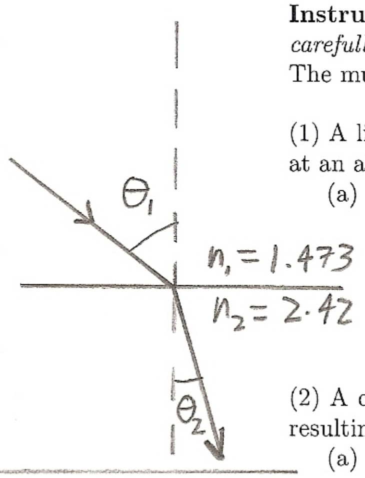
Physics 4C Mid-Term Exam 1 Name: SOLUTIONS

Instructions : There are six multiple choice questions and two longer problems. Read everything *carefully* and give the best answer based on the material presented during lecture and in the text. The multiple choice is worth 60% and the problems are worth 40%



(1) A light ray initally traveling in glycerin (n=1.473) strikes an interface with diamond (n=2.42) at an angle of 60 degrees with respect to the normal. What is the angle of refraction (in degrees)?
(a) 20 (b) 60 (c) 32 (d) 64 (e) 15

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$1.473 \sin 60^\circ = 2.42 \sin\theta_2$

$\boxed{\theta_2 = 32^\circ} \Rightarrow$ choice (c)

(2) A concave mirror has a focal length of 35.0 cm. Determine the object distance for which the resulting image is upright and five times the object height.
(a) -140 cm (b) 42.0 cm (c) 28.0 cm (d) 14.0 cm (e) 21.0 cm

A concave mirror $\Rightarrow f > 0$

$f = +35.0$ cm

Find p when: $M > 0$ (the image is upright) and $M = h'/h = 5 = -q/p$

$q = -5p$

$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$

$\frac{1}{p} + \frac{1}{(-5p)} = \frac{1}{f}$

$\frac{1}{p}\left(1 - \frac{1}{5}\right) = \frac{4}{5p} = \frac{1}{f}$

$p = \frac{4f}{5} = \frac{4(35.0\text{cm})}{5} \boxed{= 28.0\text{cm}}$ $\Rightarrow$ Choice (c)

(3) A lens is made of glass with $n = 1.5$. Its front surface is convex, with a radius of curvature of 0.20 m. Its back surface is flat. What is the focal length of the lens, in meters?
(a) 0.20 (b) 0.30 (c) 0.40 (d) 0.10 (e) 0.50

$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$= (1.5-1)\left(\frac{1}{0.2m} - \frac{1}{\infty}\right)$, $\frac{1}{\infty} = 0$

$\frac{1}{f} = \frac{(0.5)}{0.2m}$

$\therefore \boxed{f = 0.4m} \Rightarrow$ choice (c)

(4) A light ray with a frequency of 6×10^{14} Hz in a vacuum is incident on water ($n = 1.33$). The wavelength of the light after it enters the water is (in nanometers):
(a) 798 (b) 500 (c) 665 (d) 484 (e) 376

$\lambda = c/f$

$n = \lambda_0/\lambda_n$

$\Rightarrow \lambda_n = \lambda_0/n = \frac{c}{nf} = \frac{(3.0\times10^8 \,m\,s^{-1})}{(1.33)(6\times10^{14}\,s^{-1})} = \boxed{\lambda_n = 3.76\times10^{-7}\,m = 376\,nm}$

$\Rightarrow$ choice (e)

(5) The image formed by a flat mirror (with $R \to \infty$) is:
(a) real, magnified, inverted (b) virtual, upright (c) virtual, diminished, upright
(d) real, upright (e) virtual, inverted

An ordinary flat mirror, such as the one in your bathroom, has $M = 1$
and $p = -q \Rightarrow$ Choice (b)

(6) What is the critical angle for light going from diamond ($n = 2.4$) into air ($n = 1.0$) ?
(a) 65.4 (b) 24.6 (c) 2.4 (d) 76.3 (e) there is no critical angle

For total internal reflection,

$n_1 \sin\theta_1 = n_2 \sin 90^\circ$ ($\sin 90^\circ = 1$)

So $\theta_{critical} = \arcsin(n_2/n_1) = \arcsin(1.0/2.42)$

$\therefore \boxed{\theta_{critical} = 24.6^\circ} \Rightarrow$ choice (b)

Problems.

Box your final answer. No work = No credit on this part.

(A) A laser of frequency 4.6×10^{14} Hz is traveling in the positive x direction. The magnetic part of the laser light has a maximum amplitude of 6.67×10^{-7} T, and oscillates in the z direction. Assume that the electric field magnitude for the laser light can be written as $E = E_{max}\cos(kx - \omega t)$

(i) What are E_{max}, k and ω **in MKS** units?

