Name____

Physics 111 Quiz #5, February 17, 2017

Please show all work, thoughts and/or reasoning in order to receive partial credit. The quiz is worth 10 points total.

I affirm that I have carried out my academic endeavors with full academic honesty.

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1. The power output of the sun, called the luminosity, is $L = 3.87\times 10^{26}\,\frac{J}{s}$ and the earth is located at an average distance $1.5\times 10^{11}\,m$. The intensity of sunlight that reaches the earth is called the solar constant and is given as $S_0 = \frac{L}{4\pi r^2} = \frac{3.87\times 10^{26}\,\frac{J}{s}}{4\pi\left(1.5\times 10^{11}\,m\right)^2} = 1370\,\frac{W}{m^2}$. Using this information on the solar constant, what are the maximum amplitudes of the electric and magnetic fields that reach the earth's surface and what is the force that is exerted by the light on a say mirror that has an area of $A = 0.06m^2$?

$$S_0 = \frac{1}{2}c\varepsilon_0 E_{\max}^2 \rightarrow E_{\max} = \sqrt{\frac{2S_0}{c\varepsilon_0}} = \sqrt{\frac{2\times 1370\,\frac{W}{m^2}}{3\times 10^8\,\frac{m}{s}\times 8.85\times 10^{-12}\,\frac{C^2}{Nm^2}}} = 1016\,\frac{N}{C}$$

$$B_{\max} = \frac{E_{\max}}{c} = \frac{1016\,\frac{N}{C}}{3\times 10^8\,\frac{m}{s}} = 3.4\times 10^{-6}\,T$$

$$P_{ref} = \frac{2S}{c} = \frac{F}{A} \rightarrow F = \frac{2SA}{c} = \frac{2\times 1370\,\frac{W}{m^2}\times 0.06m^2}{3\times 10^8\,\frac{m}{s}} = 5.5\times 10^{-7}\,N$$

2. Suppose that the sunlight that reaches the earth passes through two polarizers. The first polarizer has its transmission axis horizontal and the second has its transmission axis oriented at an angle θ with respect to the vertical. If the intensity of sunlight that emerges from the second polarizer is 20% of the solar constant, at what angle was the second polarizer oriented with respect to the vertical?

Through the 1st polarizer the intensity is $S_1 = \frac{S_0}{2}$.

Through the 2nd polarizer the intensity is $S_2 = S_1\cos^2\left(90-\theta\right) = \frac{S_0}{2}\cos^2\left(90-\theta\right)$.

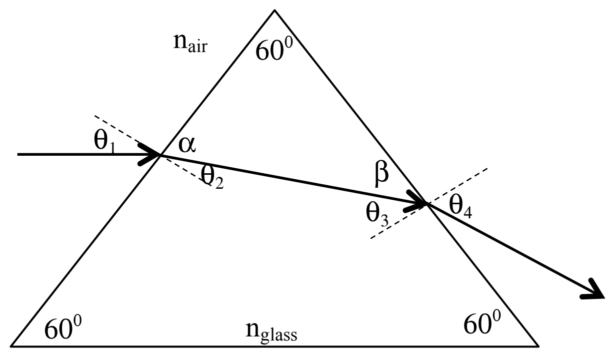
Thus

$$S_2 = 0.2S_0 = \frac{S_0}{2}\cos^2\left(90-\theta\right) \rightarrow \cos^2\left(90-\theta\right) = 0.4$$
$$\cos\left(90-\theta\right) = 0.6325 \rightarrow 90-\theta = \cos^{-1}\left(0.6325\right) = 50.8\,.$$
$$\therefore \theta = 39.2^0$$

3. Suppose that the light the emerged from the 2[nd] polarizer above was incident on a triangular prism at an angle of $\theta_1 = 30^0$, as shown below. At what angle, θ_4, will light emerge from the right side of the prism? Hint: After you determine the angle of refraction on the left surface, determine the angles α and β to get to the right surface.

