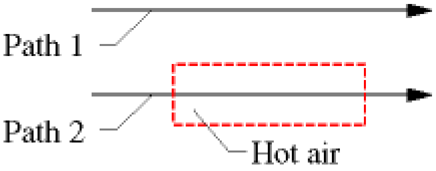
Physics 234 Exam # 2 Review

Name:_____________________________

Section A. Circle one of the answers (4 points each).

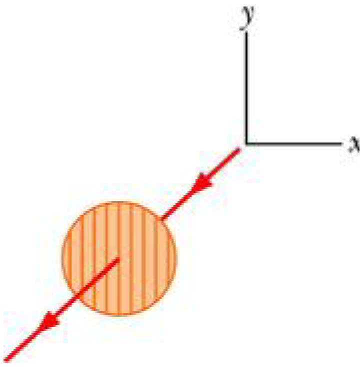
1. The figure below shows the paths taken by two pulses of sound that begin simultaneously and then race each other through equal distances in air. The only difference between the paths is that a region of hot (low density) air lies along path 2. Which pulse wins the race?

(a) path 1 (b) path 2



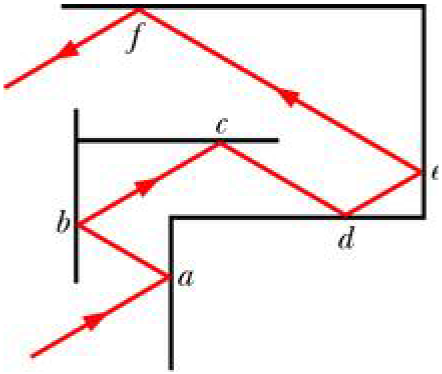
2. The figure below shows light reaching a polarizing sheet whose polarizing direction is parallel to a y axis. We shall rotate the sheet 40° clockwise about the unpolarized light's indicated line of travel. During this rotation, does the fraction of the initial light intensity passing through the sheet

(a) remains the same (b) increases (c) decreases

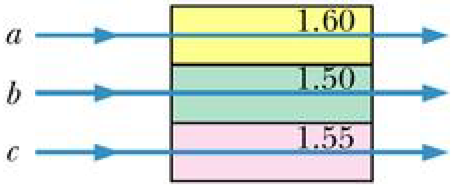


3. The figure shows the multiple reflections of a light ray along a glass corridor where the walls are either parallel or perpendicular to one another. If the angle of incidence at point *a* is 30°, what are the angles of reflection of the light ray at points *b*, *c*, *d*, *e*, and *f*?

(a) all are 30° (b) all are 60° (c) some are 30° and some are 60°



4. Three pulses of light—*a*, *b*, and *c*—of the same wavelength are sent through layers of plastic whose indexes of refraction are given. Rank the pulses according to their travel time through the plastic, greatest first.



(a) a, b, c (b) a, c, b (c) b, c, a

5. (20 Pts.) The solar constant, the power due to radiation from the sun falling on the earth's atmosphere is 1.35 kW/m^2.

(a) If the distance from the sun to the earth is 1.5 x 10^{11}m and the radius of the earth is 6.37 x10^6 m, what is the average power output of the sun?

(b) If the earth absorbs the radiation from the sun without reflecting it what is the net force on the earth?

(c) Compare it to the gravitational attraction of the earth to the sun. (The mass of the earth is 5.98 x 10^{24} kg, the mass of the sun is 2.0 x 10^{30} kg and G = 6.67 x 10^{-11} N m^2/kg^2)

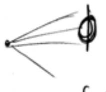
(d) What are the electric and magnetic field amplitudes (rms) near the earth's surface (due to the solar radiation)?

$I = 1.35\ kw/m^2$

$R_{SE} = 1.5\times10^{11}\ m$

$R_E = 6.37\times10^6\ m$

(a)



$I = P/A - \frac{P}{4\pi r^2}$

think of earth as a disk

$P = IA = I\underline{\pi R_E^2}$

$P_{total} = I\,4\pi R_{SE}^2$

10^{26}

$P_{tot} = (1.35\ kw/m^2)\ 4\pi\ (1.5\times10^{11}\ m)^2$

$= 3.81\times10^{23}\ kw$

(b) $F = PA$ assume disk (or more accurately $\frac{1}{2}$ sphere)

↖ pressure

$P = \frac{I}{c} = \frac{1.35\times10^3\ W/m^2}{3.0\times10^8\ m/s^2} - 4.5\times10^{-6}\ N/m^2$

Solar radiation force

$F = (4.5\times10^{-6}\ N/m^2)\ 2\pi\ (6.37\times10^6\ m)^2$

$= 1.15\times10^9\ N$

(c)

