Name____

Physics 111 Quiz #5, February 22, 2013

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. _________________

1. Suppose that you have unpolarized light incident on a polarizer with its transmission axis vertically oriented. A second polarizer is used to control the intensity of the polarized light that is output from the first polarizer and the second polarizer's transmission axis is oriented at 60° with respect to the vertical. If instead of unpolarized light you decided to use vertically polarized light incident on the first polarizer, how many additional degrees (from 60°) would the second polarizer need to be turned in order that the light output from the second polarizer in the case using polarized light was equal to the light output from the second polarizer using unpolarized light?

For the unpolarized case:

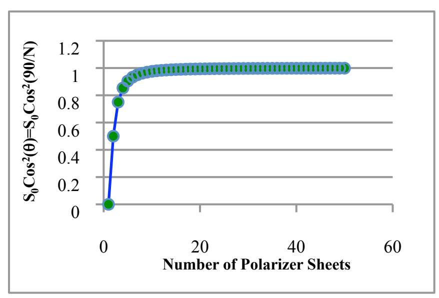
$$S_{out,1} = \tfrac{1}{2} S_0$$
$$S_{out,2} = \tfrac{1}{2} S_0 \cos^2(60) = 0.125 S_0$$

For the polarized case:

$$S_{out,1} = S_0$$
$$S_{out,2} = S_0 \cos^2(\theta) = 0.125 S_0 \rightarrow \theta = 69.3^0$$

So an additional 9.3^0 would be needed.

2. A beam of light is linearly polarized with its electric field pointing vertically. You wish to rotate its direction of polarization by 90° (so that the electric field is pointing horizontally) using one or more ideal polarizing sheets. To get the maximum transmitted intensity, you should use how many Polaroid sheets?



a. One
b. Two
c. Three
d. As many as possible.
e. It is not possible to rotate the polarization by 90°.

One sheet: $S_{out,1} = S_0 \cos^2(\theta) = S_0 \cos^2(90) = 0$

Two sheets: $S_{out,2} = \left(S_0 \cos^2(45)\right)\cos^2(45) = S_0\left(\cos^2(45)\right)^2 = 0.25 S_0$

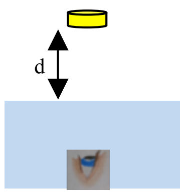
Three sheets: $S_{out,3} = \left(\left(S_0 \cos^2(30)\right)\cos^2(30)\right)\cos^2(30) = S_0\left(\cos^2(30)\right)^3 = 0.42 S_0$

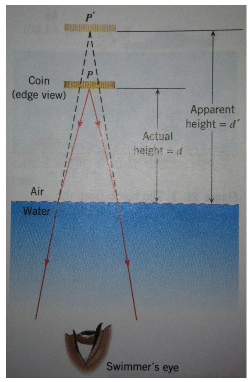
Four sheets: $S_{out,4} = \left(\left(\left(S_0 \cos^2(22.5)\right)\cos^2(22.5)\right)\cos^2(22.5)\right)\cos^2(22.5) = S_0\left(\cos^2(22.5)\right)^4 = 0.53 S_0$

N sheets: $S_{out,N} = \lim_{N\to\infty}\left(S_0 \cos^2\left(\frac{90}{N}\right)\right)^N \rightarrow S_0$

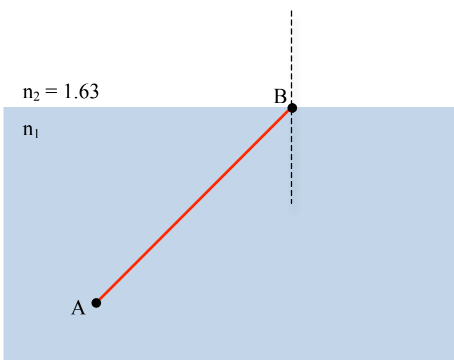
3. A swimmer is under water and looking up at the surface as shown below. Someone holds a coin in the air directly above the swimmer's eyes at a height d above the surface. To the swimmer, the coin appears to be at a certain height d' above the water. The apparent height d' of the coin

a. is greater than d, so the coin appears farther away from the swimmer.
b. is less than d, so the coin appears closer to the swimmer.
c. is the same as d, so the coin appears the same distance away from the swimmer.
d. cannot be determined since the indices of refraction of the air and water are not known.





4. The drawing below shows a ray of light traveling from point A to point B, a distance of $4.6m$ in a material that has an index of refraction of n_1. At point B, the light encounters a different material whose index of refraction is n_2. The light strikes the interface at the critical angle $\theta_c = 48.1^0$. How much time does it take the light to travel from point A to point B?



From the critical angle we can determine the index of refraction of the incident material. We have $n_1 \sin\theta_c = n_2 \sin\theta_2 = n_2 \sin 90 = n_2 \quad \therefore n_1 = \dfrac{n_2}{\sin\theta_c} = \dfrac{1.63}{\sin 48.1} = 2.19$. To determine the time we use $v = \dfrac{c}{n_1} = \dfrac{L}{t} \rightarrow t = \dfrac{Ln_1}{c} = \dfrac{4.6m \times 2.19}{3\times 10^8 \frac{m}{s}} = 3.4\times 10^{-8} s = 34 ns$.

