada
ABSTRACT: The extraction of the basic equations of thermodynamics for a grand canonical ensemble of small systems is reviewed briefly. A modified formula for the fluctuation in the number of ‘particles in a small system, for which the extensive property may not hold is derived in terms of the isothermal compressibility. 
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1987646
AFFILIATIONS: School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota, 55455, United States
ABSTRACT: Ideal gas models for equilibrium osmotic pressure and for nonequilibrium flow of solvent through an ideal semipermeable membrane are presented. These models can easily be introduced in general physics courses for students of the life sciences. The models are justified in Appendices, which include a summary of the irreversible thermodynamics of flow through membranes. Some physiological examples are presented, including the Nernst equation and Gibbs-Donnan equilibrium. 
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DOI: 10.1119/1.1987456
AFFILIATIONS: Rutherford Observatorv, Columbia University, New York, New York 10027, United States
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AFFILIATIONS: 8 Coventry Road Syosset, New York 11791, United States
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DOI: 10.1119/1.1987421
AFFILIATIONS: Department of Materials Science, University of Virginia, Charlottesvill(, Virginia, 22901, United States
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Fuller, R.M., Fuller, R.G.
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DOI: 10.1119/1.1986687
AFFILIATIONS: Department of Physics*, Gustavus Adolphus College, St. Peter, Minnesota, 56082, United States;
Department of Physics, University of Nebraska, 68508, Lincoln, Nebraska, United States
ABSTRACT: Research projects for undergraduates should satisfy several conditions with regards to the physical insight, experimental manipulation, data analyses, and time for the experimental run that are required of the students. These conditions are satisfied by the study of dipole relaxations in dielectric materials using the method of ionic thermocurrents (ITC). ITC can be used to determine the concentration, activation energy, and relaxation time of dipoles in a dielectric. The necessary equipment and some possible research projects are discussed. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Henry, U., Jr.
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DOI: 10.1119/1.1986685
AFFILIATIONS: Wichita State University, Wichita, Kansas, 67208, United States
ABSTRACT: The Callen and Tyablikov decoupling schemes used in the Green's function method are tested numerically for short Heisenberg linear chains which are first subjected to a constraint. The constraint is imposed to insure that internal excitations alone contribute to the calculated thermal averages so that in this sense these averages correspond to thermodynamic quantities. It is found that improved agreement with the exact results occurs if the Tyablikov decoupling is corrected by a term linear in the temperature. 
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1986641
AFFILIATIONS: The University of Texas, Dallas, Texas 75230, United States
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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DOI: 10.1119/1.1988058
AFFILIATIONS: Route 3 Box 334, Bel Air, Maryland 21014, United States
ABSTRACT: The theory of fluid mechanics can be profitably applied to chemistry by simply noting that many fluids are substances. Certain equations of fluid mechanics then become the counterparts of equations in the theory of the chemical thermodynamics of systems at constant temperature. Consequently, some of the most valuable parts of this theory may, for some purposes, also be regarded as a part of elementary physics completely independent of thermodynamics. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Erratum: “Introduction to the Thermodynamics of Biopolymer Growth.” [Amer. J. Phys. 40, 60 (1972)]
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Undergraduate Experiment On Low-Temperature Dependence Of The Conductivity Of Copper Wire
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DOI: 10.1119/1.1986875
AFFILIATIONS: Department of Physics and Astronomy, University of Maryland, College Park, Maryland, 20742, United States
ABSTRACT: A simple experiment is described that permits advanced undergraduates to investigate the temperature dependence of electrical conductivity in copper wire down to liquid helium temperatures. At temperatures below 40°K the experimental results approach the T5behavior expected from quantum mechanical calculations. At temperatures below 8°K a constant, nonvanishing resistance is found. The

apparatus uses a nested Dewar system in conjunction with a helium gas thermometer. 
DOCUMENT TYPE: Article
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Onn, D.G., Hofmann, M.P., Gagne, R.M.
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Thermoluminescent Dosimetry In A “Medical Physics” Course Laboratory
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DOI: 10.1119/1.1986881
AFFILIATIONS: Department of Physics, University of Delaware, Delaware, Newark 19711, United States
ABSTRACT: In developing the laboratory section of a new course in “Medical Physics” we have made extensive use of thermoluminescent dosimetry (TLD). This technique makes possible quantitative experiments in radiation physics that cannot easily be performed with other detectors. The experiments described range from an inverse-square-law demonstration to detailed radiation beam profile studies the results of which can be used by students in patient treatment planning in a simulated clinical situation. An outstanding feature of TLD techniques involves the “point detector” nature of the TLD crystals, allowing high-resolution study of spatial-dose variations. 
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1986793
AFFILIATIONS: Basser Department of Computer Science, School of Physics, University of Sydney, Sydney, Australia
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

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DOI: 10.1119/1.1986817
AFFILIATIONS: Department of Physics, University of Wisconsin—Platteville, Platteville, Wisconsin, 53818, United States
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DOI: 10.1119/1.1986447
AFFILIATIONS: Department of Physics, University of California, Berkeley, California, 94720, United States

ABSTRACT: An elementary discussion for physicists is given of the thermodynamic instability of proteins and DNA. The biochemical exploration is given of how these molecules are grown in the face of a large unfavorable free energy difference, as much as 0.2 MeV for DNA of 106 bonds. The role of A TP is described as the major fuel of the biological world. 
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1986775
AFFILIATIONS: Departmernt of Physics, University of Delaware, Newark, Delaware, 19711, United States
ABSTRACT: A new course in “medical physics ” with a basic element of direct hospital field experience is described. Noncalculus, the course is designed to follow an introductory general physics or chemistry course. Intended primarily for pre medical students, the course may be taken by nonscience majors interested in health studies. Eighteen hours of in-hospital time are included for each student, supplemented by laboratory work in the physics department, including radiaiion dosimetry studies with a 2.5 meV van de Graff accelerator using thermoluminescent dosimetry techniques that allow students to develop their interests into research projects. 
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DOI: 10.1119/1.1986444
AFFILIATIONS: Department of Physics and Astronomy, Dartmouth College, 03755, Hanover, New Hampshire, United States
ABSTRACT: The application of the thermodynamical law of mass action to the calculation of equilibrium conduction electron and hole concentrations in semiconductors is explained. The method can be applied to arbitrarily complicated systems of donors, traps, acceptors, etc., in addition to the intrinsic electron-hole excitation. The discussion is limited to small defect concentrations and quasifree charge carriers, so that the ideal-gas free energy and the Sackur-Tetrode entropy constant can be used. Exact solutions are straightforward but often so complicated that simplifying assumptions are useful. As an example the effect of compensation of donors is calculated as a function of temperature. The Fermi energy is simply related to the electron concentration. 
DOCUMENT TYPE: Article
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Thermodynamic Description of Materials at High Pressures
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DOI: 10.1119/1.1986517
AFFILIATIONS: Eric H. Wang Civil Engineering Research Facility, University of New Mexico, Albuquerque, New Mexico, 87106, United States
ABSTRACT: A technique is presented for deriving the caloric equation of state for materials at high pressures. An incomplete equation of state, giving pressure as a function of density and energy, is

used as input to a partial differential equation for entropy. The incomplete equation of state is usually inferred from shock-wave experiments. The entropy equation can be solved, provided sufficient initial data are available. The technique is illustrated by two examples, a polytropic gas and a Mie-Gruneisen-type material. 
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1987065
AFFILIATIONS: Physics Department, University of Georgia, Athens, 30601, United States; Department of Physics and Astronomy, University of Massachusetts, Amherst, Massachusetts 01002, United States
ABSTRACT: In the heat radiation literature, the words absorptivity and emissivity have both been used in different senses. This can lead to confusion, and in one case it was argued that Kirchhoff's law of equality between emissivity and absorptivity does not apply to the radiation from a material for which the stimulated emission depends on the temperature of the environment. We clarify the proper thermodynamic definition of absorptivity (and emissivity) and show that Kirchhoff's law stated in terms of those definitions correctly predicts the results of experiments. This follows even when there are large deviations from equilibrium, or when there is nonlinear absorption or emission. 
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1976642
AFFILIATIONS: Upsala College, Chemistry Department, East Orange, New Jersey 07019, United States
ABSTRACT: We show that a great many thermodynamic potentials” may be constructed by applying the Legendre transformation to mixed-representation fundamental equations. We observe that many thermodynamic relations believed to be of special significance may be obtained simply as Maxwell equations from these various potentials. 
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DOI: 10.1119/1.1986187
AFFILIATIONS: Department of Chemistry, North Carolina State University, Raleigh, North Carolina 27607, United States
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Walther, A.
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DOI: 10.1119/1.1976608
AFFILIATIONS: Diffraction Limited*, A Division of Sanders Associates, Incorporated, 01730, Bedford, Massachusetts, United States
ABSTRACT: A quantum system in a mixed state can transfer only part of its energy to a quantum system in a pure state, if we require that the final state of the second system is once again pure. We calculate this accessible energy by constructing the optimum unitary operator that connects the initial state of the combined system with its final state. We show that for large systems such as commonly considered in thermodynamics a simple entropy argument suffices but that this method of calculation may yield results that are too large for simpler systems, owing to the constraint that the time development operator must be unitary. © 1971, American Association of Physics Teachers. All rights reserved.
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DOI: 10.1119/1.1986254
AFFILIATIONS: Department of Aerospace Engineering Sciences, University of Colorado, Boulder, Colorado, 80302, United States
ABSTRACT: The characterization of plasmas in terms of the deviations from thermodynamic equilibrium is proposed. For this characterization to be meaningful, the measurements have to be independent of the constraints on the plasma. The distinction between intensive and extensive variables and the relationship between calibration of a measuring device and the interpretation of the data in an actual experiment are brought out. Finally, the commonly used measurement techniques are examined as to their suitability to effect the characterization proposed and the limits of applicability are pointed out. © 1971, American Association of Physics Teachers
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Equivalence of the Zeroth and Second Laws of Thermodynamics
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DOI: 10.1119/1.1976703
AFFILIATIONS: Physics Department, University of Arizona, Tucson, Arizona 85721, United States
ABSTRACT: The interdependence of the zeroth and second laws of thermodynamics is demonstrated by the interrelation of conceptual perpetual motion machines that violate these laws. © 1971 American Association of Physics Teachers
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1986320

AFFILIATIONS: Department of Physics, University of Arizona, Tucson, Arizona, 85721, United States
ABSTRACT: We investigate the characteristics of a perpetual motion machine whose operation depends on a violation of the zeroth law of thermodynamics. It is found that it operates by creating work, but is necessarily a composite of at least two systems in contrast to a machine of the first kind. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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DOI: 10.1119/1.1986385
AFFILIATIONS: United States Army Electronics Command, Institute for Exploratory Research, Fort Monmouth, New Jersey, 07703, United States
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Callen, H., Horwitz, G.
22987302800;22971330900;
Relativistic Thermodynamics
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DOI: 10.1119/1.1986330
AFFILIATIONS: Department of Theoretical Physics, The Hebrew University of Jerusalem, Jerusalem, Israel
ABSTRACT: The generalization of thermodynamics to special relativity is discussed, with emphasis on the thermodynamic rather than the relativistic aspects of the problem. We demonstrate and stress the fundamental role of the enthalpy in confined systems. We agree with the generally accepted Ott conclusion that heat flux appears larger to a moving observer (but other results may be equivalent if interpreted appropriately). The transformation law of the temperature is subject to choice. The simplest relativistic generalization of thermodynamics, which we describe, leads naturally to the choice of a Lorentz invariant temperature. There are also compelling heuristic reasons for adopting this definition, which we strongly favor. However it has been conventional to couple this generalization of thermodynamics with a further generalization, adopting the center-of-mass momentum as an independent thermodynamic variable. This has led to other choices of transformation laws of heat and temperature. We believe that this second generalization is unnatural from the thermodynamic point of view, despite its apparent relativistic elegance. The center-of-mass momentum is not an appropriate thermodynamic variable. The number of microstates of a system is not dependent on its state of motion relative to an observer, so that the implied dependence of entropy on momentum is a misleading formalism. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Mcfee, R.
7004469223;
Self-Rectification in Diodes and the Second Law of Thermodnamics
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DOI: 10.1119/1.1986290
AFFILIATIONS: Department of Electrical Engineering, Sracuse University, 13210, Sracuse, New York, United States
ABSTRACT: Does a diode rectif its own thermall induced voltage fluctuations? If so, it will act like a miniature batter in violation of the second law of thermodnamics. Although earl theoretical computations indicated that self-rectifica-tion could occur, no experimental confijrmation followed.