(ii) What is the full Poynting vector for this wave (magnitude and direction). I want the t and x dependent Poynting vector, NOT the time averaged Poynting vector. Everything except t and x should be written out numerically.

(i) $\frac{E_{max}}{B_{max}} = c \Rightarrow E_{max} = B_{max}c$

$= (6.67\times10^{-7}\,T)(3\times10^{8}\,m/s)$

$= 200\ T\cdot m/s$

$\boxed{E_{max} = 200\ N/C}$ (Recall $1T \equiv \frac{1N}{C\cdot m/s}$)

$k = \frac{2\pi}{\lambda} = \frac{2\pi f}{c}$ since $\lambda f = c$

$= \frac{2\pi(4.6\times10^{14}\,Hz)}{3\times10^{8}\,m/s}$ $\therefore$ $\boxed{k = 9.6\times10^{6}\,m^{-1}}$

$\omega = 2\pi f = 2\pi(4.6\times10^{14}\,Hz)$ $\therefore$ $\boxed{\omega = 2.9\times10^{15}\,s^{-1}}$

(ii) $\vec{S} = \frac{1}{\mu_0}\vec{E}\times\vec{B} = \frac{1}{\mu_0}\left[E_{max}\cos(kx-\omega t)\right]\left[B_{max}\cos(kx-\omega t)\right]\hat{x}$

$= \frac{1}{\mu_0}\left[E_{max}\cos^2(kx-\omega t)\right]\left[\frac{E_{max}}{c}\right]\hat{x}$ (since $\frac{E_{max}}{B_{max}} = c$).

$= \left[\frac{E_{max}^2}{\mu_0 c}\cos^2(kx-\omega t)\right]\hat{x}$

$= \left[\frac{(200\,N/C)^2}{(4\pi\times10^{-7}\,\frac{T\cdot m}{A})(3\times10^{8}\,\frac{m}{s})}\right]\left[\cos^2(kx-\omega t)\right]\hat{x}$

$\therefore$ $\boxed{\vec{S} = \left[106\ \frac{W}{m^2}\right]\left[\cos^2[(9.6\times10^{6}\,m^{-1})x - (2.9\times10^{15}\,s^{-1})t]\right]\hat{x}}$

(B) A dedicated sports car enthusiast polishes the inside and outside surfaces of a hubcap that is a section of a sphere.

(a) She holds the hubcap 0.25 m from her face, and looks into the inside surface of the hubcap, which has a radius of curvature of +0.60 m.

(i) She sees her image reflected by the inside surface of the hubcap. What is the image distance of this image?

(ii) What is the magnification of this image?

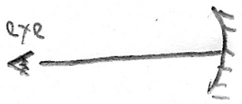
(iii) Is this a real or a virtual image? Is this image upright or inverted?

(b) She now flips the hubcap around, so that she looks into the outside surface of the hubcap. Again, she holds the hubcap 0.25 m from her face. The outside surface of the hubcap has a radius of curvature of -0.60 m.

(i) She sees her image reflected by the outside surface of the hubcap. What is the image distance of this image?

(ii) What is the magnification of this image?

(iii) Is this a real or a virtual image? Is this image upright or inverted?

(a)


(B) $p = +0.25\,m$

$R = +0.60\,m$

(i) $\frac{1}{p} + \frac{1}{q} = \frac{2}{R}$

$q = \frac{1}{\left(\frac{2}{R} - \frac{1}{p}\right)}$

$= \left[\frac{2}{+0.60\,m} - \frac{1}{0.25\,m}\right]^{-1}$

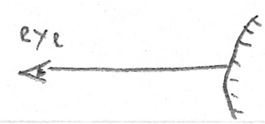
$\boxed{q = -1.50\,m}$

(ii) $M = -\frac{q}{p} = \frac{-(-1.50\,m)}{+0.25\,m}$

$\boxed{M = +6}$

(iii) Since $q < 0$, this image is **virtual** (in back of the mirror).

Since $M > 0$, the image is **upright**

(b)


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$p = +0.25\,m$ (still).

$R = -0.60\,m$

(i) $\frac{1}{p} + \frac{1}{q} = \frac{2}{R}$

$q = \left[\frac{2}{-0.60\,m} - \frac{1}{0.25\,m}\right]^{-1}$

$\boxed{q = -0.136\,m}$

(ii) $M = -\frac{q}{p} = -\frac{(-0.136\,m)}{+0.25\,m}$

$\boxed{M = +0.546}$

(iii) Since $q < 0$, this image is **virtual**.

Since $M > 0$, the image is **upright**.