Name $\qquad$
Physics 111 Quiz \#6, February 22, 2019
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 had a 250 W spherical light bulb $(\lambda=575 \mathrm{~nm})$ that emits light uniformly in all directions. At a radial distance of $2 m$ from the light bulb, what would be the power recorded on a square detector with area $1 \mathrm{~cm}^{2}$ ? Assume that the normal to the detector's surface is pointed directly at the light bulb?

$$
\begin{aligned}
& S_{L B}=\frac{P}{A}=\frac{P}{4 \pi r^{2}}=\frac{250 \mathrm{~W}}{4 \pi(2 \mathrm{~m})^{2}}=5 \frac{\mathrm{~W}}{\mathrm{~m}^{2}} \\
& P_{\text {detector }}=S_{L B} A_{\text {detector }}=5 \frac{\mathrm{~W}}{\mathrm{~m}^{2}} \times\left[1 \mathrm{~cm}^{2} \times\left(\frac{1 \mathrm{~m}}{100 \mathrm{~cm}}\right)^{2}\right]=5 \times 10^{-4} \mathrm{~W}
\end{aligned}
$$

2. Suppose that you had a different spherical light bulb than the one you used in question 1. The light bulb is a source of unpolarized light and a distance $r$ measured radially away from the light bulb, two polarizers are placed back-to-back. The one closer to the light source has its transmission axis vertical while the polarizer farther from the light bulb has its transmission axis set at an angle of $45^{\circ}$ with respect to the vertical. If the intensity of the light that is incident on the first polarizer is $S_{0}$, what fraction of the incident light emerges from the second polarizer? Assume that the normal to each polarizer's surface is pointed directly at this light bulb?
$S_{1}=\frac{1}{2} S_{0}$
$S_{2}=S_{1} \cos ^{2} \theta=\frac{1}{2} S_{0} \cos ^{2}(45)=0.25 S_{0} \Rightarrow \frac{S_{2}}{S_{0}}=25 \%$
3. Suppose that you had a green laser pointer and that you were to shine it at a piece of material with an unknown index of refraction. The piece of material is surrounded on all sides by air, as shown on the below. If the critical angle is measured and found to be $\phi=34.6^{0}$, what is the identity of the unknown material form the table on the right?


| Material | n |
| :---: | :---: |
| Glass | 1.52 |
| Sapphire | 1.76 |
| Garnet | 1.88 |
| Zircon | 2.02 |
| Diamond | 2.42 |

$n_{m} \sin \theta_{c}=n_{a} \sin 90 \rightarrow n_{m}=\frac{1}{\sin \theta_{c}}=\frac{1}{\sin 34.6}=1.76$ and the unknown material is sapphire.
4. A tall cup is partially filled with water $\left(n_{w}=1.33\right)$ to a height of $H_{\text {water }}=7.8 \mathrm{~cm}$. The diameter of the cup is $D=14.6 \mathrm{~cm}$. You look downward just over the left rim of the cup at an angle of $\theta=40.5^{0}$ with respect to the water's surface. At this angle the refraction of light at the water's surface just barely allows you to see the bottom-right corner of the cup. What
 is the height of the cup, $H_{\text {cup }}$ ?

$$
\begin{aligned}
& n_{a} \sin \theta_{a}=n_{a} \sin (90-\theta)=n_{w} \sin \theta_{w} \\
& \rightarrow \sin \theta_{w}=\frac{n_{a}}{n_{w}} \sin (90-\theta)=\frac{1.00}{1.33} \sin (90-40.5)=0.5717 \\
& \Rightarrow \theta_{w}=\sin ^{-1}(0.5717)=34.9^{0} \\
& \tan \theta_{w}=\frac{x}{H_{\text {water }}} \rightarrow x=H_{\text {water }} \tan \theta_{w}=7.8 \mathrm{~cm} \times \tan 34.9=5.4 \mathrm{~cm} \\
& y=D-x=14.6 \mathrm{~cm}-5.4 \mathrm{~cm}=9.2 \mathrm{~cm} \\
& \tan \theta=\frac{p}{y} \rightarrow p=y \tan \theta=9.2 \mathrm{~cm} \times \tan 40.5=7.9 \mathrm{~cm} \\
& H_{\text {cup }}=p+H_{\text {water }}=7.9 \mathrm{~cm}+7.8 \mathrm{~cm}=15.7 \mathrm{~cm}
\end{aligned}
$$

## Physics 111 Equation Sheet

Electric Forces, Fields and Potentials

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

Magnetic Forces and Fields

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

## Constants

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

Electric Circuits

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

Light as a Particle \& Relativity

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

$$
K E=(\gamma-1) m c^{2}
$$

## Geometry

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

Light as a Wave
$c=f \lambda=\frac{1}{\sqrt{\varepsilon_{o} \mu_{o}}}$
$S(t)=\frac{\text { energy }}{\text { time } \times \text { area }}=c \varepsilon_{o} E^{2}(t)=c \frac{B^{2}(t)}{\mu_{0}}$
$I=S_{\text {avg }}=\frac{1}{2} c \varepsilon_{o} E_{\text {max }}^{2}=c \frac{B_{\text {max }}^{2}}{2 \mu_{0}}$
$P=\frac{S}{c}=\frac{\text { Force }}{\text { Area }}$
$S=S_{o} \cos ^{2} \theta$
$v=\frac{1}{\sqrt{\varepsilon \mu}}=\frac{c}{n}$
$\theta_{\text {inc }}=\theta_{\text {refl }}$
$n_{1} \sin \theta_{1}=n_{2} \sin \theta_{2}$
$\frac{1}{f}=\frac{1}{d_{o}}+\frac{1}{d_{i}}$
$M=\frac{h_{i}}{h_{o}}=-\frac{d_{i}}{d_{o}}$
$M_{\text {total }}=\prod_{i=1}^{N} M_{i}$
$S_{\text {out }}=S_{\text {in }} e^{-\sum_{i} \mu_{x_{i}}}$
$H U=\frac{\mu_{w}-\mu_{m}}{\mu_{w}}$

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

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

