Name $\qquad$
Physics 111 Quiz \#5, February 13, 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.

The questions below are not necessarily related to one another.

1. Suppose that you have the following situation in which there are two regions of space with the same constant magnitude of a magnetic field $B$ but the direction of the field is different in the two regions. In one region the magnetic field is pointing out of the page and in the other it is pointing into the page. The magnetic field is perpendicular to the plane of the circuit. The rails have negligible resistance and the total resistance of the circuit is in the bar (of length $L$ and mass $m$, colored blue, with resistance $R$ ). If the bar (initially located at point A) is given an initial velocity ( $v_{i}$ ) to the right, describe in words what happens to the bar as it crosses between the two magnetic field regions being sure to address what is(are) the direction(s) of any induced current(s) in the bar and what is(are) the direction(s) of the force(s) that act on the bar in your answer.


Part A: In the region in which the magnetic field is pointing out of the page, the net magnetic flux is increasing as the bar moves to the right (the flux of fields is out of page). So, by Faraday's law, we need to oppose this increase in flux with a current (and an associated magnetic field produced by the current flowing in the wire.) This current will flow $\boldsymbol{C W}$ (by the RHR) and the force on the wire will be (by the RHR) opposite to the motion of the bar, or in the negative $x$-direction if the bar is moving in the $+\boldsymbol{x}$ direction.

Part B: When the bar crosses over into the region in which the magnetic field is pointing into the page, the net magnetic flux is decreasing. To see this, assume for the sake of argument that there were say " 12 " magnetic field lines pointing out of the page and when the bar gets into the field pointing into the page, say it has crossed over " 3 " field lines pointing into the page. This would leave a net " 9 " field pointing out of the page, so the net flux of field lines would be decreasing. So, by Faraday's law, we need to oppose this decrease in flux with a current (and an associated magnetic field produced by the current flowing in the wire.) This current will flow $\boldsymbol{C C W}$ (by the RHR) and the force on the wire will be (by the RHR) opposite to the motion of the bar (which is still moving in the +x -direction), so the force is in the negative $\boldsymbol{x}$-direction.
2. A region of magnetic field exists in the region of space. The magnetic field is constant in magnitude ( $B=2 T$ ) and points into the page. A brass ring (mass $m=0.5 \mathrm{~kg}$ and radius $r=10 \mathrm{~cm}$ ) is slid up the plane of the page (assumed frictionless) with the normal to the loop parallel to the magnetic field. As the ring enters the region of magnetic field at the bottom with speed $v=2 \frac{m}{s}$ and exits the region of magnetic field at the top, which of the
 following is(are) true?
a. The induced current in the ring is clockwise and the magnetic force on the ring points up the plane of the page at both points.
b. The induced current is counter-clockwise and the magnetic force on the ring points up the plane of the page at both points.
c. The induced current is clockwise and the magnetic force on the ring points down the plane of the page at both points.
d. The induced current is counter-clockwise and the magnetic force on the ring points down the plane of the page at both points.
e. The induced current alternates: clockwise as the ring enters the magnetic field, counter-clockwise as it exits the magnetic field and the magnetic force on the ring points down the plane of the page at both points.
f. The induced current alternates: counter-clockwise as the ring enters the magnetic field, clockwise as it exits the magnetic field and the magnetic force on the ring points up the plane of the page at both points.
g. The induced current and the magnetic force are both zero as the ring enters and exits the magnetic field.
3. A square loop of wire with 2.0 m sides is perpendicular to a uniform magnetic field with half of the loop in the field as shown below. Suppose that the magnetic field is pointing out of the page and is varying according to $B=0.042+0.32 t$ (where $B$ is measured in Teslas) for times $0 s \leq t \leq 10 s$ and the loop of wire is made out of a 2 mm diameter piece of copper ( $\rho_{C u}=1.7 \times 10^{-8} \Omega \mathrm{~m}$ ), what are the magnitude and direction of the induced current?

