Name $\qquad$
Physics 111 Quiz \#7, March 1, 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. A lens with a focal length of 15 mm is palced on an optical bench. A 1 cm tall object is placed 24 mm to the left of this lens. A second lens with focal length is 24 mm placed a distance of 50 mm to the right of the first lens. With respect to the first lens where will the final image be locted and what type of image will be produced?

For lens 1: $\frac{1}{d_{o 1}}+\frac{1}{d_{i 1}}=\frac{1}{f_{1}} \rightarrow d_{i 1}=\left(\frac{1}{f_{1}}-\frac{1}{d_{o 1}}\right)^{-1}=\left(\frac{1}{15 m m}-\frac{1}{24 m m}\right)^{-1}=40 \mathrm{~mm}$

The image from the first lens becomes the object for the second lens. The object distance to the second lens is given by: $D=d_{i 1}+d_{o 2} \rightarrow d_{o 2}=D-d_{i 1}=50 \mathrm{~mm}-40 \mathrm{~mm}=10 \mathrm{~mm}$.

For lens 2: $\frac{1}{d_{o 2}}+\frac{1}{d_{i 2}}=\frac{1}{f_{2}} \rightarrow d_{i 2}=\left(\frac{1}{f_{2}}-\frac{1}{d_{o 2}}\right)^{-1}=\left(\frac{1}{24 m m}-\frac{1}{10 m m}\right)^{-1}=-17.1 \mathrm{~mm}$
The final image is located 17.1 mm to the left of the second lens. With respect to the first lens the image is located 32.9 mm to the right of the first lens and the final image is virtual.
2. What will be the height of the final image produced and with respect to the original object, what is the orientation of the final image?

From the first lens: $M_{1}=\frac{h_{i 1}}{h_{o}}=-\frac{d_{i 1}}{d_{o 1}} \rightarrow h_{i 1}=\left(-\frac{d_{i 1}}{d_{o 1}}\right) h_{o}=\left(-\frac{40 \mathrm{~mm}}{24 m m}\right) 1 \mathrm{~cm}=-1.7 \mathrm{~cm}$
From the second lens:

$$
M_{2}=\frac{h_{i 2}}{h_{o 2}}=\frac{h_{i 2}}{h_{i 1}}=-\frac{d_{i 2}}{d_{o 2}} \rightarrow h_{i 2}=\left(-\frac{d_{i 2}}{d_{o 2}}\right) h_{i 1}=\left(-\frac{-17.1 \mathrm{~mm}}{10 \mathrm{~mm}}\right) 1.7 \mathrm{~cm}=2.9 \mathrm{~cm}
$$

The final image is 2.9 cm tall and is inverted with respect to the original object.
3. A proton is accelerated from rest through a $150 M V$ potential difference. After accelerating, what is the speed of the proton expressed as a fraction of the speed of light?

$$
\begin{aligned}
& W=-q \Delta V=-e(-150 \mathrm{MV})=150 \mathrm{MeV}=(\gamma-1) m c^{2}=(\gamma-1)\left(937.1 \frac{\mathrm{MeV}}{c^{2}}\right) c^{2} \\
& \gamma=\frac{150 \mathrm{MeV}}{937.1 \mathrm{MeV}}+1=1.1601=\frac{1}{\sqrt{1-\frac{v^{2}}{c^{2}}}} \\
& \rightarrow v=\sqrt{1-\frac{1}{\gamma^{2}}} c=\sqrt{1-\frac{1}{(1.1601)^{2}}} c=0.507 c
\end{aligned}
$$

4. After accelerating, what is the momentum of the proton, expressed in $\mathrm{MeV} / \mathrm{c}$ units?
$p=\gamma m v=1.1601 \times \frac{937.1 \mathrm{MeV}}{c^{2}} \times 0.507 c=547.7 \frac{\mathrm{MeV}}{\mathrm{c}}$
5. Uranium-238 $\left({ }_{92}^{238} U\right)$ is radioactive and decays by emitting an alpha particle (a helium nucleus ${ }_{2}^{4} \mathrm{He}$ ) into thorium-232 ( $\left.{ }_{90}^{234} \mathrm{Th}\right)$. If the uranium nucleus is at rest at the time of decay and if we ignore the recoil of the thorium nucleus, which of the following could be used to determine the speed of the ejected alpha particle?


c. $\left(m_{238,}-m_{2}^{4} \mathrm{He}\right) c^{2}=\left(\gamma_{2}^{4} \mathrm{He}-1\right) m_{2}^{4} \mathrm{He}$
d. $\left(m_{{ }_{92}^{238} U}-m_{2_{4} \mathrm{He}}\right) c^{2}=\frac{1}{2} m_{{ }_{2}{ }_{4} \mathrm{He}} v_{{ }_{2} \mathrm{He}}^{2}$
(e. $\left(m_{92}^{238} \mathrm{U}-m_{\substack{233 \\ 90 \\ \hline 0}}-m_{2}^{4} \mathrm{He}\right) c^{2}=\left(\gamma_{2}^{4} \mathrm{He}-1\right) m_{2}{ }_{2} c_{e} c^{2}$

## 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

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

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

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

$$
p=\gamma m v
$$

$$
E_{\text {total }}=K E+E_{\text {rest }}=\gamma m c^{2}
$$

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

$$
E_{r e s t}=m c^{2}
$$

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

## Geometry

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

Light as a Wave

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

Nuclear Physics

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

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

