Name $\qquad$
Physics 111 Quiz \#4, February 9, 2018
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.

A rectangular loop of conducting wire of length
$L=25 \mathrm{~cm}$ and width $W=17 \mathrm{~cm}$ has a mass
$m=250 \mathrm{~g}$ and an electrical resistance $R=0.018 \Omega$.
The loop is suspended vertically in a magnetic field of strength $B=8 T$ oriented perpendicular to the plane of the conducting loop. The magnetic filed exists only above the line labeled AA. The wire released from rest and is allowed to fall vertically through the magnetic field. As it falls it accelerates and ultimately reaches a terminal speed $v_{t}$, where the terminal speed is the speed reached when the net acceleration vanishes.


1. What is the terminal speed of the wire loop?

$$
\begin{aligned}
& F_{B}-F_{W}=m a_{y}=0 \\
& \rightarrow I W B=\left(\frac{B W v}{R}\right) W B=\frac{B^{2} W^{2} v_{t}}{R}=m g \\
& v_{t}=\frac{R m g}{B^{2} W^{2}}=\frac{0.018 \Omega \times 0.25 \mathrm{~kg} \times 9.8 \frac{\mathrm{~m}}{\mathrm{~s}^{2}}}{(8 T \times 0.17 \mathrm{~m})^{2}}=0.024 \frac{\mathrm{~m}}{\mathrm{~s}}=2.4 \frac{\mathrm{~cm}}{\mathrm{~s}}
\end{aligned}
$$

2. What is the direction of the current induced in the wire loop? To earn partial to full credit, explain you answer fully.

As the loop falls the magnetic flux through the loop is decreasing through the area bounded by the loop. To oppose the decrease in the magnetic flux the loop produces a current that flows clockwise. This clockwise current produces a magnetic field through the area bounded by the loop that adds to the field that is there to oppose the decrease in magnetic flux.
3. As the loop falls, how much energy per second is dissipated across the conducting loop as heat?

$$
P=I^{2} R=\left(\frac{B W v}{R}\right)^{2} R=\frac{B^{2} W^{2} v^{2}}{R}=\frac{\left(8 T \times 0.17 \mathrm{~m} \times 0.024 \frac{\mathrm{~m}}{s}\right)^{2}}{0.018 \Omega}=0.059 \mathrm{~J}=59 \mathrm{~mJ}
$$

4. A bar magnet is dropped into a vertical aluminum tube. Suppose the north pole of the magnet is pointing down. You look down the tube from the top (south pole end of the magnet is pointing up at you). Which one of the following is true at any instant, as viewed by you, while the magnet is inside the tube?
a. Current circulates around the tube in a counterclockwise fashion below the magnet and the magnet experiences a net force pointing up.
b. Current circulates around the tube in a clockwise fashion below the magnet and the magnet experiences a net force pointing up.
c. Current circulates around the tube in a counterclockwise fashion below the magnet and the magnet experiences a net force pointing down-
d. Current circulates around the tube in a clockwise fashion below the magnet and the magnet experiences a net force pointing down-
e. The direction of the net force on the bar and the direction of the induced current cannot both be determined without knowing the speed of the falling magnet.

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

$$
\begin{aligned}
& F=q v B \sin \theta \\
& F=I l B \sin \theta \\
& B=\frac{\mu_{0} I}{2 \pi r}
\end{aligned}
$$

$$
\varepsilon_{\text {induced }}=-N \frac{\Delta \phi_{B}}{\Delta t}=-N \frac{\Delta(B A \cos \theta)}{\Delta t}
$$

## Constants

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

Electric Circuits

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

$$
Q_{\text {discharge }}(t)=Q_{\max } e^{-\frac{t}{R C}}
$$

$$
C_{\text {parallel }}=\sum_{i=1}^{N} C_{i}
$$

$$
\frac{1}{C_{\text {series }}}=\sum_{i=1}^{N} \frac{1}{C_{i}}
$$

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

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

Nuclear Physics

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

Misc. Physics 110 Formulae

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

$$
\phi=\tan ^{-1}\left(\frac{A_{y}}{A_{x}}\right)
$$

$\vec{v}_{f}=\vec{v}_{i}+\vec{a} t$
$v_{f}^{2}=v_{i}^{2}+2 a \Delta x$
$\vec{x}_{f}=\vec{x}_{i}+\vec{v}_{i} t+\frac{1}{2} \vec{a} t^{2}$