In 1960 Van Kampen published an analsis which demonstrated that the self-rectification voltage should be zero. His analsis is reviewed here, where it is found to impl another closel related effect, not self-rectification, which could be in conflict with the second law. This hpothetical effect arises from the quantization of charge and can in Theory be seen at ver low temperatures (50 millidegrees) and small diode capacitance ( 0.01 pF). 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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AFFILIATIONS: Department of Biochemistry, University of Missouri, United States
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DOI: 10.1119/1.1976456
AFFILIATIONS: Center for Theoretical Physics, Department of Physics and Astronomy, University of Maryland, College Park, Maryland 20742, United States
ABSTRACT: When the gas of a system consisting of two volumes of ideal-gas molecules at the same temperature and pressure is allowed to mix, there is a change of thermodynamic entropy of the system if the gas molecules of the two volumes are distinguishable, and no change of thermodynamic entropy if they are indistinguishable.1 This entropy of mixing gives rise to problems, which are generally termed Gibbs5 paradox.2 In this note, we first separate out the two distinct aspects of Gibbs5 paradox. We mention a traditional and also an untraditional resolution of the first aspect and then considerably sharpen Bridgman's resolution of the second aspect. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Cheng, C.-C.
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DOI: 10.1119/1.1976548
AFFILIATIONS: Department of Physics, Northwestern College, Orange City Iowa 51041, United States
ABSTRACT: A general Born diagram has been constructed for any Legendre transformation. The general Maxwell equations are derived. Their applications are illustrated for the cases of thermodynamics, fluid dynamics, and classical mechanics. 
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1976010
AFFILIATIONS: Meteorology Division, Deseret Test Center, Fort Douglas, Utah, 84113, United States
ABSTRACT: Formulas are derived for expressing the state of polarization of thermal radiation in an axially symmetric cavity. These formulas are then used to demonstrate that thermal emission from the cavity is unpolarized when the cavity is in thermodynamic equilibrium and that any state of polarization may exist in a diathermanous medium which is enclosed by perfectly reflecting walls. It is also demonstrated that formulas which prescribe the emittance or reflectance of the cavity, neglecting polarization effects, are inherently erroneous. © 1970, American Association of Physics Teachers
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DOI: 10.1119/1.1976430
AFFILIATIONS: Department of Chemistry, University of Western Ontario, London 72, Ontario, Canada
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DOI: 10.1119/1.1976406
AFFILIATIONS: Department of Physics, The Johns Hopkins University, Baltimore, Maryland 21218, United States
ABSTRACT: The paramagnetic system discussed by Curry and Henry presents an example of isentropie curves appearing to intersect when viewed in the H-M plane. A similar example is given by liquid water near its density maximum when represented in the p-V plane. These apparent paradoxes arise because a point in a particular coordinate plane may correspond to two or more different thermodynamic states of the system. By a slight generalization of Trevor's earlier analysis, a sufficient condition is derived for choosing the (n+1) variables describing an (n+1) -degree-of-f reedom system so that each point represents a unique thermodynamic state. For a simple fluid the (T, p), (T, V), (S, p), and (S, V) representations satisfy the uniqueness condition; the widely used (p, V) and (T, S) ones do not. © 1970 American Association of Physics Teachers
DOCUMENT TYPE: Article
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Equivalents of Kelvin's and Clausius' Statements of the Second Law of Thermodynamics
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DOI: 10.1119/1.1976139
AFFILIATIONS: Northeast Utilities Service Company, Hartford, Connecticut 06101, United States
ABSTRACT: The use of physics for demographic analyses is not a form of alchemy. A brief reflection on the use of abstract structures to organize knowledge suggests a commonness to both social and physical science. Population distribution is examined using the structure of thermodynamics. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Kaplan, J.I., Stenschke, H.
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Absolutely Stable and Metastable Thermodynamic States of a Magnetic Model Exhibiting a First-Order Phase Transition
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DOI: 10.1119/1.1976087
AFFILIATIONS: Battelle Memorial Institute, Columbus, Ohio 43201, United States
ABSTRACT: The thermodynamic states of a particular magnetic model are obtained in terms of the temperature, external magnetic field, and magnetic moment. The magnetic moment plays the role of the order parameter in the usual Landau theory of phase transitions. Absolute and local minima of the free energy as a function of the order parameter (the magnetization) are obtained which correspond, respectively, to absolutely stable and metastable states of the system. 
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DOI: 10.1119/1.1976295
AFFILIATIONS: Department of Physics, University of Toronto, Toronto 181, Ontario, Canada
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DOI: 10.1119/1.1976370
AFFILIATIONS: Department of Physics, Kenyon College, Gambier, Ohio 43022, United States
ABSTRACT: Apparatus suitable for measurements of the thermoelectric power of wires in the temperature region from 77 to 300 K is described. An outline of the theoretical treatment of thermoelectric power is presented and typical results are given for aluminum, gold, and iron. This experiment has been used in the undergraduate advanced laboratory. 
DOCUMENT TYPE: Article
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Particle Identity Entropy and Maxwell-Boltzmann Counting
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DOI: 10.1119/1.1976482
AFFILIATIONS: Center for Theoretical Physics, Department of Physics and Astronomy, University ovf Maryland, Maryland, 20742, Australia
ABSTRACT: The entropy smb found from Maxwell-Boltzmann counting in classical statistical mechanics may be regarded as a sum of terms smb^8q +&ident?where SQ is the extensive entropy of thermodynamics and jSident is an entropy connected solely with the identity of particles. The failure to separate out Sident is seen to occasion one form of Gibbsts paradox. © 1970, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Benabraham, S.L.
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DOI: 10.1119/1.1976093
AFFILIATIONS: Departmento de Fisica, Institute Tecnologico de Aeronautica, C.T.A., sãn Jose dos Campos, São Paulo, Brazil
ABSTRACT: A hypothetical gas of identical spinless particles obeying r-parastatistics is dealt with. The method allows a unified treatment of both the Fermi and the Bose gases. The partition function, the equation of state, and the thermodynamic functions are simple generalizations of those for the physical quantum gases, which are included as special cases. All paragases have a Fermi energy and a Bose-Einstein condensation. A quantitative criterion of degeneracy for the physical quantum gases is proposed. The fluctuations of occupation numbers and density are also discussed. Expansions for high and low temperatures are given to third order. © 1970, American Association of Physics Teachers. All rights reserved.
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DOI: 10.1119/1.1976450
AFFILIATIONS: Joint Institute for Laboratory Astrophysics, Department of Physics and Astrophysics, University of Colorado, Boulder, Colorado, 80302, United States
ABSTRACT: The principle of detailed balancing is used in a consistent manner to derive equilibrium

distribution functions, such as the Maxwell-Boltzmann zmann and Saha-Boltzmann distributions, and the Bose-Einstein and Fermi-Dirac distributions. The same technique is then applied to matter at very high temperatures at which radiation and elementary particles are in thermodynamic equilibrium, that is, to situations postulated in supernova explosions and the early stages of an evolutionary universe. 
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1975849
AFFILIATIONS: Gannon College, Erie, Pennsylvania 16501, United States
ABSTRACT: It is shown that those molecular collisions which tend toward equalization of molecular energies also tend to maximize the phase space available to a closed system. This helps to motivate the hypothesis that a functional relationship exists between the thermodynamic entropy and the available phase space for a closed system. The calculation, simple enough for an introductory course, is also illuminating in itself as an insight into the statistical nature of the second law of thermodynamics. © 1969, American Association of Physics Teachers. All rights reserved.
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DOI: 10.1119/1.1975594
AFFILIATIONS: Department of Physics, Queen's University, Kingston, Ontario, Canada
ABSTRACT: Temperature scales and the evaluation of thermodynamic temperature for a nongaseous system are discussed, and a simple practical arrangement using a stretched wire is described. Measured thermal quantities can be compared directly with theoretical predictions based on tabulated material constants, and the phenomenon of adiabatic cooling on stretching is readily observed. © 1969, American Association of Physics Teachers. All rights reserved.
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DOI: 10.1119/1.1975223
AFFILIATIONS: Phillips University, Enid, Oklahoma 73701, United States
ABSTRACT: Student design of an “acoustic suspension” speaker system as a laboratory project is reported. The characteristics of the loudspeaker employed are measured as an extension of the inertia-balance experiment. The experiment may be diverged to a study of Helmholtz resonators, coupled oscillators, electromagnetic forces, thermodynamics, and ac-circuit theory. 
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1975192
AFFILIATIONS: Lawrence Radiation Laboratory, University of California, Livermore, California 94550, United States
ABSTRACT: An attempt is made to clarify some of the concepts concerning the interaction of magnetic fields with material bodies. The various ways of writing the equation of the first law of thermodynamics for paramagnets are derived, and apparent contradictions between them are resolved. These different expressions are also compared as to relative utility and esthetic appeal. 
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1975926
AFFILIATIONS: Department of Physics University of Denver, Denver, Colorado 80210, United States
ABSTRACT: A systematization of the mathematical formulae in thermodynamics is presented. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Zoller, P., Dillinger, J.R.
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DOI: 10.1119/1.1975659

AFFILIATIONS: Department of Physics, University of Wisconsin, Madison, Wisconsin 5S706, United States
ABSTRACT: Under the assumption that no latent heat is associated with the phase changes that occur when a superconducting ellipsoid of type I material (or type II material) enters or leaves the intermediate (or mixed) state in a constant uniform applied field, we expect finite jumps in the specific heat at constant applied field, when these phase changes occur. The jumps are related to the magnetization curves at constant temperature. 
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DOI: 10.1119/1.1975408
AFFILIATIONS: Case Western Reserve University, Department of Physics, Cleveland, Ohio 44106, United States
ABSTRACT: The canonical, grand-canonical, and constant-pressure ensembles of statistical mechanics are related to thermodynamic functions by simple canonical forms. The basic such form is [formula omitted], where [formula omitted] represents a Legendre transformation of the entropy and [formula omitted] is an appropriate partition function. This expression is of the Boltzmann form, which arises naturally in the microcanonical ensemble. The canonical structure, which is demonstrated, is pedagogically useful as (1) a memorization device, (2) an example of the utility of Legendre transformations in statistical mechanics, and (3) an aid in understanding the relationships of the various ensembles to one another. 
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DOI: 10.1119/1.1975430
AFFILIATIONS: 35 Marion Avenue, Stony Brook, Long Island, New York 11790, United States
ABSTRACT: Although Maxwell was directly involved in teaching and writing a textbook on heat theory he did not actively engage in research in this area until after he had read Gibbs' papers on thermodynamics. The stimulus of Gibbs's first two papers on the thermodynamics of homogeneous substances was such that Maxwell went beyond Gibbs and developed his own ideas on heterogeneous substances. These concepts remained unpublished, probably because they were included in Gibbs's thermodynamics later. Maxwell developed the concept that Gibbs subsequently called the potential. He also realized the importance of Gibbs's work for chemistry as well as for physics and proceeded, privately and in public to make Gibbs's work better known. Not only did he work in thermodynamics but he also stimulated colleagues at Cambridge to start research in this area, several years before Gibbs was “discovered” by Ostwald. 
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DOI: 10.1119/1.1975226

AFFILIATIONS: Department of Physics, The University of Bridgeport, Bridgeport, Connecticut 06600 and The Perkin-Elmer Corporation, Norwalk, Connecticut 06852, United States
ABSTRACT: The second law of thermodynamics is stated in the form J>'dS=J>'dQ/T = 0 for a thermodynamic system undergoing a cyclic, reversible process. It is shown that this makes it possible to construct a T-S diagram. The Clausius and Kelvin-Planek statements, as well as the properties of the Carnot engine and general statements about engine and refrigerator efficiencies, are deduced from the properties of the T-S diagram. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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DOI: 10.1119/1.1975851
AFFILIATIONS: 840 Delaware Street, Berkeley, California 94710, United States
ABSTRACT: Though used with precision, time is often called a mystery. The paradox is resolved by a theoretical conclusion: time is a general property of matter, described by the law that all isolated material changes occur (or would occur) in invariant ratios to each other. The law of time is a corollary of the first law of thermodynamics. 
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DOI: 10.1119/1.1975771
AFFILIATIONS: University of Ceylon, Peradeniya, Ceylon, Sri Lanka
ABSTRACT: A review is given of three methods of defining heat, viz., the definition using the first law of thermodynamics, the definition through heat capacities, and the definition using the ice-calorimeter. It is shown that the concept of heat and a measure for the heat absorbed by a body can be defined in all its generality only through the use of the first law. 
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DOI: 10.1119/1.1975592
AFFILIATIONS: Department of Physics, Simon Fraser University, Burnaby 2, British Columbia, Canada
ABSTRACT: The principle of increase of entropy is used to obtain the condition for mechanical equilibrium in an isolated system divided into two parts by a frictionless, weightless piston which is made of a perfectly thermally insulating material. The result emphasizes that the principle can be used to obtain the condition for mechanical equilibrium without the assumption, frequently made in the textbooks, that the mechanical equilibrium is accompanied by thermal equilibrium. 
DOCUMENT TYPE: Article