$$n_{air}\sin\theta_1 = n_{glass}\sin\theta_2 \rightarrow \theta_2 = \sin^{-1}\left(\frac{n_{air}}{n_{glass}}\sin\theta_1\right) = \sin^{-1}\left(\frac{1.00}{1.41}\sin 30\right)$$

$$\theta_2 = 20.8^0$$



$$90 = \alpha + \theta_2 \rightarrow \alpha = 90 - \theta_2 = 69.2^0$$

$$180 = \alpha + \beta + 60 \rightarrow \beta = 120 - \alpha = 50.8^0$$

$$90 = \beta + \theta_3 \rightarrow \theta_3 = 90 - \beta = 39.2^0$$

$$n_{glass}\sin\theta_3 = n_{air}\sin\theta_4 \rightarrow \theta_4 = \sin^{-1}\left(\frac{n_{glass}}{n_{air}}\sin\theta_3\right) = \sin^{-1}\left(\frac{1.41}{1.00}\sin 39.2\right)$$

$$\theta_4 = 63^0$$

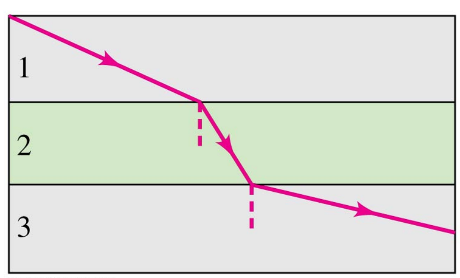
4. Parallel light rays cross parallel interfaces from medium 1 into medium 2 and then into medium 3 as shown in the figure on the right. The relative indices of refraction are ordered according to

a. $n_1 > n_2 > n_3$.

b. $n_1 > n_3 > n_2$.

c. $n_3 > n_2 > n_1$.

d. $n_2 > n_1 > n_3$.



Physics 111 Equation Sheet

Electric Forces, Fields and Potentials

$$\vec{F} = k\frac{Q_1Q_2}{r^2}\hat{r}$$
$$\vec{E} = \frac{\vec{F}}{q}$$
$$\vec{E}_Q = k\frac{Q}{r^2}\hat{r}$$
$$PE = k\frac{Q_1Q_2}{r}$$
$$V(r) = k\frac{Q}{r}$$
$$E_x = -\frac{\Delta V}{\Delta x}$$
$$W = -q\Delta V_{f,i}$$

Magnetic Forces and Fields

$$F = qvB\sin\theta$$
$$F = IlB\sin\theta$$
$$\tau = NIAB\sin\theta = \mu B\sin\theta$$
$$PE = -\mu B\cos\theta$$
$$B = \frac{\mu_0 I}{2\pi r}$$
$$\varepsilon_{induced} = -N\frac{\Delta\phi_B}{\Delta t} = -N\frac{\Delta(BA\cos\theta)}{\Delta t}$$

Constants

$$g = 9.8\,\tfrac{m}{s^2}$$
$$1e = 1.6\times10^{-19}\,C$$
$$k = \frac{1}{4\pi\varepsilon_o} = 9\times10^9\,\tfrac{Nm^2}{C^2}$$
$$\varepsilon_o = 8.85\times10^{-12}\,\tfrac{C^2}{Nm^2}$$
$$1eV = 1.6\times10^{-19}\,J$$
$$\mu_o = 4\pi\times10^{-7}\,\tfrac{Tm}{A}$$
$$c = 3\times10^8\,\tfrac{m}{s}$$
$$h = 6.63\times10^{-34}\,Js$$
$$m_e = 9.11\times10^{-31}\,kg = \frac{0.511MeV}{c^2}$$
$$m_p = 1.67\times10^{-27}\,kg = \frac{937.1MeV}{c^2}$$
$$m_n = 1.69\times10^{-27}\,kg = \frac{948.3MeV}{c^2}$$
$$1amu = 1.66\times10^{-27}\,kg = \frac{931.5MeV}{c^2}$$
$$N_A = 6.02\times10^{23}$$
$$Ax^2 + Bx + C = 0 \rightarrow x = \frac{-B\pm\sqrt{B^2-4AC}}{2A}$$