Solar gravitational force

$F = \frac{m_E M_S G}{r^2} = \frac{(5.98\times10^{24}\ kg)(2.0\times10^{30}\ kg)\ 6.67\times10^{-11}\ N\ m^2/kg^2}{(1.5\times10^{11}\ m)^2}$

$= 3.5\times10^{22}\ N$

Solar radiation force is much weaker

$$I_{ave} = \frac{1}{\mu_0 c} (E_{rms})^2 \quad \leftarrow$$

$$E_{rms} = \sqrt{I_{ave}\, \mu_0 c}$$

$$= \sqrt{(1.35 \times 10^3 \, W/m^2)(4\pi \times 10^{-7} \, H \cdot m)(3.0 \times 10^8 \, m/s)}$$

$$= 714 \, V/m$$

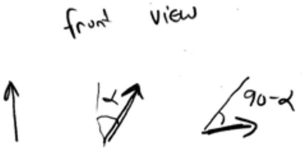
$$B_{rms} = \frac{E_{rms}}{c} = \frac{714 \, V/m}{3.0 \times 10^8 \, m/s} = 2.38 \times 10^{-6} \, T$$

Compared to 10^{-4} T from earth's magnetic field

6. (12 pts) Two polarized sheets have their transmission axes crossed so that no light is transmitted. A third sheet is inserted between the first sheet and its transmission angle is α (with respect to that of the first sheet). Unpolarized light of intensity I_0 is incident on the first sheet.

(a) Find the intensity transmitted through the sheets for α = 30° and 45° .

(b) Show that the transmitted intensity is a maximum at 45° .



$\frac{I_0}{2}$ $\quad$ $\frac{I_0}{2}\cos^2\alpha$ $\quad$ $\frac{I_0}{2}\cos^2\alpha\cos^2(90^\circ-\alpha)$

$$I = \frac{I_0}{2}\cos^2\alpha\cos^2(90^\circ-\alpha)$$

$$= \frac{I_0}{2}\cos^2\alpha\sin^2\alpha$$

$\cos(A+B) = \cos A\cos B - \sin A\sin B$

$\cos(90^\circ-\alpha) = \sin\alpha$

(a) $I(\alpha=45^\circ) = \frac{I_0}{2}\,\frac{1}{2}\times\frac{1}{2} = \frac{I_0}{8} = 0.125\,I_0$

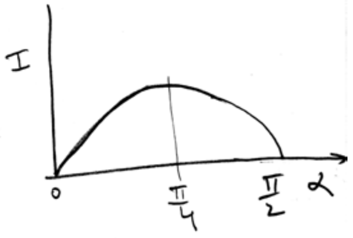
$I(\alpha=30) = \frac{I_0}{2}\cos(30^\circ)\sin^2(30^\circ)$

$= 0.0938$

(b) $\sin(2\theta) = 2\sin\theta\cos\theta$

$\sin^2\theta\cos^2\theta = \frac{1}{4}\sin^2(2\theta)$

$$I = \frac{I_0}{8}\sin^2(2\alpha)$$

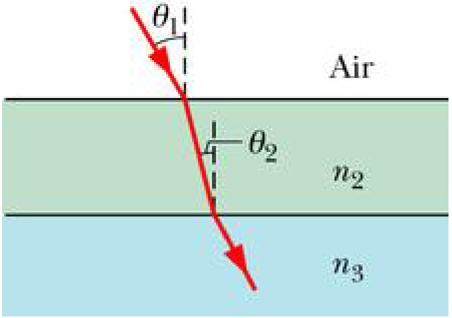


$\alpha = 0 \rightarrow 90^\circ$ range

maximum is at 45°

$$I_{max} = \frac{I_0}{8}$$

7. (10 pts.) A ray in air is incident on a flat layer of material 2 that has an index of refraction $n_2 = 1.5$. Beneath material 2 is material 3 with an index of refraction n_3. The ray is incident on the air–material 2 interface at the critical angle for that interface. What at are the possible values for n_3 and θ_3?