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DOI: 10.1119/1.1974977
AFFILIATIONS: Research Laboratories, General Motors Corporation, Warren, Michigan, United States
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DOI: 10.1119/1.1975159
AFFILIATIONS: Institute of Theoretical Physics, Department of Physics, Stanford University, Stanford, California 94305, United States
ABSTRACT: In elementary presentations of thermodynamics, it is sometimes stated that the second law implies that adiabatic surfaces never intersect. A simple counterexample to this statement is constructed, and some remarks are made on the sufficient conditions for the nonintersection of adiabatic surfaces. 
DOCUMENT TYPE: Article
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Thermodynamic and Statistical Aspects of Magnetic Cooling
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DOI: 10.1119/1.1974406
AFFILIATIONS: Department of Physics, Illinois Institute of Technology, Chicago, Illinois, United States
ABSTRACT: A unified account is given of the thermodynamic and statistical aspects of magnetic cooling with particular reference to adiabatic demagnetization of a paramagnetic salt. Nuclear cooling and the adiabatic magnetization of antiferromagnets and superconductors are also considered along with the related phenomena of negative temperatures and para-electric cooling. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

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Integral-Differential Equation for the Temperature-Dependent Spatial Distribution Function
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https://www.scopus.com/inward/record.uri?eid=2-s2.0-84955022589&doi=10.1119%2f1.1974517&partnerID=40&md5=6cc0676adf2594e5c12929e0e589c9f7

DOI: 10.1119/1.1974517
AFFILIATIONS: School of Engineering, Applied Science, Princeton University, Princeton, New Jersey, United States
ABSTRACT: An integral-differential equation was derived for the temperature-dependent spatial distribution function of quantum statistical thermodynamics and analytical solutions for several

quantum systems were given. It was shown that the classical and quantum-mechanical equations for the temperature-dependent spatial distribution function for a separable potential differ by one term proportional to Planck's constant squared. In several limiting cases it was found that solutions obtained from the integral-differential equation agreed with those obtained by Uhlenbeck using other methods. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Glasses, M.L., Lucas, A.A.
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Influence of Band Structure on the Thermal Properties of Metals
(1968) American Journal of Physics, 36 (5), pp. 445-450.
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DOI: 10.1119/1.1974557
AFFILIATIONS: Battelle Memorial Institute, 505 King Avenue, Columbus, Ohio 43201, United States
ABSTRACT: The assumption that a three-dimensional band structure is separable greatly simplifies the calculation of various properties of solids. In this paper this approach is demonstrated for thermodynamic properties of metals within the independent-particle model. A detailed application is made to the influence of a band gap on the temperature dependence of the magnetic susceptibility and specific heat. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

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(1968) American Journal of Physics, 36 (2), pp. 171-172.
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DOI: 10.1119/1.1974468
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Callen, H.
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Crystal Symmetry and Macroscopic Laws
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DOI: 10.1119/1.1975102
AFFILIATIONS: Department of Physics, University of Pennsylvania, Philadelphia, Pennsylvania 19104, United States
ABSTRACT: The macroscopic response of a system is often expressible by linear or bilinear laws, of the form X = x.F or X=F.x.F’. The “forces” F and “responses” X may be scalars, polar or axial vectors, or tensors. Crystal symmetry then imposes severe restrictions on the form of x. Tables of basis functions for crystallographic point groups are provided in a form which directly dictates the form of % (and which requires no knowledge or application of group theory). Various special cases, such as that presented by a complex representation, are illustrated by concrete examples. If X and F are conjugate thermodynamic variables, the crystal symmetry is augmented by thermodynamic symmetry relations. If X and F are thermodynamically conjugate dynamical variables, crystal symmetry is augmented by Onsager reciprocity. These thermodynamic cases are most conveniently treated by applying symmetry considerations to the free energy or the dissipation function respectively, as is illustrated by specific applications. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Wheatley, J.C.

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Dilute Solutions of [formula omitted]
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DOI: 10.1119/1.1974483
AFFILIATIONS: Department of Physics, University of California at San Diego, La Jolla, California 92037, United States
ABSTRACT: Properties of dilute solutions of [formula omitted] in [formula omitted] at low temperatures and their application to dilution refrigeration are discussed from a review and tutorial point of view. A comprehensive review of the properties of dilute solutions is not given. Rather, the simple physical notions underlying an understanding of their properties are discussed. Special emphasis is placed on those phenomena which are of importance in understanding the dilution refrigerator. After a review of the phase-separation phenomenon in [formula omitted] solutions, the experimental and theoretical basis for the effective interaction between [formula omitted] quasiparticles is discussed. Then the energy of the [formula omitted] quasiparticles, their chemical potential, and their dependence on the local density and velocity of the superfluid are treated. A few brief remarks on a possible superfluid transition are made. A discussion is given of the qualitative aspects of different types of dilution refrigerators: the “evaporation”-like continuous and single-cycle refrigerators and the “adiabatic expansion”-like superleak operated dilution refrigerator. Then a thermodynamic treatment of these refrigerators is given. Finally some numerical and graphical information, based on the actual properties of [formula omitted] and dilute solutions, is given to illustrate the possibilities and problems of the methods. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

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DOI: 10.1119/1.1974191
AFFILIATIONS: Department of Physics, Oberlin College, Oberlin, Ohio, United States
ABSTRACT: The problem of relating the statistical mechanics of a weakly interacting system to its macroscopic thermodynamic description is confronted. Following a brief discussion of previous solutions, a treatment exhibiting some novel features is presented first for a pure system, then with generalization to mixed systems in which combination and dissociation may or may not occur. In each case the second law, along with a small number of explicitly stated additional assumptions, is employed in the derivation of formulas for absolute temperature and entropy in terms of quantities indigenous to the statistical mechanics of the system. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Schulz, M.
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Debye Shielding and Virtual Plasma Oscillations
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DOI: 10.1119/1.1973903
AFFILIATIONS: Department of Physics and Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Massachusetts, United States
ABSTRACT: It is noted that Debye shielding between charges in a one-fluid plasma, and under certain conditions in a two-fluid plasma, can be represented formally by coupling the charges to a field of isothermal plasma oscillations. The field-theoretic calculation required in such a model would be equivalent mathematically to the coupling of point sources to a field having quanta of nonzero mass, and so the resulting potentials would have the same form, as is known to be the case in the usual

thermodynamic model for Debye shielding. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Thermodynamics, An Auto-Instructional Text
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DOI: 10.1119/1.1973762
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DOCUMENT TYPE: Article
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DOI: 10.1119/1.1973869
AFFILIATIONS: University of British Columbia, Vancouver 8, Canada
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Cowperthwaite, M., Ahrens, T.J.
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Thermodynamics of the Adiabatic Expansion of a Mixture of Two Phases
(1967) American Journal of Physics, 35 (10), pp. 951-955. Cited 6 times.
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DOI: 10.1119/1.1973649
AFFILIATIONS: Stanford Research Institute, , Menlo Park, California 94025, United States
ABSTRACT: The thermodynamics of the adiabatic expansion of a mixture of two phases capable of interchanging heat and matter across the phase boundary is presented. The law of conservation of energy is applied to each phase considered as an open system and to the mixture of phases considered as a closed system. Expressions for the entropy production resulting from internal irreversible processes demonstrate the difference between adiabatic and isentropic changes and specify conditions under which the expansion of a closed twophase system is isentropic. Three such possible isentropic processes are defined, and expressions are derived for the temperature-pressure-volume states achieved in them. The thermodynamic treatment is useful in studies of the adiabatic release of a shock-induced mixture of phases. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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DOI: 10.1119/1.1974241
AFFILIATIONS: Department of Physics, Cornell University Ithaca, New York, United States
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Tykodi, R.J.
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Thermodynamics and Classical Relativity
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DOI: 10.1119/1.1974021
AFFILIATIONS: Department of Chemistry, Southeastern Massachusetts Technological Institute North Dartmouth, Massachusetts 02747, United States
ABSTRACT: The classical principle of relativity (invariance of the laws of motion to a Galilean transformation of coordinates) with its change of viewpoint from one coordinate system to another rarely comes into question in the routine sort of thermodynamic analysis. By analysis of the Joule-Thomson porous-plug experiment under various conditions, it is shown that the standard formalism of thermodynamics is consistent with the classical relativity principle. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

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Thermocouple Corrections from Irreversibility Theory
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DOI: 10.1119/1.1973110
AFFILIATIONS: U. S. Army Mathematics Research Center, Department of Mechanical Engineering, University of Wisconsin, Madison, United States
ABSTRACT: The correction for finite impedance of thermocouple instrumentation is derived rigorously from irreversible thermodynamics. Also, the indistinguishability of Peltier and Thomson “emf's” is elucidated. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Sussman, M.V.
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DOI: 10.1119/1.1972533
AFFILIATIONS: Department of Chemical Engineering, Tufts University, Medford, Massachusetts, United States
ABSTRACT: Entropy change, work and heat effects, temperature, distribution functions, Brownian movement, and other elementary concepts of statistical thermodynamics can be visually demonstrated with a mechanical device that simulates some of the microscopic thermodynamic behavior of a nonatomic ideal gas. 
DOCUMENT TYPE: Article

PUBLICATION STAGE: Final
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Collins, R.E.
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Structure of Physical Theory
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DOI: 10.1119/1.1973076
AFFILIATIONS: University of Houston, Houston, Texas, United States
ABSTRACT: This essay begins with considerations of the relational structure of a set of variables taken to represent a conceptual universe. A plausible argument is used to establish the necessity for a statistical description of any nonstatic set of such variables. A particular statistical description is then constructed based on a partition of the set of variables into two statistically independent sets. This statistical description is then shown to yield equations formally equivalent to familiar equations of thermodynamics, quantum mechanics, and classical mechanics. This mathematical development is strongly suggestive of a unified way of looking at several divergent fields of physics. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Mundy, J.L., Newhouse, V.L.
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DOI: 10.1119/1.1972662
AFFILIATIONS: General Electric Research & Development Center, Schenectady, New York, United States
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Levitas, A.D.
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DOI: 10.1119/1.1973476
AFFILIATIONS: State University of New York at Albany, Albany, New York, United States
ABSTRACT: The problem of integrating the energy equation of thermodynamics to obtain the caloric equation of state is treated. Two integration procedures, differing in the amount of information required concerning the system isotherms, are obtained and applied to several simple systems. A necessary restriction on the functional form of the energy of a system is shown to follow from the character of the system isotherms. A unified derivation is given for three well-known equations of state. 
DOCUMENT TYPE: Article
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Innes, K.K.
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DOI: 10.1119/1.1972939

AFFILIATIONS: Vanderbilt University, Nashville, Tennessee 37203, United States
ABSTRACT: It is suggested that an electronic energy-level diagram that includes a molecule and some of its possible dissociation products on a single scale is a useful summary of widely scattered experimental results. Since such diagrams seem to be rare in both the original and the textbook literature, four illustrations are offered. These consist of some lower energy levels available to the respective atomic combinations: [formula omitted], [formula omitted], [formula omitted], and [formula omitted]. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Jossem, E.L.
22988743900;
Dialogues Concerning Some Old Sciences-The Seattle Interdisciplinary Conference
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DOI: 10.1119/1.1973602
AFFILIATIONS: The Ohio State University, Columbus, Ohio, United States
ABSTRACT: A conference to identify specific problems in areas which are of interest in instruction at the undergraduate level in two or more disciplines was held at Seattle in June 196S. The meetings were organized jointly by the commissions on college physics, chemistry, and biology and were attended by representatives of the college commissions on geology, geography, engineering, agriculture, and mathematics. The work of the conference was carried out by four subgroups which were charged with the investigation of interdisciplinary problems and opportunities in the following areas: (1) The biology-chemistry interface; molecular structure; (2) The chemistry-physics interface, macroscopic and statistical thermodynamics; (3) Quantum mechanics; (4) Interdisciplinary experimental science. Each of the groups made recommendations for future efforts in the area with which it was concerned. Ways of implementing these recommendations are under consideration by the relevant commissions. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Pau Chang, P.-C.
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DOI: 10.1119/1.1973006
AFFILIATIONS: Case Institute of Technology, Cleveland, Ohio, United States
ABSTRACT: Whaples's highly abstract proof that the zeroth law of thermodynamics leads to the existence of empirical temperature functions is paraphrased so as to make it more accessible to physicists. An understanding of Whaples's work is all the more important if one recognizes that it may be the only correct proof. 
DOCUMENT TYPE: Article
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Kalantar, A.H.
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DOI: 10.1119/1.1972338
AFFILIATIONS: Department of Chemistry, University of Alberta, Edmonton, Alberta, Canada
ABSTRACT: A number of interesting sketches of the Carnot cycle (operated as a heat engine and with an ideal gas as the working substance) are presented. Heat and work are used as the coordinates in addition to several thermodynamic variables (P, V, T, E, H, S, G, and A). The teaching value of such diagrams is stressed as some characteristics of the diagrams are pointed out. 

