Name________________________________________

Physics 111 Quiz #6, February 20, 2015

*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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The questions below are not necessarily related to one another.

1. A vertically polarized beam of light with intensity $S_0$ passes through a sheet of Polaroid with its transmission axis at a $30^0$ angle to the vertical. The light that emerges from the first Polaroid is incident of a second sheet of Polaroid with its transmission axis along the vertical. What fraction of the beam's original intensity is transmitted?

   A vertically polarized beam of light is passed through a Polaroid with its transmission axis at $30^o$ with respect to the vertical has $S_{T,1} = S_o \cos^2 30 = 0.75 I_o$ transmitted. This transmitted beam is incident on a Polaroid whose transmission axis is aligned with the vertical. The transmitted intensity is given by the equation above with $S_{T,2} = 0.75 S_o \cos^2 30 = 0.563 S_o = 56.3\% S_o$.

2. Suppose a point source of light generates $60W$. Four meters away there is a light detector that is 75% efficient and the detector has an area $10cm^2$ of oriented with its normal directed at the point source. What power will the detector record?

   The intensity is defined as the power radiated per unit area. Thus the intensity *4m* away in any direction from the light source is $S = \frac{P}{A} = \frac{60W}{4\pi(4m)^2} = 0.298 \frac{W}{m^2}$. The detector only occupies a small fraction of the total surface area of the sphere centered on the light source and further the detector is only 75% efficient. Thus the power at the detector is

$$P_D = 0.75 S A_D = 0.75 \times 0.298 \tfrac{W}{m^2}\left(10cm^2 \times \frac{1m^2}{(100cm)^2}\right) = 2.2 \times 10^{-4} W$$

3. A small bright light is at the bottom of a large $8\,ft$ deep swimming pool filled with water ( $n_{water} = 1.33$). As viewed from above, what will be the radius of the circle of light?

We find the critical angle from

$n_1 \sin\theta_1 = n_2 \sin\theta_2 \rightarrow n_1 \sin\theta_c = n_2 \sin 90 \rightarrow \sin\theta_c = \frac{1.00}{1.33} \rightarrow \theta_c = 48.8^o$. The radius of the ring of light is given from $r = d\tan\theta_c = 8\,ft \times \tan 48.8 = 9.1\,ft$

4. When light strikes a plane boundary between two media with different refractive indices which of the following cannot occur?
   a. There is a reflected beam, but no transmitted beam.
   b. There is a transmitted beam, but no reflected beam.
   c. There are both transmitted and reflected beams.
   d. The speed of light increases on entering the second medium from the first.

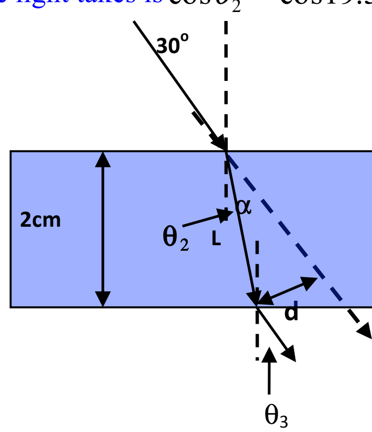
5. Consider a slab of glass ($n_{glass} = 1.50$) with thickness $t = 2.0cm$. Suppose that the upper and lower surfaces of the glass are parallel to each other and that light is incident on the upper surface of the glass at an angle of $\theta = 30^0$ with respect to the normal to the surface. What is displacement (the *perpendicular distance shifted*) of the emerging beam from its incident direction?

Using the diagram below we have at the upper surface, using Snell's law

$n_{air} \sin 30 = n_2 \sin\theta_2 = 1.5 \sin\theta_2 \rightarrow \theta_2 = \sin^{-1}(0.333) = 19.5^o$. Since the upper and lower surfaces are parallel, the ray emerges parallel to itself, but is displaced by an amount *d* from its incident direction. To determine the displacement of the beam we first realize that $30^o = \theta_2 + \alpha$, so that $\alpha = 30^o - 19.5^o = 10.5^o$. Therefore from the geometry we have

$\sin\alpha = \frac{d}{L} \rightarrow d = L\sin\alpha = \frac{0.02m}{\cos(19.5)}\sin(10.5) = 0.00389m = 0.39cm = 3.9mm$. Where again from the geometry the path the light takes is $\cos\theta_2 = \cos 19.5 = \frac{2cm}{L} \rightarrow L = \frac{0.02m}{\cos 19.5} = 0.021m$.

The diagram is below.



# 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

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

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

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

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

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

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

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

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

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

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

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

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

$N_A = 6.02\times10^{23}$

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

## Electric Circuits

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

## Light as a Wave

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

## 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

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

## Misc. Physics 110 Formulae

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

## Geometry

$$Circles: \quad C = 2\pi r = \pi D \qquad A = \pi r^2$$
$$Triangles: \quad A = \tfrac{1}{2}bh$$
$$Spheres: \quad A = 4\pi r^2 \qquad V = \tfrac{4}{3}\pi r^3$$