Medium	Index of Refraction
Vacuum	1 (exactly)
Air	1.00029
Water	1.33
Acetone	1.36
Sugar Solution (80 %)	1.49

$n_1 \sin\theta_1 = n_3 \sin\theta_3$

$\theta_3 = 90°$

$n_3 = n_1 \sin\theta_1$

$n_3 = 1.00029 \sin\theta_1$

$\longrightarrow \quad n_3 \leq 1.00029$

Trivial case $\quad n_3 = 1.00029$

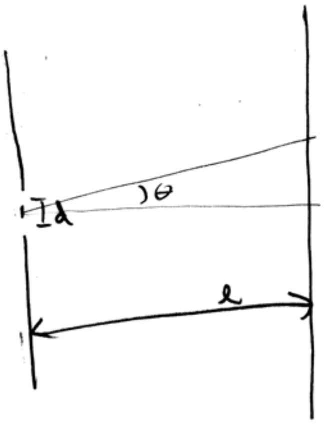
$\theta_1 = 0$

nontrivial case $\quad n_3 = 1.$ vaccum

$\theta_1 = \sin^{-1}\left(\frac{1}{1.00029}\right)$

$= 88.62°$

8. (10 pts.) Suppose that Young's experiment is performed with blue-green light of wavelength 500 nm. The slits are 1.20 mm apart, and the viewing screen is 5.40 m from the slits. How far apart are the bright fringes?



maxima occur at $\Delta L = n\lambda$

$m\lambda = d\sin\theta$

$\theta_m = \sin^{-1}\left(\frac{m\lambda}{d}\right)$

$m = 0 \rightarrow \theta_0 = 0$

$m = 1 \rightarrow \theta_1 = \sin^{-1}\left(\frac{\lambda}{d}\right)$ first side maximum

$d = 1.20\,mm$

$\lambda = 500\,nm$

$\theta_1 = \sin^{-1}\left(\frac{500\times10^{-9}m}{1.20\times10^{-3}m}\right) = 0.02387^\circ$

$\nwarrow 4.17\times10^{-4}$ Radians

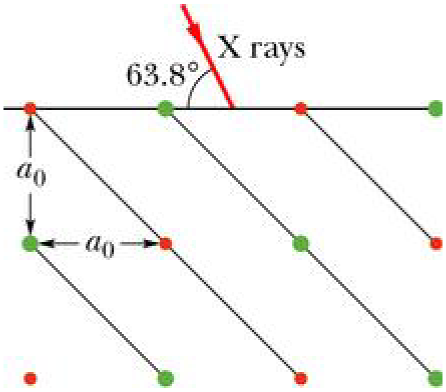
$h/\ell = \tan\theta = \frac{\sin\theta}{\cos\theta} \approx \theta$ Small angles

$h = \ell\,\underset{\uparrow\,\text{radians}}{\theta} = 5.40 * 4.17\times10^{-4}$

$= 2.25\times10^{-3}m$

$= 2.25\,mm$

9. (15 pts) The first-order reflection from the reflection planes shown occurs when an x-ray beam of wavelength 0.260 nm makes an angle of 63.8° with the top face of the crystal. What is the unit cell size a_0?



Angle between rays and atomic planes in question $= \theta = 63.8 - 45 = 18.8^\circ$

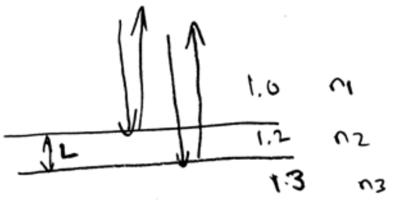
$$d = \frac{a_0}{\sqrt{2}}$$

$$2d\sin\theta = m\lambda \qquad m=1$$

$$a_0 = \sqrt{2}d = \frac{\sqrt{2}\lambda}{2\sin\theta} = \frac{\sqrt{2}\,(0.260\,nm)}{2\cdot\sin(18.8)}$$

$$= 0.570\,nm$$

10. (15 pts) A disabled tanker leaks kerosene (*n* = 1.20) into the Persian Gulf, creating a large slick on top of the water (*n* = 1.30). (a) If you are looking straight down from an airplane, while the Sun is overhead, at a region of the slick where its thickness is 460 nm, for which wavelength(s) of visible light is the reflection brightest because of constructive interference? (b) If you are scuba diving directly under this same region of the slick, for which wavelength(s) of visible light is the transmitted intensity strongest?



(a) **maxima** determined by path difference

$$2L = m\lambda_n = \frac{m\lambda}{n_2}$$

$$\lambda = \frac{n_2 2L}{m} = \frac{2(1.2)(460nm)}{n} \rightarrow 1104,\ 552,\ 368\ nm$$

↑ visible

(b) maxima in transmission ⇔ minima in reflection

$$2L = \frac{2m+1}{2}\lambda_n = \frac{2m+1}{2}\frac{\lambda}{n_2}$$

$$\lambda = \frac{n_2 2L}{\frac{2m+1}{2}} = \frac{4(1.2)(460nm)}{2m+1}$$

$$= 2208,\ 736,\ 442\ nm$$

↑ visible