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Crawford, J.A.
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DOI: 10.1119/1.1972892
AFFILIATIONS: Systems Research Laboratories, Inc., Dayton, Ohio, United States
ABSTRACT: A somewhat neglected area of research in the optical properties of solids is the study of thermoluminescence. The experimental method is to measure the temperature variation of the fluorescence which results from warming a sample in the dark after excitation by some form of radiation at low temperatures. Its usefulness lies in the information it furnishes concerning defect and impurity energy levels in the band gap in semiconductors and insulators. The experimental results when combined with supplementary data (obtained with the same equipment), yield information concerning the energy distribution of trapping levels and luminescent centers in the material. The relatively small investment required for experimental equipment, the very large range of potential materials for study, and the fact that comparatively little is being done in this field all combine to make thermoluminescence a good possibility for solid-state research in the smaller colleges. © 1966, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Zemansky, M.W.
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(1966) American Journal of Physics, 34 (10), pp. 914-920. Cited 16 times.
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DOI: 10.1119/1.1972279
AFFILIATIONS: The City College, City University of New York, New York, United States
ABSTRACT: In conventional thermodynamics, the two most important consequences of the second law of thermodynamics, namely, the existence of an absolute temperature scale and the existence of an entropy function are deduced from the Kelvin-Planck statement or its equivalent, the Clausius statement, with the aid of the Carnot engine and Carnot refrigerator. In the Caratheodory method, a new statement of the second law is made; the Carnot cycle is dispensed with and purely analytical methods are used to derive the absolute temperature and the entropy. It is shown in this paper how the analytic methods of Caratheodory may be used without replacing the traditional statements of the second law by a new axiom. Both the Caratheodory statement of the second law and the Caratheodory theorem on Pfafnan differential forms are unnecessary. © 1966, American Association of Physics Teachers. All rights reserved.
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Cowperthwaite, M.
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Significance of Some Equations of State Obtained from Shock-Wave Data
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DOI: 10.1119/1.1972422
AFFILIATIONS: Stanford Research Institute, Menlo Park, California, United States
ABSTRACT: A single Hugoniot curve determined from shock-wave experiments does not provide enough thermodynamic information to specify an equation of state. The assumptions which, along with shock-wave data, are sufficient to determine a complete equation of state are instructive to a serious student of thermodynamics, because they illustrate the significance of the state variables and the

relations among them. This paper considers the specific problem of calculating the state variables of shock-induced states and discusses calculations based on the assumption of either constant Cv or constant Cp from a structural point of view. Methods of calculating the state variables are formulated to show how the assumptions make them possible. The assumption of constant Cv specifies implicitly the functional forms of the {E-p-v) and (p-vT) equations of state. Similarly, the assumption of constant Cp specifies the functional forms of the (H-p-v) and (p-v-T) equations of state. The experimental Hugoniot curve is used as a boundary condition to determine arbitrary functions in these equations of state and to show how the assumptions and the experimental data lead to a complete thermodynamic description of shock-induced states. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Offenbacher, E.L.
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Complexions of an Assembly of Quasi-Independent Localized Systems
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DOI: 10.1119/1.1971088
AFFILIATIONS: Temple University, Philadelphia, Pennsylvania, United States
ABSTRACT: The total number of complexions is computed exactly for an isolated assembly of N quasi-independent localized systems with equally-spaced energy levels. This number (N), is equal to St{Nk,} where each term depends on a particular set of energy-level occupation numbers, Nk, allowed by the energy and system-number conservation conditions. In thermodynamic calculations, the approximation is usually made of replacing by the maximum term in this sum tmax. A procedure is proposed for obtaining the exact value of tmax for integral N. The error made in the approximation is then calculated, and x = ln imax/ln? is computed for N =2r. For N=212 = 4096 one finds that (x-1) is less than 0.005. An approximate analytic form for x valid for higher N is also given. © 1965, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Arons, A.B., Peppard, M.B.
6602887669;56961074900;
Einstein's Proposal of the Photon Concept and a Translation of the Annalen der Physik Paper of 1905
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DOI: 10.1119/1.1971542
AFFILIATIONS: Amherst College, Amherst, Massachusetts, United States
ABSTRACT: Of the trio of famous papers that Albert Einstein sent to the Annalen der Physik in 1905 only the paper proposing the photon concept has been unavailable in English translation. The American Journal of Physics is publishing the following translation in recognition of the sixtieth anniversary of the appearance of the original work. Physics teachers may take particular interest in the following aspects: (1) Einstein's keen awareness of the heuristic character of his new conception. (2) His demonstration from thermodynamic and statistical considerations that electromagnetic radiation might be conceived as consisting of finite numbers of discrete corpuscles of energy hv. (3) His prediction of the linear relation between the stopping potential of photoelectrons and the frequency of the incident light. This latter aspect of the photoelectric effect was not included among Lenard's early investigations. It remained for Millikan and others to develop the elegant experimental techniques that confirmed Einstein's bold prediction. Readers interested in pursuing the background in greater depth will find it rewarding to refer to the critical analyses by Martin J. Klein in “Einstein's First Paper on Quanta,” in The Natural Philosopher (Blaisdell Publishing Company, New York, 1963), Vol. II, and “Einstein and the Wave-Particle Duality,” in The Natural Philosopher, Vol. III, 1964. We are grateful to Professor Klein for his criticism and advice regarding this translation and for his generosity in making available to us an unpublished translation of his own. © 1965, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
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Van Rysselberghe, P., Hinrichs, C.H.
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AFFILIATIONS: Washington State University, United States
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DOI: 10.1119/1.1971382
AFFILIATIONS: University of Oregon, Eugene, Oregon, United States
ABSTRACT: A proof of the second law of thermodynamics is given, starting from elementary quantum mechanics. The theorem proved states that, for a macroscopic body, the state of thermal equilibrium has a larger entropy than any other possible state which is subject to the same external constraints and has the same total energy. 
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1971075
AFFILIATIONS: University of Pennsylvania, Philadelphia, Pennsylvania 19104, United States
ABSTRACT: The general theory of thermodynamic fluctuations in canonical ensembles is derived in a simple and exact form in terms of the semiinvariants (or “cumulants”) of the distribution. 
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DOI: 10.1119/1.1971557
AFFILIATIONS: Department of Physics, Washington University, St. Louis, Missouri, United States
ABSTRACT: The status of the Gibbs and Boltzmann expressions for entropy has been a matter of some confusion in the literature. We show that: (1) the Gibbs H function yields the correct entropy as defined in phenomenological thermodynamics; (2) the Boltzmann H yields an “entropy” that is in error by a nonnegligible amount whenever interparticle forces affect thermodynamic properties; (3) Boltzmann's other interpretation of entropy, [formula omitted], is consistent with the Gibbs H, and derivable from it; (4) the Boltzmann H theorem does not constitute a demonstration of the second law for dilute gases; (5) the dynamical invariance of the Gibbs H gives a simple proof of the second law for arbitrary interparticle forces; (6) the second law is a special case of a general requirement for any macroscopic process to be experimentally reproducible. Finally, the “anthropomorphic” nature of

entropy, on both the statistical and phenomenological levels, is stressed. 
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DOI: 10.1119/1.1970989
AFFILIATIONS: School of General Studies, Australian National University, Canberra, Australia
ABSTRACT: A teaching experiment based on a commercial thermoelectric heat pump which utilizes semiconductor materials is described. The measurements made yield the figure of merit for the thermocouple as well as its coefficient of performance as a pump. © 1965, American Association of Physics Teachers. All rights reserved.
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AFFILIATIONS: Lehigh University, United States
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DOI: 10.1119/1.1970890
AFFILIATIONS: California State Polytechnic College, Kellogg-Voorhis Campus, Pomona, California, United States
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DOI: 10.1119/1.1970877
AFFILIATIONS: 28 Lee Street, Cambridge, Massachusetts, United States
ABSTRACT: It is shown that the sign of a magnetic monopole can be given an absolute significance, and not merely a relative significance. This is a consequence of the following three properties of our universe: (a) the existence of electromagnetism, (b) the existence of parity nonconserving weak interactions, and (c) the nonsymmetry with respect to the two directions of time which is manifest in the second law of thermodynamics and the expansion of the universe. 
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DOI: 10.1119/1.1970898
AFFILIATIONS: Berkeley Astronomical Department, University of California, Berkeley, California, United States
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DOI: 10.1119/1.1970883
AFFILIATIONS: Physics Department, Columbia University, New York, United States
ABSTRACT: This paper presents relatively unknown, though not new, theorems applicable to a real axially symmetrical optical system. It treats the situation where rays leaving a particular axial object point 0 in object space are assumed to image perfectly at axial image point 0’. A ray through 0 at angle a with the axis passes through 0’ at angle a’ with the axis. The Abbe and Herschel conditions state the required functional relationship between a and a’ to ensure that rays from P image perfectly into P’, when P is infinitesimally displaced from 0 perpendicular to, or parallel to the axis, respectively. The formulas derived here give the detailed variation of 1, 2, and in terms of the functional relation between a and a’, independent of the further specification of the system. They are derived using Fermat's theorem and the second law of thermodynamics. Here 1, 2, and represent, respectively, the meridional (primary) lateral magnification, the sagittal (secondary) lateral magnification, and the longitudinal magnification relative to small displacements from 0. The variation of 1 and 2 with a specifies the coma figure, while the variation of y gives the

longitudinal spherical aberration for an axially displaced object point. © 1964, American Association of Physics Teachers. All rights reserved.
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DOI: 10.1119/1.1969861
AFFILIATIONS: Department of Chemistry, Princeton University, Princeton, New Jersey, United States
ABSTRACT: In the usual development of quantum statistical mechanics the microcanonical ensemble is introduced in order to present the basic postulates of this subject with utmost clarity. However practical calculations of elementary problems using the microcanonical ensemble directly are seldom carried out. Either the method of the most probable distribution is introduced, or the canonical ensemble is introduced. Both of these methods require the development of further mathematical and physical concepts. It is shown here that very elementary methods can be used to develop the thermodynamic properties of monatomic crystals and the “corrected” Boltzmann monatomic gas directly from the basic concepts of the microcanonical ensemble. For more complex problems, it is shown that the microcanonical ensemble emphasizes the relation between basic concepts in statistical mechanics and certain unsolved problems in the theory of numbers. © 1964, American Association of Physics Teachers. All rights reserved.
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DOI: 10.1119/1.1969887
AFFILIATIONS: Depertment of Physics, Lake Forest College, Lake Forest, Illinois, United States
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DOI: 10.1119/1.1970014
AFFILIATIONS: The William Marsh Rice University, Houston, Texas 77001, United States
ABSTRACT: In developing the ensemble theory of statistical mechanics, the thermodynamic temperature T, can be introduced in a direct manner avoiding the intermediate use of a Lagrange multiplier, if one adopts the Gibbs entropy postulate and uses a general criterion for thermodynamic equilibrium. This procedure is described in detail for both closed and open systems. © 1964, American Association of Physics Teachers. All rights reserved.
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DOI: 10.1119/1.1969860
AFFILIATIONS: Department of Physics, Arizona State University, Tempe, Arizona 85281, United States
ABSTRACT: The energy levels of a one-dimensional quantum system of hard lines are obtained exactly and the resulting thermodynamic properties are evaluated by means of the grand partition function. No phase transitions occur. At high temperatures the thermodynamic properties of this system reduce to the well-known results for a classical system of hard lines. © 1964, American Association of Physics Teachers. All rights reserved.
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Thomsen, J.S.
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DOI: 10.1119/1.1970933
AFFILIATIONS: Department of Physics, Johns Hopkins University, Baltimore, Maryland, United States
ABSTRACT: A simple, concise method is presented for deriving any desired thermodynamic first derivative in terms of a minimal basic set. The method is given in detail for a two-degree-of-freedom system, specifically a homogeneous fluid. The variables involved, including thermodynamic potentials, are briefly reviewed and the Maxwell relations derived. Differentials of all variables are expressed in terms of those of p and T with the use of a basic set of three partial derivatives. A four-step method is then stated for deriving any desired first derivative from these expressions; three examples are presented as illustrations. The Jacobian formalism is given for comparison at appropriate points, but not otherwise used. Finally, a natural, straightforward extension of the method to an iV-degree-of-freedom system is outlined. © 1964, American Association of Physics Teachers. All rights reserved.
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DOI: 10.1119/1.1970148
AFFILIATIONS: Physics Department, Utica College of Syracuse University, Utica, New York 13502, United States
ABSTRACT: A number of problems connected with the use of semipermeable membrane in thermodynamics including the Gibbs paradox are discussed from logical and physical points of view. © 1964, American Association of Physics Teachers. All rights reserved.
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DOI: 10.1119/1.1970334
AFFILIATIONS: Cornell University, Ithaca, New York, United States
ABSTRACT: Information is quantitatively defined in terms of probability, and the statistical interpretation of entropy is given. Entropy change and information are shown to be related on a