Electric Circuits

$$I = \frac{\Delta Q}{\Delta t}$$
$$V = IR = I\left(\frac{\rho L}{A}\right)$$
$$R_{series} = \sum_{i=1}^{N} R_i$$
$$\frac{1}{R_{parallel}} = \sum_{i=1}^{N}\frac{1}{R_i}$$
$$P = IV = I^2R = \frac{V^2}{R}$$
$$Q = CV = \left(\frac{\kappa\varepsilon_0 A}{d}\right)V = (\kappa C_0)V$$
$$W = U = \tfrac{1}{2}QV = \tfrac{1}{2}CV^2 = \frac{Q^2}{2C}$$
$$Q_{\text{charge}}(t) = Q_{\max}\left(1-e^{-\frac{t}{RC}}\right)$$
$$Q_{\text{discharge}}(t) = Q_{\max}e^{-\frac{t}{RC}}$$
$$C_{parallel} = \sum_{i=1}^{N} C_i$$
$$\frac{1}{C_{series}} = \sum_{i=1}^{N}\frac{1}{C_i}$$

Light as a Particle & Relativity

$$E = hf = \frac{hc}{\lambda} = pc$$
$$KE_{\max} = hf - \phi = eV_{stop}$$
$$\Delta\lambda = \frac{h}{m_e c}(1-\cos\phi)$$
$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$
$$p = \gamma mv$$
$$E_{total} = KE + E_{rest} = \gamma mc^2$$
$$E_{total}^2 = p^2c^2 + m^2c^4$$
$$E_{rest} = mc^2$$
$$KE = (\gamma - 1)mc^2$$

Geometry

$Circles:\quad C = 2\pi r = \pi D \qquad A = \pi r^2$

$Triangles:\quad A = \tfrac{1}{2}bh$

$Spheres:\quad A = 4\pi r^2 \qquad V = \tfrac{4}{3}\pi r^3$

Light as a Wave

$$c = f\lambda = \frac{1}{\sqrt{\varepsilon_o\mu_o}}$$
$$S(t) = \frac{energy}{time\times area} = c\varepsilon_o E^2(t) = c\frac{B^2(t)}{\mu_0}$$
$$I = S_{avg} = \tfrac{1}{2}c\varepsilon_o E_{\max}^2 = c\frac{B_{\max}^2}{2\mu_0}$$
$$P = \frac{S}{c} = \frac{Force}{Area}$$
$$S = S_o\cos^2\theta$$
$$v = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{c}{n}$$
$$\theta_{inc} = \theta_{refl}$$
$$n_1\sin\theta_1 = n_2\sin\theta_2$$
$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$
$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$
$$M_{total} = \prod_{i=1}^{N} M_i$$
$$S_{out} = S_{in}e^{-\sum_i \mu_i x_i}$$
$$HU = \frac{\mu_w - \mu_m}{\mu_w}$$

Nuclear Physics

$$E_{binding} = (Zm_p + Nm_n - m_{rest})c^2$$
$$\frac{\Delta N}{\Delta t} = -\lambda N_o \rightarrow N(t) = N_o e^{-\lambda t}$$
$$A(t) = A_o e^{-\lambda t}$$
$$m(t) = m_o e^{-\lambda t}$$
$$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

Misc. Physics 110 Formulae

$$\vec{F} = \frac{\Delta\vec{p}}{\Delta t} = \frac{\Delta(m\vec{v})}{\Delta t} = m\vec{a}$$
$$\vec{F} = -k\vec{y}$$
$$\vec{F}_C = m\frac{v^2}{R}\hat{r}$$
$$W = \Delta KE = \tfrac{1}{2}m\left(v_f^2 - v_i^2\right) = -\Delta PE$$
$$PE_{gravity} = mgy$$
$$PE_{spring} = \tfrac{1}{2}ky^2$$
$$|\vec{A}| = \sqrt{A_x^2 + A_y^2}$$
$$\phi = \tan^{-1}\left(\frac{A_y}{A_x}\right)$$
$$\vec{v}_f = \vec{v}_i + \vec{a}t$$
$$v_f^2 = v_i^2 + 2a\Delta x$$
$$\vec{x}_f = \vec{x}_i + \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2$$