Name____

Physics 111 Quiz #4, October 24, 2014

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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Light from an unpolarized light source with intensity S_0, is incident on a polarizer with its transmission axis vertically oriented. The light that passes through the polarizer is then passed through a second polarizer (an analyzer). It is noted that the light that emerges from the analyzer is only 20% of the light that entered the analyzer.

a. At what angle was the analyzer set with respect to the first polarizer?

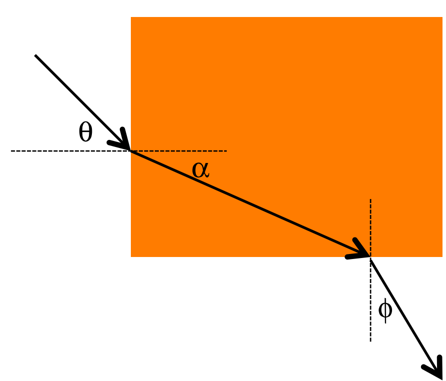
Through the first polarizer the intensity is $\frac{1}{2}S_0$. Through the second polarizer (the analyzer) the intensity varies as $S_{out} = S_{in}\cos^2\theta \rightarrow \theta = \cos^{-1}\left(\sqrt{\frac{S_{out}}{S_{in}}}\right) = \cos^{-1}\left(\sqrt{\frac{0.2S_{in}}{S_{in}}}\right) = 63.4^0$.

Suppose that the light from the analyzer is incident on a cubical sample of material with an unknown index of refraction n_{mat}. This material is surrounded on all sides by air ($n_{air} = 1.00$) and the incident light ray is shown below. The light is incident on the left side of the cube at an angle of $\theta = 70^0$ with respect to the normal to the surface and emerges from the bottom surface at an angle $\phi = 51^0$ with respect to the normal to the surface.

b. What is the value of the angle α? (Hint: $\sin(90-\beta) = \cos\beta$)

On the left surface the law of refraction looks like $n_{air}\sin\theta = n_{mat}\sin\alpha$ while on the lower surface we have (defining the angle of incidence to be β)
$n_{mat}\sin\beta = n_{mat}\sin(90-\alpha) = n_{mat}\cos\alpha = n_{air}\sin\varphi$. Dividing the two expressions we can determine the angle of refraction α. We have

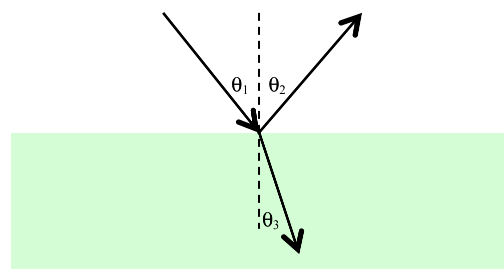
$$\frac{n_{air}\sin\theta}{n_{air}\sin\varphi} = \frac{n_{mat}\sin\alpha}{n_{mat}\cos\alpha} \rightarrow \tan\alpha = \frac{\sin\theta}{\sin\varphi} \rightarrow \alpha = \tan^{-1}\left(\frac{\sin 70}{\sin 51}\right) = 50.4^0.$$



c. What is the index of refraction n_{mat} of the material?

Using the law of refraction applied to one of the surfaces we can determine the index of refraction. We have $n_{air}\sin\theta = n_{mat}\sin\alpha \rightarrow n_{mat} = n_{air}\left(\frac{\sin\theta}{\sin\alpha}\right) = 1.00\left(\frac{\sin 70}{\sin 50.4}\right) = 1.22$.

d. Suppose that you were given the following situation in which light is incident at an angle θ_1 with respect to the normal to the surface. If θ_1 were to increase, which of the following is (are) true? (Note: This is worth 4 points and there may be more than one correct answer. Partial credit will be given for each answer you select that is correct and for each answer that you don't select that is incorrect.)



1. $\theta_2\uparrow$ and $\theta_3\uparrow$
2. $\theta_2\uparrow$ and $\theta_3\downarrow$
3. $\theta_2\downarrow$ and $\theta_3\uparrow$
4. $\theta_2\downarrow$ and $\theta_3\downarrow$
5. $\theta_2\downarrow$ and θ_3 remains constant
6. $\theta_2\uparrow$ and θ_3 remains constant
7. θ_2 remains constant and $\theta_3\uparrow$
8. θ_2 remains constant and $\theta_3\downarrow$

By the law of reflection as θ_1 increases so too must θ_2 independent of the material. If $n_2 > n_1$ then by the law of refraction, as θ_1 increases so to will θ_3. Here I assumed (although not explicitly stated) that $n_2 > n_1$. However, if $n_1 > n_2$ then as θ_1 increases θ_3 will decrease. So since it was not explicitly stated which way the indices of refraction were, everyone gets credit for choice 2.

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

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

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

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

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

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

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

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

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

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

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

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

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

$N_A = 6.02\times10^{23}$

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

Electric Circuits

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

Light as a Wave

$$c = f\lambda = \frac{1}{\sqrt{\varepsilon_o\mu_o}}$$
$$S(t) = \frac{energy}{time\times area} = c\varepsilon_o E^2(t) = c\frac{B^2(t)}{\mu_0}$$
$$I = S_{avg} = \tfrac{1}{2}c\varepsilon_o E_{\max}^2 = c\frac{B_{\max}^2}{2\mu_0}$$
$$P = \frac{S}{c} = \frac{Force}{Area}$$
$$S = S_o\cos^2\theta$$
$$v = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{c}{n}$$
$$\theta_{inc} = \theta_{refl}$$
$$n_1\sin\theta_1 = n_2\sin\theta_2$$
$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$
$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$
$$M_{total} = \prod_{i=1}^{N} M_i$$
$$d\sin\theta = m\lambda \text{ or } (m+\tfrac{1}{2})\lambda$$
$$a\sin\phi = m'\lambda$$

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

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

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

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