physical basis, treating a simple volume expansion as an example. Maxwell's demon is discussed as an example of an irreversible process. The argument used by Brillouin in his discussion of the demon is corrected. A generalized second law of thermodynamics is set forth. © 1964, American Association of Physics Teachers. All rights reserved.
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DOI: 10.1119/1.1970760
AFFILIATIONS: Berkeley Astronomical Department, University of California, Berkeley, California, United States
ABSTRACT: Thermodynamical properties of a gaseous mixture undergoing dissociation or ionization, or both, have been considered in a general way. As a special case, the behavior of ionizing hydrogen gas has been studied. It is found that a perfect gas behaves as an imperfect gas in many ways, when undergoing dissociation or ionization. © 1964, American Association of Physics Teachers. All rights reserved.
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AFFILIATIONS: Division of Engineering, Brown University, Providence, Rhode, United States
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DOI: 10.1119/1.1969507
AFFILIATIONS: Department of Physics, Oberlin College, Oberlin, Ohio, United States
ABSTRACT: The First and Second Laws of Thermodynamics are used directly to investigate the internal energy and specific heats of a gas for which only Boyle's law is assumed to hold. The behavior of these quantities is found to be intimately linked with the relation between the absolute thermodynamic temperature scale and a temperature scale defined in terms of the pressure-volume product for one mole of the gas. It is deduced that the difference Cp Cv of specific heats can be at most a function of temperature alone. © 1963, American Association of Physics Teachers. All rights reserved.
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DOI: 10.1119/1.1969234
AFFILIATIONS: Institute of Atmospheric Physics, The University of Arizona, Tucson, Arizona, United States
ABSTRACT: In the absence of foreign nucleants, phase transition from vapor to liquid is blocked by a free-energy barrier implicit in the appearance of new surface when embryos of the new phase start to form. Drawing upon thermodynamic relationships discussed in Part I, Part II here summarizes the kinetics of the homogeneous nucleation process for the case of the vapor-to-liquid phase transition. Emphasis is placed upon physical interpretation of the mathematical model used to obtain a nucleation rate equation for the unbalanced steady-state case. 
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DOI: 10.1119/1.1969606
AFFILIATIONS: The St. Lawrence University, Canton, New York, United States

ABSTRACT: The heat Q2 exchanged with the high-temperature reservoir and the heat Q1 exchanged with the low-temperature reservoir identify each Carnot cycle with a single point on the heat exchange plane, the Q2-Q1 plane. The axes and the zero work line divide this plane into half-planes whose physical interpretation is described with the aid of the laws of thermodynamics. 
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AFFILIATIONS: Texas A & M University, Texas, United States
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DOI: 10.1119/1.1969535
AFFILIATIONS: University of British Columbia, Vancouver, B. C., Canada
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DOI: 10.1119/1.1969067
AFFILIATIONS: Dartmouth College, Hanover, New Hampshire, Germany
ABSTRACT: The generality of Carthéodory's treatment can be retained if one considers a composite system whose state is defined by only three variables. Carathéodory's axiomatic approach is rendered less abstract by discussing a specific system, and by supplementing a purely analytic treatment with appropriate diagrams. 
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DOI: 10.1119/1.1941810
AFFILIATIONS: Argonne National Laboratory, Argonne, Illinois, United States
ABSTRACT: The zeroth law of thermodynamics is shown to be a consequence of the absence of appreciable long-range forces between different portions of bodies of the kind usually under consideration in thermodynamic discussion. Revisions of the arguments given in an earlier paper are suggested in order to meet objections raised by Thomsen. © 1962, American Association of Physics Teachers. All rights reserved.
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DOI: 10.1119/1.1941963
AFFILIATIONS: Washington University, St. Louis, Missouri, United States
ABSTRACT: If we are to improve the preparation of physics majors, in keeping with the needs of the times and with the improved preparation that students in increasing numbers will be bringing from their high schools, we must decide on what parts of physics are most important. It is suggested that our courses must pay greater attention to phenomena and less to mathematical formalism. Specific suggestions about the ways in which courses in mechanics, electricity and magnetism, optics, atomic and nuclear physics, and thermodynamics can be modified to accomplish this are given. © 1962, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Mcdonald, J.E.
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DOI: 10.1119/1.1941841
AFFILIATIONS: Institute of Atmospheric Physics, The University of Arizona, Tuczon, Arizona, United States
ABSTRACT: In absence of all foreign materials or wall surfaces, phase transitions of the type vapor-to-liquid or liquid-to-solid are blocked by an activation-free-energy barrier. The latter arises from surface-free energy increases resulting from appearance of embryos of the more condensed phase. The thermodynamics of this type of phase transition are examined in Part I for the particular case of vapor condensation, a case for which theory and experiment now stand in tolerably good agreement. In Part II, kinetic aspects will be considered. © 1962, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article

PUBLICATION STAGE: Final
SOURCE: Scopus

Bridgman, P.W., Page, T.
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DOI: 10.1119/1.1941910
AFFILIATIONS: Wesleyan University, United States
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Swalin, R.A., King, A.L.
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Thermodynamics of Solids
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DOI: 10.1119/1.1941797
AFFILIATIONS: Dartmouth College, United States
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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AFFILIATIONS: Dartmouth College, United States
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DOI: 10.1119/1.1942006
AFFILIATIONS: Wesleyan University, United States
DOCUMENT TYPE: Article
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Santarelli, V.
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Elementary But Exact Treatment of a Dipole Ring
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DOI: 10.1119/1.1941930
AFFILIATIONS: Rutgers University, Newark, New Jersey, United States

ABSTRACT: The partition function of a ring of dipoles interacting only in pairs is derived in an elementary manner. The resulting exact expression is used to derive the thermodynamic behavior at very high and low temperatures. It is shown that an even number of antiferromagnetic dipoles is thermodynamically equivalent to any number of ferromagnetic dipoles at all temperatures as far as the average energy and entropy are concerned. 
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PUBLICATION STAGE: Final
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DOI: 10.1119/1.1941775
AFFILIATIONS: University of Nevada, Reno, Nevada, United States
ABSTRACT: The concepts of cavity potential (electrostatic potential in a cavity in a conductor) and Fermi potential (energy per unit charge for an electron at the Fermi level) are defined and used to discuss the work function, contact potentials, Ohmâ  s law, electrode-solution equilibria, and chemical emfâ  s. With the introduction of the entropy transport per unit charge for electrons in a metal (S*), the Seebeck, Peltier, and Thomson effects are elucidated, and the fact that no emf exists at a thermal junction is made clear. Certain other common confusions are cleared up. It is suggested that use of this conceptual scheme will allow the basic physics of these important processes to be taught effectively in general physics courses. 
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1941993
AFFILIATIONS: Allen Strickler Company, Fullerton, California, United States
ABSTRACT: The thermosensitive double iodide of mercury and silver (HgI2.2AgI), which changes reversibly from yellow to red on heating, is made the basis of a thermal imaging medium permitting new, vivid demonstrations of many heat phenomena. The sensitive pigment is coated on a thin insulating sheet such as cardboard. The back of the sheet may be variously coated with black, metallic, and electrically conductive areas to absorb, reflect, or inject heat in recognizable patterns. Images are produced by friction, conductive heat transfer, convective heat flow, infrared absorption and reradiation, focusing and shadow casting with infrared rays, electrical heating and evaporative cooling. 
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DOI: 10.1119/1.1941991
AFFILIATIONS: Mechanics Department, Johns Hopkins University, Baltimore 18, Maryland, United States
ABSTRACT: Turner's proof of the Zeroth law as a consequence of the second law is examined and two criticisms are noted. It is also pointed out that most conventional statements of the Zeroth law do not necessarily imply that temperature is a scalar. A new formulation is given and two corollaries

are stated; one of these is the usual form of the Zeroth law. The restrictions thus imposed on permissible temperature scales are briefly discussed. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Zimmerman, E.J.
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The Macroscopic Nature of Space-Time
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DOI: 10.1119/1.1941954
AFFILIATIONS: Department of Physics, University of Nebraska, Lincoln, Nebraska, United States
ABSTRACT: Current interpretations of quantum mechanics suggest that the classical concepts of space and time are not applicable to microscopic systems. Salecker and Wigner have recently proved that these concepts have no operational meaning for microsystems. Therefore, space-time descriptions may be valid only for macroscopic systems. It is here suggested that space and time themselves arise from, but do not have analogs in, the properties of microscopic particles, in the same way that thermodynamic properties arise as a result of interactions among the many actually existing particles of the universe. Neither the particles nor the interactions need to be described in spatial-temporal terms. This macroscopic interpretation of space-time seems compatible with the known properties of the physical world, suggests a more direct interpretation of the statistical nature of microscopic events, and offers a new approach to some physical problems. © 1962, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Heikes, R.R., Ure, R.W., Jr., Mullin, A.A.
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Thermoelectricity: Science and Engineering
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DOI: 10.1119/1.1941916
AFFILIATIONS: University of Illinois, United States
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Schamp, H.W., Jr.
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DOI: 10.1119/1.1941816
AFFILIATIONS: Institute for Molecular Physics, University of Maryland, College Park, Maryland, United States
ABSTRACT: It is pointed out that several conclusions ordinarily treated as being based on both the first and second laws of thermodynamics are actually dependent only on the second law. These include the efficiency of engines working between two heat reservoirs, an absolute thermometric scale, and the Clapeyron equation. © 1962, American Association of Physics Teachers. All rights reserved.
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Turner, L.A.
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Simplification of Carathodory's Treatment of Thermodynamics. II

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DOI: 10.1119/1.1942085
AFFILIATIONS: Argonne National Laboratory, Argonne, Illinois, United States
ABSTRACT: The simplified treatment can be based on the assumptions as to continuity made by Carathodory. Although Landsberg is correct that the general conclusion that the change of entropy must always have the same sign involves a further unstated assumption, it does follow without further assumption that the change of entropy must have the same sign in all adiabatic changes away from initial states having the same entropy. The results for ordinary systems, however, remain the same. 
DOCUMENT TYPE: Article
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Carroll, P.J., Jr., Kyame, J.J.
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Matrix Representation of Thermodynamics of Multicomponent Systems
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DOI: 10.1119/1.1941989
AFFILIATIONS: Tulane University, New Orleans, Louisiana, United States
ABSTRACT: The extension of a matrix representation for the thermodynamics of a multicomponent system is demonstrated. Specific applications of these matrices are made to stability conditions and phase transitions. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Thomsen, J.S., Hartka, T.J.
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DOI: 10.1119/1.1941890
AFFILIATIONS: Mechanics Department, Johns Hopkins University, Baltimore 18, Maryland, United States
ABSTRACT: Sommerfeld has given an apparent case of a perpetual motion machine of the second kind. This consists of a Carnot engine employing liquid water and operating between the normal and anomalous regions of thermal expansion. His explanation of the paradox is shown to be incomplete when the temperature of maximum density is pressure-dependent. To analyze this case a simple thermodynamic model for a substance with a density extremum is given; this model yields a reasonable approximation to the data for water. Standard thermodynamic properties of the system are computed and useful approximate forms given. Various Carnot cycles and a non-trivial â two-processâ cycle are then shown in the pâ T, Tâ s, and pâ v planes. Sommerfeldâ s paradox is resolved by showing that a Carnot cycle qualitatively similar to that in his problem involves expansions for both isothermal processes. Theoretical implications of the analysis and applications to sound waves and shock waves are briefly discussed. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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DOI: 10.1119/1.1942021
AFFILIATIONS: Research-Cottrell, Incorporated, Bound Brook, New Jersey, United States

