Name $\qquad$
Physics 111 Quiz \#5, February 21, 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.

1. Consider the situation shown below. A piece of glass $\left(n_{\text {glass }}=1.5\right)$ has been cut into an equilateral triangle and a beam of light is incident on the left side at an angle $\theta=45^{\circ}$. What is the angle (with respect to the normal) at which the light ray will emerge from the right side of the equilateral triangle? Draw the path of the light ray on the diagram below. (The normal on the right side surface is drawn for you.)


On the left surface, we apply the law of refraction
$n_{1} \sin \theta_{1}=n_{2} \sin \theta_{2} \rightarrow \theta_{2}=\sin ^{-1}\left(\frac{n_{1} \sin \theta_{1}}{n_{2}}\right)=\sin ^{-1}\left(\frac{1.00 \sin 45}{1.50}\right)=28.1^{0}$.
Next using the geometry of the system, we have
$90^{\circ}=\theta_{2}+\theta_{3} \rightarrow \theta_{3}=90^{\circ}-28.1^{0}=61.9^{\circ}$
$\theta_{3}+60^{0}+\theta_{4}=180 \rightarrow \theta_{4}=58.1^{0}$
$\theta_{4}+\theta_{5}=90^{\circ} \rightarrow \theta_{5}=31.9^{\circ}$
On the right surface, we apply the law of refraction
$n_{\text {glass }} \sin \theta_{5}=n_{\text {air }} \sin \theta_{6} \rightarrow \theta_{6}=\sin ^{-1}\left(\frac{n_{\text {glass }} \sin \theta_{5}}{n_{\text {air }}}\right)=\sin ^{-1}\left(\frac{1.50 \sin 31.9}{1.00}\right)=52.4^{0}$
2. Suppose that the light incident on the left surface is unpolarized and has intensity $S_{0}$. Each time that the light strikes a surface it loses $4 \%$ of its intensity. If the light that emerges from the right side were allowed to be incident on a polarizer with a vertically oriented transmission axis, in terms of $S_{0}$, what fraction of the incident light will be transmitted through the polarizer?
a. $\quad 0.96$
b. 0.92
c. $\quad 0.50$
d. 0.46
e. 0
3. A ray of light strikes a material whose index of refraction is $n$, resulting in a reflected ray and a refracted ray. The index of refraction of air is 1.0 . If the incident angle $\theta$ is decreased slightly, what happens to the reflected angle, $\theta_{l}$ and the refracted angle $\theta_{2}$ ?
a. Both $\theta_{l}$ and $\theta_{2}$ increase.
b. $\theta_{l}$ increases and $\theta_{2}$ decreases.
c. $\theta_{1}$ decreases and $\theta_{2}$ increases.
d. Both $\theta_{1}$ and $\theta_{2}$ decrease.


## Physics 111 Equation Sheet

Electric Forces, Fields and Potentials

$$
\begin{aligned}
& \vec{F}=k \frac{Q_{1} Q_{2}}{r^{2}} \hat{r} \\
& \vec{E}=\frac{\vec{F}}{q} \\
& \vec{E}_{Q}=k \frac{Q}{r^{2}} \hat{r} \\
& P E=k \frac{Q_{1} Q_{2}}{r} \\
& V(r)=k \frac{Q}{r} \\
& E_{x}=-\frac{\Delta V}{\Delta x} \\
& W_{A, B}=q \Delta V_{A, B}
\end{aligned}
$$

Magnetic Forces and Fields

$$
\begin{aligned}
& F=q v B \sin \theta \\
& F=I l B \sin \theta \\
& \tau=N I A B \sin \theta=\mu B \sin \theta \\
& P E=-\mu B \cos \theta \\
& B=\frac{\mu_{0} I}{2 \pi r} \\
& \varepsilon_{\text {induced }}=-N \frac{\Delta \phi_{B}}{\Delta t}=-N \frac{\Delta(B A \cos \theta)}{\Delta t}
\end{aligned}
$$

Constants
$g=9.8 \frac{\mathrm{~m}}{\mathrm{~s}^{2}}$
$1 e=1.6 \times 10^{-19} \mathrm{C}$
$k=\frac{1}{4 \pi \varepsilon_{o}}=9 \times 10^{9} \frac{\mathrm{C}^{2}}{\mathrm{Nm}}{ }^{2}$
$\varepsilon_{o}=8.85 \times 10^{-12} \frac{\mathrm{~N} m^{2}}{\mathrm{C}^{2}}$
$1 \mathrm{eV}=1.6 \times 10^{-19} \mathrm{~J}$
$\mu_{o}=4 \pi \times 10^{-7} \frac{\mathrm{~T}_{m}}{\mathrm{~A}}$
$c=3 \times 10^{8} \frac{\mathrm{~m}}{\mathrm{~s}}$
$h=6.63 \times 10^{-34} \mathrm{JS}$
$m_{e}=9.11 \times 10^{-31} \mathrm{~kg}=\frac{0.511 \mathrm{MeV}}{c^{2}}$
$m_{p}=1.67 \times 10^{-27} \mathrm{~kg}=\frac{937.1 \mathrm{MeV}}{c^{2}}$
$m_{n}=1.69 \times 10^{-27} \mathrm{~kg}=\frac{948.3 \mathrm{MeV}}{c^{2}}$
$1 \mathrm{amu}=1.66 \times 10^{-27} \mathrm{~kg}=\frac{931.5 \mathrm{MeV}}{c^{2}}$
$N_{A}=6.02 \times 10^{23}$
$A x^{2}+B x+C=0 \rightarrow x=\frac{-B \pm \sqrt{B^{2}-4 A C}}{2 A}$