Physics 111 Equation Sheet

Electric Forces, Fields and Potentials

$$\vec{F} = k\frac{Q_1Q_2}{r^2}\hat{r}$$

$$\vec{E} = \frac{\vec{F}}{q}$$

$$\vec{E}_Q = k\frac{Q}{r^2}\hat{r}$$

$$PE = k\frac{Q_1Q_2}{r}$$

$$V(r) = k\frac{Q}{r}$$

$$E_x = -\frac{\Delta V}{\Delta x}$$

$$W_{f,i} = -q\Delta V_{f,i}$$

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

$g = 9.8\frac{m}{s^2}$

$1e = 1.6\times10^{-19}C$

$k = \frac{1}{4\pi\varepsilon_o} = 9\times10^9\frac{C^2}{Nm^2}$

$\varepsilon_o = 8.85\times10^{-12}\frac{Nm^2}{C^2}$

$1eV = 1.6\times10^{-19}J$

$\mu_o = 4\pi\times10^{-7}\frac{Tm}{A}$

$c = 3\times10^8\frac{m}{s}$

$h = 6.63\times10^{-34}Js$

$m_e = 9.11\times10^{-31}kg = \frac{0.511MeV}{c^2}$

$m_p = 1.67\times10^{-27}kg = \frac{937.1MeV}{c^2}$

$m_n = 1.69\times10^{-27}kg = \frac{948.3MeV}{c^2}$

$1amu = 1.66\times10^{-27}kg = \frac{931.5MeV}{c^2}$

$N_A = 6.02\times10^{23}$

$Ax^2 + Bx + C = 0 \rightarrow x = \frac{-B\pm\sqrt{B^2-4AC}}{2A}$

Electric Circuits

$$I = \frac{\Delta Q}{\Delta t}$$

$$V = IR = I\left(\frac{\rho L}{A}\right)$$

$$R_{series} = \sum_{i=1}^{N} R_i$$

$$\frac{1}{R_{parallel}} = \sum_{i=1}^{N}\frac{1}{R_i}$$

$$P = IV = I^2R = \frac{V^2}{R}$$

$$Q = CV = \left(\frac{\kappa\varepsilon_0 A}{d}\right)V = (\kappa C_0)V$$

$$PE = \tfrac{1}{2}QV = \tfrac{1}{2}CV^2 = \frac{Q^2}{2C}$$

$$Q_{charge}(t) = Q_{max}\left(1 - e^{-\frac{t}{RC}}\right)$$

$$Q_{discharge}(t) = Q_{max}e^{-\frac{t}{RC}}$$

$$C_{parallel} = \sum_{i=1}^{N} C_i$$

$$\frac{1}{C_{series}} = \sum_{i=1}^{N}\frac{1}{C_i}$$

Light as a Wave

$c = f\lambda = \frac{1}{\sqrt{\varepsilon_o\mu_o}}$

$S(t) = \frac{energy}{time\times area} = c\varepsilon_o E^2(t) = c\frac{B^2(t)}{\mu_0}$

$I = S_{avg} = \tfrac{1}{2}c\varepsilon_o E_{max}^2 = c\frac{B_{max}^2}{2\mu_0}$

$P = \frac{S}{c} = \frac{Force}{Area}$

$S = S_o\cos^2\theta$

$v = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{c}{n}$

$\theta_{inc} = \theta_{refl}$

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

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$

$M_{total} = \prod_{i=1}^{N} M_i$

$d\sin\theta = m\lambda$ or $(m+\tfrac{1}{2})\lambda$

$a\sin\phi = m'\lambda$

Light as a Particle & Relativity

$$E = hf = \frac{hc}{\lambda} = pc$$

$$KE_{max} = hf - \phi = eV_{stop}$$

$$\Delta\lambda = \frac{h}{m_e c}(1-\cos\phi)$$

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$p = \gamma mv$$

$$E_{total} = KE + E_{rest} = \gamma mc^2$$

$$E_{total}^2 = p^2c^2 + m^2c^4$$

$$E_{rest} = mc^2$$

$$KE = (\gamma - 1)mc^2$$

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

$$\vec{F} = \frac{\Delta\vec{p}}{\Delta t} = \frac{\Delta(m\vec{v})}{\Delta t} = m\vec{a}$$

$$\vec{F} = -k\vec{y}$$

$$\vec{F}_C = m\frac{v^2}{R}\hat{r}$$

$$W = \Delta KE = \tfrac{1}{2}m(v_f^2 - v_i^2) = -\Delta PE$$

$$PE_{gravity} = mgy$$

$$PE_{spring} = \tfrac{1}{2}ky^2$$

Geometry

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

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

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