ABSTRACT: The electric wind was one of the earliest manifestations of the gaseous discharge to have been discovered and a subject of active investigation among electrical experimenters of the eighteenth and nineteenth centuries. Today, after a period of relative neglect, interest in this phenomenon has been revived. Recent publications consider the practicability of applying the wind mechanism to fluid pumps, high-voltage generators, loudspeakers, thermoelectric converters, and other devices. The historical background of the electric wind from the earliest times is presented here together with a selected bibliography. 
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DOI: 10.1119/1.1937635
AFFILIATIONS: The City College of New York, New York 10, New York, United States
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1937686
AFFILIATIONS: University of Rochester, Rochester, New York, United States
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DOI: 10.1119/1.1937792
AFFILIATIONS: Northwestern University, Evanston, Illinois, United States
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DOI: 10.1119/1.1937689
AFFILIATIONS: Division of Pure Physics, National Research Council, Ottawa, Ontario, Canada
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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DOI: 10.1119/1.1937843
AFFILIATIONS: Lehigh University, United States
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DOI: 10.1119/1.1937699
AFFILIATIONS: Argonne National Laboratory, Argonne, Illinois, United States
ABSTRACT: The following is shown with respect to the zeroth law of thermodynamics. (1) Planckâ s argument that it follows from a general theorem concerning establishment of thermal equilibrium among numerous bodies does not appear to be conclusive. (2) The zeroth law is a consequence of the first and second laws in classical thermodynamics and need not, therefore, be considered as a separate assumption or law. (3) The zeroth law must be assumed as supplementary to the second axiom in CarathÃ©odoryâ s theory, as CarathÃ©odory did, if one wishes to adhere to that axiom precisely as he gave it. If, however, the axiom be amplified slightly in a natural way, the zeroth law can be derived as a consequence. © 1961, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
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A Useful Thermodynamic Diagram
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DOI: 10.1119/1.1937556
AFFILIATIONS: Glarkson College of Technology, Potsdam, New York, United States
ABSTRACT: Using the equations for the efficiency of a heat engine and the coefficient of performance of a refrigerator, it is shown that a diagram constructed of straight lines can express the heat flows, efficiencies, COP‘s, and work terms of such devices. The diagram may also be used for Carnot-type machines when temperatures of the heat sources and sinks are given. A hypothetical system is shown in schematic and plotted on the diagram. © 1961, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1937668
AFFILIATIONS: Argonne National Laboratory, Argonne, Illinois, United States
ABSTRACT: It is shown that Buchdahl's treatment involves a tacit extension of CarathÃ©odory's second axiom, that if such extension be made the zeroth law becomes a consequence of the other basic assumptions, and that Buchdahl's parameter s, the empirical entropy for a system, is the same as x0,

the nondeformation coordinate of a simple system related to the system in question. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Thomsen, J.S.
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Operational Formulation of the Second Law of Thermodynamics
(1961) American Journal of Physics, 29 (5), pp. 300-307. Cited 3 times.
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DOI: 10.1119/1.1937756
AFFILIATIONS: Mechanics Department, The Johns Hopkins University, Baltimore, Maryland, United States
ABSTRACT: Various forms of the second law are discussed from the viewpoint of what is necessary to provide a direct experimental proof of the postulates. A new formulation is presented in the form of three axioms, not involving the usual notions of quasi-static processes and cyclic engines on the one hand or adiabatic inaccessibility on the other. Definitions of absolute temperature and entropy are given, and necessary theorems proved in order to derive the usual thermodynamic results. The method is shown to be substantially equivalent to the usual ones; the advantages of the various formulations are discussed. It is noted that the concept of absolute temperature may be derived from a weaker postulate than the second law. 
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Michener, W.H.
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Apparatus Review: Thermoelectric Generator
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DOI: 10.1119/1.1937741
AFFILIATIONS: Allegheny College, Meadville, Pennsylvania, United States
ABSTRACT: A review written at the request of the Committee on Apparatus of the AAPT. 
DOCUMENT TYPE: Article
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Gross, E.T.B.
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DOI: 10.1119/1.1937584
AFFILIATIONS: Illinois Institute of Technology, Chicago, Illinois, United States
ABSTRACT: The known expressions for various efficiencies of thermoelectric energy converters can be so modified that the Carnot efficiency ?c of the ideal heat engine cycle appears as one of two significant parameters. The other parameter ZT (Z = figure of merit, T = hot spot temperature in K) is a significant characteristic of the thermoelectric material used in the device. Using these parameters leads to a realistic evaluation of presently possible efficiencies under ideal conditions. 
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DOI: 10.1119/1.1986484
AFFILIATIONS: Physics, Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Massachusetts, United States
ABSTRACT: Observations of the radio-frequency emission from extraterrestrial plasmas and plasmas produced in the laboratory are described, and various attempts at interpretation of the results are reviewed. Estimates are made of the probable loss of radiant energy from plasmas in proposed thermonuclear reactors. 
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DOI: 10.1119/1.1937760
AFFILIATIONS: 88 Central Park West, New York 23, New York, United States
ABSTRACT: A short summary of the two principles of thermodynamics, together with the statistical interpretation of entropy, is given. It is shown that the definition of â  informationâ  leads to a direct connection between information and the negative of entropy (abbreviated: negentropy). Every experiment consumes negentropy (increases entropy) and yields information. The negentropy principle of information is a generalization of Carnot's principle, and is explained on different examples. The informational value of physical laws is discussed and the role of creative thinking emphasized. 
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DOI: 10.1119/1.1935945
AFFILIATIONS: Harvard University, United States
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Armstrong, H.L.
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DOI: 10.1119/1.1935934
AFFILIATIONS: Queen's University, Kingston, Ontario, Canada
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Weber, R.L.
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DOI: 10.1119/1.1935825
AFFILIATIONS: Pennsylvania State University, United States
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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DOI: 10.1119/1.1935105
AFFILIATIONS: Corpus Christi College, Cambridge, United Kingdom
ABSTRACT: The possibility of extracting energy in a controlled manner from the nuclei of deuterium holds out the hope of a permanent solution of the problem of the supply of energy. It involves heating the gas to temperatures in the 100-million degree range. The outstanding difficulty is to prevent the heat escaping. Inevitable loss by radiation can be accepted. Loss by conduction must be greatly reduced. This means using magnetic fields. Among the methods that have been tried to contain a plasma, three are: the pinch discharge in which a large current is passed through the rarified deuterium in a torus; containment by magnetic mirrors in which the diamagnetic character of the plasma is used to exclude it from regions of high magnetic field; Spitzer's stellerator in which gas is contained by re-entrant lines of force due to currents outside the vessel which holds it. Difficulties arise in all cases; for the pinch discharge and to some extent the stellerator, these are due to some of the many forms of instability which can affect plasma in magnetic fields; for the magnetic mirrors to the poor containment at relatively low temperatures and to difficulties of injection. No method has yet been successful, but all these are very hopeful. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Armstrong, H.L.
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Statement of the Second Law of Thermodynamics
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DOI: 10.1119/1.1935889
AFFILIATIONS: Queen's University Kingston, Ontario, Canada
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Visiting Foreign Staff Project (V.F.S.P.) at Temple University
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DOI: 10.1119/1.1935098
AFFILIATIONS: Temple University, Philadelphia 22, Pennsylvania, United States
ABSTRACT: We describe the National Science Foundation supported V.F.S.P. for institutes for secondary school teachers of science and mathematics, conducted for the first time in the summer of 1959. The need for the program stems both from the international nature of science itself and from the lag in our present secondary school science education. It is emphasized that lectures on recent advances in physics can be made more effective by organized programs such as the V.F.S.P. A briefing session is most important. Highlights of the visits' evaluation are followed by an introduction to the twelve papers constituting the heart of the project report. The fields of physics included are

thermodynamics and molecular physics, low and high energy nuclear physics, thermonuclear physics, cosmic rays, three topics in solid state physics and metallurgical physics. 
DOCUMENT TYPE: Article
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Parsegian, V.L.
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DOI: 10.1119/1.1935078
AFFILIATIONS: Rensselaer Polytechnic Institute, Troy, New York, United States
ABSTRACT: It has been said that engineering education has been overspecialized, compartmentalized, and insufficiently founded on fundamentals, not only with respect to engineering courses but equally in the basic science courses. Improvements are being attempted through reorganization and integration of engineering science materials, given as common courses in categories such as thermodynamics, fluid mechanics, materials and solid state, etc. Science courses must also eliminate compartmental thinking. Students need more than the elements and concepts of basic science in a limited frame of reference; they must achieve quantitative understanding of the interrelationship and underlying unity of the laws of nature, through a wide range of natural phenomena. Transition and translation from micro to engineering macro realms, from physical to chemical to biological phenomena, must be made meaningful in a quantitative sense. The role of physics is not to teach engineering mechanics or electrical circuitry, but the phenomena that underlie and introduce these effectively. There is particular need to stress and to take examples from atomic systems as far as possible, even with freshman physics. 
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1935074
AFFILIATIONS: Johns Hopkins University, Baltimore 18, Maryland, United States
ABSTRACT: Quasi-static processes are not reversible when sliding friction forces are present. An example is considered consisting of a cylinder containing a gas and equipped with a piston for which sliding friction forces are significant. It is assumed that the frictional force may be a function of temperature, displacement, and direction of motion. From measurements on the boundary of the system it is then possible to determine energy as a function of temperature and volume. However, force and entropy are not uniquely determined although thermodynamic considerations impose severe restrictions on the possible choice of these quantities. The generalized definition of entropy proposed by Bridgman is discussed in light of these conclusions. The possible analogy between this model and a perfectly plastic material is briefly discussed. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Christy, R.W.
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DOI: 10.1119/1.1935837
AFFILIATIONS: Dartmouth College, Hanover, New Hampshire, United States

ABSTRACT: Many of the most interesting mechanical and electrical properties of solids, especially at high temperatures or after radiation damage, depend on the presence of point defectsinter-stitials and vacanciesin the crystal lattice. Ionic crystals are especially suited for the study of these defects, because in them the defects are electrically charged. The ionic conductivity mechanism is reviewed, with reference to the information it yields about the properties of the defects. Recently, further information about the defects has been derived from the thermo-electric power (Seebeck effect), and these new developments are summarized. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Buchdahl, H.A.
6701858066;
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DOI: 10.1119/1.1935102
AFFILIATIONS: Department of Physics, University of Tasmania, Australia
ABSTRACT: This paper, which is itself in the nature of an abstract, discusses how one can gain an understanding of the basic concepts of classical (phenomenological) thermodynamics, using virtually no mathematics at all, and without the introduction of the usual artifices such as abstract engines, cycles, perfect gases, and so on. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Alfv n, H.
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(1960) American Journal of Physics, 28 (7), pp. 613-618. Cited 2 times.
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DOI: 10.1119/1.1935919
AFFILIATIONS: The Royal Institute of Technology, Stockholm, Sweden
ABSTRACT: A review is given of the development in the field of cosmical electrodynamics. It is mentioned that the great interest in thermonuclear research has produced a considerable progress in plasma physics. This is of astrophysical interest because it is now possible to check the theories of a plasma by experiment. As an example, a recent experiment in a “homopolar” machine is discussed, and its importance to the theory of the origin of the solar system is emphasized. Conclusions about the origin of the solar system are drawn. In particular, the mechanism by which Saturn's ring has been produced is discussed. It is further pointed out that the moon probably was born as a planet later captured by the earth. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Flnfgeld, C., Machlup, S.
57069075700;21934025900;
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DOI: 10.1119/1.1935796
AFFILIATIONS: Western Reserve University, Cleveland, Ohio, United States
ABSTRACT: Further analysis is presented of a thought experiment due to Raymond, which permits an apparent violation of the second law of thermodynamics (the conversion of heat into work by a cyclic process), utilizing spontaneous fluctuations, and supplying the negentropy in the form of information obtained by counting. The thermodynamic efficiency of the heat engine itself is unity; considering the engine and counting demon together preserves the sanctity of the second law. An expression is

derived for the power delivered by the engine, and the maximum value of this expression is studied as a function of the various parameters. © 1960, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Lucke, W.H.
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(1960) American Journal of Physics, 28 (6), pp. 563-564. Cited 2 times.
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DOI: 10.1119/1.1935888
AFFILIATIONS: V. S. Naval Research Laboratory, Washington 25, D. C, United States
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Miller, D.G., Dennis, W.
7407280911;35127133500;
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DOI: 10.1119/1.1936005
AFFILIATIONS: Department of Chemistry and Department of Physiology, University of Louisville, Louisville, Kentucky, United States
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Turner, L.A.
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Simplification of Caratheodory's Treatment of Thermodynamics
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DOI: 10.1119/1.1936001
AFFILIATIONS: Argonne National Laboratory, Argonne, Illinois, United States
ABSTRACT: A simplified development of Caratheodory's thermodynamics, which obviates the principal mathematical complications of the original paper, is presented. A sketch of Caratheodory's treatment is given in an Appendix. © 1960, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Carroll, C.W.
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Systematic Approach to the Calculation of Thermodynamic Transforms
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DOI: 10.1119/1.1934840
AFFILIATIONS: The Institute of Paper Chemistry, Appleton, Wisconsin, United States
ABSTRACT: In thermodynamics, transformation of intangible partial derivatives (for single-phase, constant-mass systems) into an experimentally measurable or easily calculable form is often necessary. Appropriate transformations may be systematically and efficiently derived by employing a minimum of basic thermodynamic concepts and applying selected mathematical techniques (including a limited use of Jacobians). It is hoped that the particular approach suggested will help students avoid gross memorization and artificial mnemonic or tabular schemes. In so doing, greater familiarity

should be developed with the thermodynamic and mathematical interrelationships involved. 
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PUBLICATION STAGE: Final
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Brennan, W.D.
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DOI: 10.1119/1.1934889
AFFILIATIONS: Armour Research Foundation, Illinois Institute of Technology, Chicago, Illinois, United States
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Seeger, R.J.
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On Teaching Thermophysics
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DOI: 10.1119/1.1996115
AFFILIATIONS: National Science Foundation, Washington, D. C., United States
ABSTRACT: The objectives of all thermodynamics courses, both graduate and undergraduate, need to be clarified. There is a need to treat introductory thermodynamics as physics in relation to other branches of physics, and not just to heat. It should be taught (1) from an operational point of view with respect to the world of physical phenomena, (2) with an emphasis upon the use of mathematics with respect to the world of physical concepts, and (3) with a concern for philosophical interpretations with respect to the world of physical theory. 
DOCUMENT TYPE: Article
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Creutz, E.
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DOI: 10.1119/1.1934738
AFFILIATIONS: General Dynamics Corporation, United States
DOCUMENT TYPE: Article
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Band, W.
23000366400;
New Look at von Neumann's Operator Method in Quantum Statistics. II
(1958) American Journal of Physics, 26 (8), pp. 540-548.
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DOI: 10.1119/1.1934680
AFFILIATIONS: Washington State College, Pullman, Washington, United States
ABSTRACT: In this second part of the paper, the quantum-mechanical equation of change with time is applied to an ensemble, and the quantum-mechanical analog of the classical Liouville theorem is derived. The conflict between the quantum-mechanical equation of change of an isolated system, and