$$
\begin{aligned}
& R=\frac{\rho L}{A}=\frac{\rho(4 L)}{\pi r^{2}}=\frac{4 \times 1.8 \times 10^{-8} \Omega m \times 2 m}{\pi\left(1 \times 10^{-3} m\right)^{2}}=4.6 \times 10^{-2} \Omega \quad \\
& |I|=\left|\frac{\varepsilon}{R}\right|=\left|\frac{N \Delta(B A \cos \theta)}{R \Delta t}\right|=\left|\frac{L^{2}}{2 R}\left(\frac{\Delta B}{\Delta t}\right)\right|=\left|\frac{(2 m)^{2}}{2 \times 4.6 \times 10^{-2} \Omega}\left(\frac{(0.042+0.32(10))-(0,042)}{10 s}\right)\right|=13.9 \mathrm{~A}
\end{aligned}
$$

The direction of the current flow is clockwise to oppose the increase in magnetic flux. On the actual quiz no diameter of the wire was given so an actual current cannot be determined. I didn't penalize anyone for calculating a current, but everyone should have realized that the area term in the formula for the resistance is not the area of the loop, but rather the cross-sectional area of the wire.

## Physics 111 Equation Sheet

Electric Forces, Fields and Potentials

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

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

## Constants

$g=9.8 \frac{m}{s^{2}}$
$1 e=1.6 \times 10^{-19} \mathrm{C}$
$k=\frac{1}{4 \pi \varepsilon_{o}}=9 \times 10^{9} \frac{\mathrm{C}^{2}}{\mathrm{Nm}^{2}}$
$\varepsilon_{o}=8.85 \times 10^{-12} \frac{\mathrm{~N} n^{2}}{c^{2}}$
$1 \mathrm{e} V=1.6 \times 10^{-19} \mathrm{~J}$
$\mu_{o}=4 \pi \times 10^{-7} \frac{T_{m}}{A}$
$c=3 \times 10^{8} \frac{m}{s}$
$h=6.63 \times 10^{-34} \mathrm{Js}$
$m_{e}=9.11 \times 10^{-31} \mathrm{~kg}=\frac{0.511 \mathrm{MeV}}{c^{2}}$
$m_{p}=1.67 \times 10^{-27} \mathrm{~kg}=\frac{937.1 \mathrm{MeV}}{c^{2}}$
$m_{n}=1.69 \times 10^{-27} \mathrm{~kg}=\frac{948.3 \mathrm{MeV}}{c^{2}}$
$1 \mathrm{amu}=1.66 \times 10^{-27} \mathrm{~kg}=\underline{931.5 \mathrm{MeV}}$

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

Light as a Particle \& Relativity

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

## Light as a Wave

$$
\begin{aligned}
& c=f \lambda=\frac{1}{\sqrt{\varepsilon_{o} \mu_{o}}} \\
& S(t)=\frac{\text { energy }}{\text { time } \times \text { area }}=c \varepsilon_{o} E^{2}(t)=c \frac{B^{2}(t)}{\mu_{0}} \\
& I=S_{\text {arg }}=\frac{1}{2} c \varepsilon_{o} E_{\max }^{2}=c \frac{B_{\max }^{2}}{2 \mu_{0}} \\
& P=\frac{S}{c}=\frac{\text { Force }}{\text { Area }} \\
& S=S_{o} \cos ^{2} \theta \\
& v=\frac{1}{\sqrt{\varepsilon \mu}}=\frac{c}{n} \\
& \theta_{\text {inc }}=\theta_{\text {ref }}
\end{aligned}
$$

$$
n_{1} \sin \theta_{1}=n_{2} \sin \theta_{2}
$$

$$
\frac{1}{f}=\frac{1}{d_{o}}+\frac{1}{d_{i}}
$$

$$
M=\frac{h_{i}}{h_{o}}=-\frac{d_{i}}{d_{o}}
$$

$$
M_{\text {tooal }}=\prod_{i=1}^{N} M_{i}
$$

$$
S_{o u t}=S_{i n} e^{-\sum^{\mu x_{i}}}
$$

$$
H U=\frac{\mu_{w}-\mu_{m}}{\mu_{w}}
$$

Nuclear Physics

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

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

## Geometry

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