Electric Circuits

$$
\begin{aligned}
& I=\frac{\Delta Q}{\Delta t} \\
& V=I R=I\left(\frac{\rho L}{A}\right) \\
& R_{\text {series }}=\sum_{i=1}^{N} R_{i} \\
& \frac{1}{R_{\text {parallel }}}=\sum_{i=1}^{N} \frac{1}{R_{i}} \\
& P=I V=I^{2} R=\frac{V^{2}}{R} \\
& Q=C V=\left(\frac{\kappa \varepsilon_{0} A}{d}\right) V=\left(\kappa C_{0}\right) V \\
& P E=\frac{1}{2} Q V=\frac{1}{2} C V^{2}=\frac{Q^{2}}{2 C} \\
& Q_{\text {charge }}(t)=Q_{\max }\left(1-e^{-\frac{t}{R C}}\right) \\
& Q_{\text {discharge }}(t)=Q_{\max } e^{-\frac{t}{R C}} \\
& C_{p a r a l e l}=\sum_{i=1}^{N} C_{i} \\
& \frac{1}{C_{\text {series }}}=\sum_{i=1}^{N} \frac{1}{C_{i}}
\end{aligned}
$$

Light as a Particle \& Relativity

$$
\begin{aligned}
& E=h f=\frac{h c}{\lambda}=p c \\
& K E_{\max }=h f-\phi=e V_{\text {stop }} \\
& \Delta \lambda=\frac{h}{m_{e} c}(1-\cos \phi) \\
& \gamma=\frac{1}{\sqrt{1-\frac{v^{2}}{c^{2}}}} \\
& p=\gamma m v \\
& E_{\text {total }}=K E+E_{\text {rest }}=\gamma m c^{2} \\
& E_{\text {total }}^{2}=p^{2} c^{2}+m^{2} c^{4} \\
& E_{\text {rest }}=m c^{2} \\
& K E=(\gamma-1) m c^{2}
\end{aligned}
$$

Geometry
Circles: $\quad C=2 \pi r=\pi D \quad A=\pi r^{2}$
Triangles: $\quad A=\frac{1}{2} b h$
Spheres: $A=4 \pi r^{2} \quad V=\frac{4}{3} \pi r^{3}$

Light as a Wave
$c=f \lambda=\frac{1}{\sqrt{\varepsilon_{o} \mu_{o}}}$
$S(t)=\frac{\text { energy }}{\text { time } \times \text { area }}=c \varepsilon_{o} E^{2}(t)=c \frac{B^{2}(t)}{\mu_{0}}$
$I=S_{\text {avg }}=\frac{1}{2} c \varepsilon_{o} E_{\text {max }}^{2}=c \frac{B_{\text {max }}^{2}}{2 \mu_{0}}$
$P=\frac{\text { Force }}{\text { Area }}=\left\{\begin{array}{l}\frac{S}{c} \\ \frac{2 S}{c}\end{array}\right.$
$S=S_{o} \cos ^{2} \theta$
$v=\frac{1}{\sqrt{\varepsilon \mu}}=\frac{c}{n}$
$\theta_{\text {inc }}=\theta_{\text {refl }}$
$n_{1} \sin \theta_{1}=n_{2} \sin \theta_{2}$
$\frac{1}{f}=\frac{1}{d_{o}}+\frac{1}{d_{i}}$
$M=\frac{h_{i}}{h_{o}}=-\frac{d_{i}}{d_{o}}$
$M_{\text {total }}=\prod_{i=1}^{N} M_{i}$
$d \sin \theta=m \lambda$ or $\left(m+\frac{1}{2}\right) \lambda$
$a \sin \phi=m^{\prime} \lambda$

Nuclear Physics
$E_{\text {binding }}=\left(Z m_{p}+N m_{n}-m_{\text {rest }}\right) \dot{c}^{2}$
$\frac{\Delta N}{\Delta t}=-\lambda N_{o} \rightarrow N(t)=N_{o} e^{-\lambda t}$
$A(t)=A_{0} e^{-\lambda t}$
$m(t)=m_{o} e^{-\lambda t}$
$t_{\frac{1}{2}}=\frac{\ln 2}{\lambda}$

Misc. Physics 110 Formulae
$\vec{F}=\frac{\Delta \vec{p}}{\Delta t}=\frac{\Delta(m v)}{\Delta t}=m \vec{a}$
$\vec{F}=-k \vec{y}$
$\vec{F}_{C}=m \frac{v^{2}}{R} \hat{r}$
$W=\Delta K E=\frac{1}{2} m\left(v_{f}^{2}-v_{i}^{2}\right)=-\Delta P E$
$P E_{\text {gravity }}=m g y$
$P E_{\text {spring }}=\frac{1}{2} k y^{2}$
$x_{f}=x_{i}+v_{i x} t+\frac{1}{2} a_{x} t^{2}$
$v_{f x}=v_{i x}+a_{x} t$
$v_{f x}^{2}=v_{i x}^{2}+2 a_{x} \Delta x$