the second law of thermodynamics is explained. The connection between entropy and the uncertainty principle and the effect of measurement on entropy are discussed in detail. It is pointed out that in quantum mechanics, the uncertainty principle forbids the complete specification of the boundaries of a truly isolated system. The effects of random disturbances at the boundary, within the limits permitted by the uncertainty principle, are shown to cause a rapid spontaneous approach to maximum entropy of any “isolated” system. Applications to quasi-stationary irreversible effects are briefly discussed, and it is indicated how the concept of random fluctuations of the boundary leads to a deduction of the Fokker-Planck equation for irreversible processes. 
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DOI: 10.1119/1.1934711
AFFILIATIONS: University of Nebraska, United States
DOCUMENT TYPE: Article
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Wilson, A.H., Green, M.S.
55458789300;35616230700;
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DOI: 10.1119/1.1934712
AFFILIATIONS: National Bureau of Standards, United States
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Noon, J.H., O'Brien, B.J.
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Sophomore Experiment in Thermoelectricity
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DOI: 10.1119/1.1996162
AFFILIATIONS: University of Sydney, Sydney, Australia
ABSTRACT: A laboratory experiment is described in which the temperature change caused at the junction of two metals is studied for both directions of current through the junction. It extends the usual thermocouple-calibration experiment and encourages consideration of thermoelectric cooling as a possible source of refrigeration. © 1958, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
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Duvall, G.E.
6701319882;
Pressure-Volume Relations in Solids
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DOI: 10.1119/1.1996112

AFFILIATIONS: Poulter Laboratories, Stanford Research Institute, Menlo Park, California, United States
ABSTRACT: An equation of state of the form P(V) =f(V) + Tg(V), which is useful for condensed matter, is proposed for the illustration of thermodynamic principles. Pressure-volume relations for adiabatic and shock compressions are derived with the assumption that specific heat at constant volume is independent of temperature. These derived relations are illustrated for a “Murnaghan” equation of state, and constants of this equation for several metals are tabulated. 
DOCUMENT TYPE: Article
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The First Law of Thermodynamics for a Continuous Medium in Mass Motion
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DOI: 10.1119/1.1934412
AFFILIATIONS: University of California, Berkeley, California, United States
ABSTRACT: The integral form of the conservation of energy for a continuous medium in motion is derived from the usual differential expression of the first law of thermodynamics. Various special cases of this relation are considered, and in particular it is shown that the invariance of the sum of kinetic energy, potential energy, and e+p/p may be written for arbitrary dissipative motions under certain definitions of the boundary conditions of the system. 
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DOI: 10.1119/1.1934356
AFFILIATIONS: Tulane University, New Orleans, Louisiana, United States
ABSTRACT: The use of matrices for representing fundamental thermodynamic relations is demonstrated. Maxwell's relations and other thermodynamic derivatives are readily obtained by differentiation of the matrices defined. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Zemansky, M.W.
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DOI: 10.1119/1.1934463
AFFILIATIONS: City College, Convent Avenue and 139th Street, New York, United States
ABSTRACT: It is pointed out that thermodynamics is a useful subject in widely varying fields, such as engineering, chemistry, and physics. It is, however, used in such different ways by scientists in these fields, that one group hardly recognizes what the other is doing. Some of the controversies in the nomenclature of thermodynamics are mentioned and some of the changing styles in thermodynamics are explained in terms of the thermocouple. Some unfortunate tendencies in the teaching of thermodynamics are deplored. The author ends with a tribute to many of his former students. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final

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Christie, D.E.
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DOI: 10.1119/1.1934516
AFFILIATIONS: Bowdoin College, Brunswick, Maine, United States
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

Hoxton, L.G.
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“Ratio of the Specific Heats” and Thermodynamics
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DOI: 10.1119/1.1934507
AFFILIATIONS: University of Virginia, Charlottesville, Virginia, United States
ABSTRACT: Attention is directed to certain adiabatic equations, which are deducible from definitions independent of thermodynamic principles. The facts appear to be little known; textbooks and other writings disagree about them. The very simple proofs discussed here result in economy of thought with attendant benefits to both student and instructor. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Rothstein, J.
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DOI: 10.1119/1.1934539
AFFILIATIONS: Signal Corps Engineering Laboratories, Fort Monmouth, New Jersey, United States
ABSTRACT: The problem of reconciling the irreversibility of thermodynamics with the completely reversible mechanics of the ultimate constituents of the thermodynamical system is examined from an operational viewpoint. The informational nature of entropy is demonstrated, and the famous paradoxes of statistical mechanics, due to Loschmidt and Zermelo, are resolved with its aid. Spin echo experiments are shown to realize the conditions of Loschmidt's reflection paradox, and used to illustrate how reversibility occurs only with perfect “memory” or information storage, while “forgetting” or loss of information implies irreversibility. 
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1934339
AFFILIATIONS: Chemistry Department, Brookhaven National Laboratory, New York, United States
ABSTRACT: Using the thermodynamic theory of irreversible processes, a general equation is derived for

the solution potential of a multicomponent fluid containing both charged and uncharged species situated in a gravitational or centrifugal field. The argument fully takes into account the irreversible processes of sedimentation and diffusion, and it is shown rigorously how the Hittorf transference numbers of ions and nonelectrolytes enter into the expression. The cell emf is derived and specialized for three cases of experimental interest; the concentration cell with transference, the homogeneous solution in the field cell, and the sedimentation equilibrium cell. These equations are applied to three common electrode systems with a single binary electrolyte in a single neutral solvent. 
DOCUMENT TYPE: Article
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Shanks, D.
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A Study of Postulates: The “Thermodynamic” Derivation of the Adiabatic Gas Law
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DOI: 10.1119/1.1934226
AFFILIATIONS: U. S. Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland, United States
ABSTRACT: The adiabatic gas law, pvγ = const, is usually derived in thermodynamic textbooks as if it were a consequence of the first law of thermodynamics. It is shown here that the first law, and other assumptions made, are really irrelevant. These “thermodynamic” derivations are then analyzed in order to clarify the nature of the irrelevancies. © 1956, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1934174
AFFILIATIONS: Missouri School of Mines, Metallurgy, Rolla, Missouri, United States; University of Wisconsin, Madison, Wisconsin, United States
ABSTRACT: Satisfactory laboratory apparatusbased on the electric refrigeratorfor demonstration and quantitative work with the second law of thermodynamics has been devised and is now in use at the University of Wisconsin and the Missouri School of Mines and Metallurgy. The design and operation of the Wisconsin apparatus is described and the possible calculations discussed. © 1956, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Miller, D.G.
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Thermodynamic Theory of Irreversible Processes. II. Sedimentation Equilibrium of Fluids in Gravitational and Centrifugal Fields
(1956) American Journal of Physics, 24 (8), pp. 555-561. Cited 4 times.
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DOI: 10.1119/1.1934319
AFFILIATIONS: Chemistry Department, Brookhaven National Laboratory, Upton, Long Island, New York, United States
ABSTRACT: Using results of the thermodynamic theory of irreversible processes, general equations are given for the transport of all charged and uncharged constituents of a multicomponent fluid situated in a gravitational or centrifugal field. From these equations, relations describing the special case of sedimentation equilibrium are derived. It is pointed out that the Onsager relations are not required in this case. Different integration paths lead to certain useful exact equations, one of

which has been given recently by Young, Kraus, and Johnson. These equations may be used to obtain from sedimentation experiments (1) the activity as a function of the pressures and compositions associated with sedimentation equilibrium; (2) the activity as a function of composition at a given pressure if it is known at one composition and the same pressure and if partial molal volume and density data are known as a function of P; (3) the activity as a function of pressure for one composition if it is known as a function of composition at a single pressure, and conversely. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

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Thermodynamic Theory of Irreversible Processes I. The Basic Macroscopic Concept
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DOI: 10.1119/1.1934260
AFFILIATIONS: Chemistry Department, Brookhaven National Laboratory, Upton, Long Island, New York, United States
ABSTRACT: The foundations of the thermodynamic theory of irreversible processes are presented in macroscopic terms. The concept of entropy production in systems with gradients is discussed in relation to classical thermodynamics and to what new hypotheses are necessary. The entropy production is computed in some simple cases, and it is found that its factors can be related to well-known linear laws such as Ohm's. It is shown on experimental grounds that the linear laws must be generalized in complex cases involving interacting flows. Further appeal to experiment shows that the Onsager relations must be valid. The range of validity of the theory is discussed. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Hirshfeld, M.A.
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On “some current misinterpretations of carnot's memoir”
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DOI: 10.1119/1.1933909
AFFILIATIONS: Moravian College, Bethlehem, Pennsylvania, United States
ABSTRACT: Although Carnot's contributions to thermodynamics have been universally recognized, it is usually with the reservation that there were serious gaps in his proof. Careful study of his memoir shows that Carnot implicitly defined heat so as to make it equivalent to entropy. With this interpretation it may be shown that his logic was flawless, that he believed in the kinetic nature of heat, and that his theorems are based on the first and second laws of thermodynamics. 
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PUBLICATION STAGE: Final
SOURCE: Scopus

Bancroft, D.
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DOI: 10.1119/1.1933929
AFFILIATIONS: Swarthmore College, Swarthmore, Pennsylvania, United States
ABSTRACT: An undergraduate experiment is described for determining thermodynamic temperature directly from the definition of entropy. A simple system is arranged so that the entropy change due to the addition of heat may be calculated from the resulting change in the pressure exerted by the system. For this calculation the isentropic thermal expansion of the system must be determined

experimentally. It is shown that in principle the temperature as determined does not require calibration of the thermometer used except at two fixed points. Accuracy of the order of 1 percent can be attained. 
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PUBLICATION STAGE: Final
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Sharp, R.T.
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DOI: 10.1119/1.1933890
AFFILIATIONS: Department of Mathematics, McGill University, Montreal, Quebec, Canada
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Barr, T.A.
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Influence of Permeable Membranes on the Measured Values of Osmotic Pressures
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DOI: 10.1119/1.1934044
AFFILIATIONS: University of Georgia, Vanderbilt University, Nashville, Tennessee, United States
ABSTRACT: An “operational” definition of osmotic pressure is presented and the difference between this definition and the thermodynamic definition of osmotic pressure is pointed out. By the use of a negative pressure osmometer a formula is developed to express the values of “osmotic pressures” when the osmometer membrane is permeable to both solvent and solute. A membrane factor [formula omitted] is introduced to account for the efflux of solute from the osmometer. [formula omitted] is evaluated in terms of the effective solute diffusion coefficient, [formula omitted]. © 1955, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Stimson, H.F.
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Heat Units and Temperature Scales for Calorimetry
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DOI: 10.1119/1.1934112
AFFILIATIONS: National Bureau of Standards, Washington, D. C., United States
ABSTRACT: Calorimetry is the measurement of quantities of heat. Temperature scales are usually involved. The General Conference on Weights and Measures adopted the International Temperature Scale (practical scale) in 1927 and its first revision in 1948. This scale is nearly parallel to the thermodynamic scale, proposed by Kelvin in 1854. In 1954 the General Conference redefined the Kelvin Scale, in the manner which Kelvin originally said “must be adopted ultimately,” by assigning a value for the temperature of a single fixed point, viz. 273.16° for the triple point of water (ice point = 273.15°). Several calories have been used in the past but the joule was adopted for the unit of quantity of heat in 1948. The need is stressed for using units of heat which are unambiguous. © 1955, American Association of Physics Teachers
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1933907
AFFILIATIONS: Harvard University, Cambridge, Massachusetts, United States
ABSTRACT: The desirability and the difficulty of retrieving modern scientific concepts in classical scientific authors is discussed with particular reference to a recently published re-evaluation of Sadi Carnot's memoir. Evidence is presented to support the interpretation of Carnot provided by his nineteenth-century successors and current in modern texts: Carnot's use of the material theory of heat led him to misconstrue the foundations of thermodynamics, but the misconstruction, discoverable only in retrospect, is irrelevant to his stature as a profound and original investigator. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Lande, A.
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Quantum Mechanics and Thermodynamic Continuity. II
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DOI: 10.1119/1.1933626
AFFILIATIONS: The Ohio State University, Columbus, Ohio, United States
ABSTRACT: The program of deducing quantum mechanics from the postulate of thermodynamic continuity is extended to embrace the principles of symmetry and quantum statistics, in particular the rule of conservation of symmetry type when a system of N particles in resonance interaction is augmented by one more particle. The special quantitative definition of quantum conjugacy contained in the commutation rule of Born and in the Schrdinger replacement of the momentum p by a differential operator may be replaced by a general qualitative physical definition: “p and q are conjugate observables in a mechanical system when the manifold of q reactions of the system uniquely determines the manifold of its p reactions.” When interpreted in terms of superposition mechanics this definition leads to the rules of Born and Schrdinger and from there to quantum dynamics. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Brown, S.C.
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Discovery of the Differential Thermometer
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DOI: 10.1119/1.1933598
AFFILIATIONS: Massachusetts Institute of Technology, Cambridge, Massachusetts, United States
ABSTRACT: The differential thermometer was simultaneously discovered by Sir John Leslie and Count Rumford. The priority controversy between these two men is presented. Some years later Sir Humphry Davy depreciated Leslie's claim to the discovery. The ensuing debates cast interesting light on the personalities of the protagonists. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Green, R.B.
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A New Examination of the Laws of Thermodynamics
(1954) American Journal of Physics, 22 (4), pp. 191-193.
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DOI: 10.1119/1.1933678
AFFILIATIONS: Stevens Institute of Technology, Hoboken, New Jersey, United States
ABSTRACT: The first law is stated in a new, simpler form which is qualitative, and its quantitative content is proven as a corollary. This is done for both the Poincare and the Carathdodory methods. A statement of the second law is given. Minimum requirements for statements of the laws are discussed, and new alternative statements suggested. 
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DOI: 10.1119/1.1933736
AFFILIATIONS: University of Minnesota, United States
DOCUMENT TYPE: Article
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(1953) American Journal of Physics, 21 (7), pp. 580-581.
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DOI: 10.1119/1.1933570
AFFILIATIONS: Williams College, United States
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1933565
AFFILIATIONS: Kansas State College, United States
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Waage, H.M.
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A Projection Thermometer for Lecture Demonstrations

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DOI: 10.1119/1.1933490
AFFILIATIONS: Palmer Physical Laboratory, Princeton University, Princeton, New Jersey, United States
DOCUMENT TYPE: Article
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Watson, E.C.
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Reproductions of Prints, Drawings, and Paintings of Interest in the History of Physics. 51. Caricature of Sir John Leslie
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DOI: 10.1119/1.1933366
AFFILIATIONS: California Institute of Technology, Pasadena 4, California, Colombia
ABSTRACT: An excellent caricature of Sir John Leslie, Professor of Natural Philosophy in the University of Edinburgh and inventor of the differential thermometer, was made by John Kay shortly before his death. It is here reproduced together with some amusing biographical notes. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
SOURCE: Scopus

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DOI: 10.1119/1.1933111
AFFILIATIONS: The Pennsylvania State College, United States
DOCUMENT TYPE: Article
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Lin, C.C.
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Thermodynamics of Fluid Flow
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DOI: 10.1119/1.1933110
AFFILIATIONS: Massachusetts Institute of Technology, United States
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1933184
AFFILIATIONS: Illinois Institute of Technology, United States
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DOI: 10.1119/1.1933259
AFFILIATIONS: University of Pennsylvania, United States
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Landé, A.
22988923400;
Quantum Mechanics and Thermodynamic Continuity
(1952) American Journal of Physics, 20 (6), pp. 353-358.
https://www.scopus.com/inward/record.uri?eid=2-s2.0-84953651823&doi=10.1119%2f1.1933235&partnerID=40&md5=494168652eabd1743c12cfeda2996429

DOI: 10.1119/1.1933235
AFFILIATIONS: Mendenhall Laboratory, The Ohio State University, Columbus, Ohio, United States
ABSTRACT: The basic concepts and rules of quantum mechanics are shown to be immediate consequences, on the basis of simple reasoning, of a postulate of continuity in the domain of macroscopic thermodynamics. The continuity principle leads first to the concept of a fractional likeness between two states in general, as opposed to the classical alternative of either like or unlike. Then all possible states of a system can be arranged in sets of mutually unlike or “orthogonal” states, with members A and B of different sets interconnected by fractional likeness factors q(A, B) between zero and unity. These factors q are identical with the relative intensities in a splitting effect of a state into components, ruled by probability relations and by the basic principle of quantum statistics of not counting permutations of individual particles. The problem of relation between the various fractional likenesses, or probabilities of transition under analysis, is a purely mathematical problem and is solved by the introduction of probability amplitudes necessarily subject to a matrix law of multiplication, i.e., to the principle of superposition. Thus, starting from the continuity postulate of thermodynamics, quantum theory in its general outline is obtained by simple reasoning. All further details, such as the duality of waves and particles, the uncertainty relation, and the mechanics of special systems, need only one more bit of empirical information, namely, the symmetric and periodic form of the amplitude of fractional likeness between a state of given coordinate and a state of given momentum. 
DOCUMENT TYPE: Article
PUBLICATION STAGE: Final
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Porter, A.W., Frost, R.H.
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DOI: 10.1119/1.1933185
AFFILIATIONS: University of Missouri, United States
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Quantitative Evaluation of Rocket Propellants
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DOI: 10.1119/1.1933097
AFFILIATIONS: Guggenheim Jet Propulsion Center, California Institute of Technology, Pasadena, California, United States
ABSTRACT: A method for the quantitative evaluation of chemicals as rocket propellants is described. The procedure utilizes the fact that adiabatic expansion through a nozzle may be considered to be isentropic. Treatments are presented for the two limiting conditions of expansion, corresponding to flow without chemical change and to flow which is characterized, at all times, by the existence of thermodynamic equilibrium. © 1952, American Association of Physics Teachers. All rights reserved.
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Miller, A.R.
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The Concept of Temperature
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DOI: 10.1119/1.1933298
AFFILIATIONS: Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom
ABSTRACT: The logical deduction of the existence of the concept of temperature from the laws of thermal equilibrium is examined. The mathematical proof that the relation given by Carathéodory, in his phenomenological discussion of the laws of thermodynamics, is a necessary and sufficient condition is supplied, thus refuting criticism that has been made of his work. The descriptive account sometimes given from a consideration of corresponding isotherms is also examined. It is shown how this qualitative idea can be put into analytical form. © 1952, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
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Sleator, W.W.
55304200800;
Potential against Resistance a Graphical Review
(1951) American Journal of Physics, 19 (5), pp. 262-275.
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DOI: 10.1119/1.1932801
AFFILIATIONS: University of Michigan, Ann Arbor, Michigan, United States
ABSTRACT: In this paper the graph of potential against resistance, often used to picture the discharge of an electric cell, is shown to represent the transformations of energy involved in the process. With this property in view, the V R diagram becomes applicable to every energy transformation that can occur in an electric circuit. Such a diagram is used accordingly to represent the charging of a storage cell as well as its discharge, the charging of a condenser, the operation of the dc generator and motor, the performance of the copper-iron thermocouple, and the increase and decrease of current in an inductive coil without iron. It is hoped that this unified treatment of important electric processes may reveal their essential similarities and make them better understood and more easily remembered. © 1951, American Association of Physics Teachers. All rights reserved.
DOCUMENT TYPE: Article
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Raymond, R.C.
36346162400;
Thermodynamics
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DOI: 10.1119/1.1932765
AFFILIATIONS: The Pennsylvania State College, United States
DOCUMENT TYPE: Article

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Pesterfield, C.H.
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Engineering Thermodynamics
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DOI: 10.1119/1.1933087
AFFILIATIONS: Michigan State College, United States
DOCUMENT TYPE: Article
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Little, N.C.
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A Unified Approach to Physics
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DOI: 10.1119/1.1932824
AFFILIATIONS: Bowdoin College, Brunswick, Maine, United States
ABSTRACT: The general elementary course is unified on a basis of underlying theory. Part I introduces seriatim five fundamental concepts to serve a dimensional analysis for the whole of physics. Selected topics make the nature of these concepts clear, e.g., (1) geometric optics for length, (2) kinematics for time, (3) statics of a rigid body lor force, (4) electrolysis for electricity, and (5) thermometry and calorimetry for temperature. Part II contains five sections which cut horizontally across the conventional subdivisions of physics. (1) Energetics, in which dynamics, thermodynamics, and the relativity mass-energy relation find a place; (2) Flow Phenomena stress the parallelisms between fluids, heat, and electricity; (3) Field Phenomena apply the inverse square law to gravitation, electro- and magnetostatics, photometry, and radiation; (4) Periodic Phenomena, starting with circular and simple harmonic motions, end with waves of all kinds; and (5) Quantum Phenomena deal with the elemental particles and the indeterminancy principle. 
DOCUMENT TYPE: Article
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Robertson, J.K.
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Maxwell's Thermodynamic Relations
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DOI: 10.1119/1.1932736
AFFILIATIONS: Queen's University Kingston, Ontario, United States
DOCUMENT TYPE: Article
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DOI: 10.1119/1.1933053
AFFILIATIONS: University of Maryland, College Park, Maryland, United States
DOCUMENT TYPE: Article
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Menger, K.
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DOI: 10.1119/1.1933069
AFFILIATIONS: Walla Walla College, Washington, United States
ABSTRACT: An interesting variation of Joule's classical experiment on the mechanical equivalent of heat is described. It makes use of a rotary stirring mechanism for adding energy to water in a calorimeter, the energy being measured by a bifilar suspension of the driving motor. The motor is operated at synchronous speed. Temperature measurements are by means of a thermocouple and potentiometer. With reasonable care results can be obtained which are consistent to about 3 percent:.

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DOI: 10.1119/1.1932804
AFFILIATIONS: Williams College, Williamstown, Massachusetts, United States
ABSTRACT: The question of an appropriate and precise statement of the first law of thermodynamics suitable for infinitesimal reversible changes is approached through a suitable integral form. This latter expresses the work done on and the heat added to the system in terms of “curve” (line) integrals along a specified curve of change, C. As a result, heat functions Qc and work functions Wc are defined in such a way as to be, on specifically restricted types of curves, single-valued continuous functions of a single variable. The first law is then written as dU dQc-\-dWc, where dU is expressible in terms of two independent increments, while the “curve” differentials, dQc and dWe, need but one. Applications are made to the heat capacities Cp, Cv, etc., the calculation of second derivatives, etc. In systems with more than two independent variables the concept of “curve” differentials leads at once to “surface” differentials with immediate applications. 
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DOI: 10.1119/1.1933073
AFFILIATIONS: Patterson Wheaton College, Norton, Massachusetts, United States
ABSTRACT: Between 1663 and 1665, Robert Hooke designed a thermometer for the Royal Society which served as a standard for the graduation of other seventeenth-century instruments. This paper describes the construction and scale of the standard, the use of Hooke's scale in meteorological diaries of the period 1669 to 1709, and its modification by Francis Hauksbee, the Younger, in the early eighteenth century. It includes a suggestion for interpretation of the barometric observations in Hooke's Guildhall diary. It points out the influence of the Royal Society's meteorological observations in the age of Fahrenheit, Reaumur, and Celsius. 
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DOI: 10.1119/1.1932823
AFFILIATIONS: Sun Physical Laboratory, Newtown Square, Pennsylvania, United States
ABSTRACT: In Part 3, the principles developed in the preceding parts are illustrated by applying them to the problem of a sphere, with arbitrary material properties, immersed in a fluid with linear dielectric properties, in an applied electric field that is symmetric about an axis but is otherwise arbitrary. The long-range electric force and the short-range force due to fluid pressure are calculated separately; the sum of these is what is usually calculated by the maxwell stress method, and the resolution into two terms is admittedly not unique. In Part 4, some general work and energy relations are developed; these are put into a form such that elementary thermodynamic principles can be applied directly, without resort to physical interpretations of the macroscopic field vectors. The application to magnetoelastic and piezoelectric phenomena is indicated. The standard formulas of piezoelectricity, as developed by Voigt, are shown to be correct only if the “stresses” occurring in them are given a particular one of several possible interpretations. 
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DOI: 10.1119/1.1932722
AFFILIATIONS: The Pennsylvania State College, State College, Pennsylvania, United States
ABSTRACT: The failure of a heat engine to defeat the second law of thermodynamics by using density fluctuations to convert heat to work without leaving other changes in the universe is usually explained by saying that the fluctuations of the engine itself would defeat such an operation or that the microscopic nature of the fluctuations prevents their being put to a macroscopic use. It is shown here that with a proper definition of stored information, a heat engine can be made to convert heat to work without other changes in its immediate system, provided that an outside observer creates in the system a negative information entropy equal to the negative entropy change involved in the operation of the engine. This equivalence of a communication entropy change to a thermodynamic entropy change leads to the definition of the entropy of a nonequilibrium system as the algebraic sum of the thermodynamic entropy which the system would have at equilibrium and the information entropy necessary to construct the specified state from the equilibrium state. 
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