Name____

Physics 111 Quiz #4, February 10, 2017

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.

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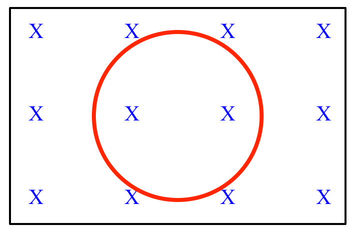
1. Suppose that there is a region of space below in which a magnetic field exists. The magnetic field is pointing into the page as shown below and varies in time according to $B(t) = 1.7 + 0.4t$ over the interval $0 \le t \le 10$. The magnetic field is measured in teslas and time in seconds. A circular loop of wire with a diameter $D = 30cm$ lies in the plane of the page with its normal parallel to the magnetic field. If the loop has a resistance $R = 2.3\Omega$, what is the magnitude and direction of the current flowing in the loop of wire over the time interval $0 \le t \le 10$?



$$\varepsilon = \left| -N \frac{\Delta\phi_B}{\Delta t} \right| = \pi \left(\frac{D}{2} \right)^2 \frac{\Delta B}{\Delta t} = \pi \left(\frac{0.3m}{2} \right)^2 \left(0.4 \tfrac{T}{s} \right) = 0.028V$$

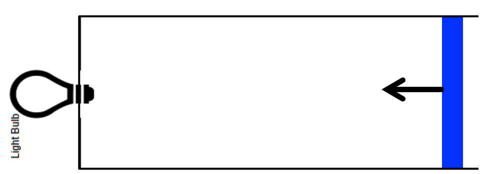
$$B_f = 1.7T + 0.4 \tfrac{T}{s} \times 10s = 5.7T; \quad B_i = 1.7T + 0.4 \tfrac{T}{s} \times 0s = 1.7T$$

$$I = \frac{\varepsilon}{R} = \frac{0.028V}{2.3\Omega} = 0.0123A = 12.3mA$$

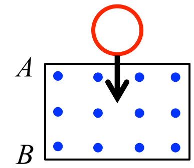
and the direction CCW to oppose the change in magnetic flux.

2. Consider the following circuit in which a light bulb is connected to low-resistance rails on which a moveable metal bar with resistance R is placed. The bar with length l initially at rest on the right side of the rails is given a small kick and travels along the rails toward the left at a velocity v. A constant magnetic field of strength B points perpendicular to the plane of the loop everywhere. As the bar moves to the left energy is dissipated across the light bulb. What is the expression for the energy that's dissipated per unit time in terms of B, l, v, and R?

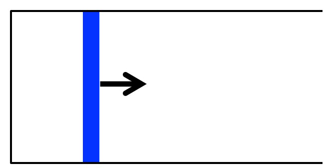
$$P = \frac{\varepsilon^2}{R} = \frac{B^2 l^2 v^2}{R}$$



3. A copper ring is dropped vertically through a horizontally oriented magnetic field as shown below. The direction of the force on the ring due to electromagnetic induction only at point A (as the ring enters the region of magnetic field) and at point B (as the ring exits the region of magnetic field) is
   a. zero because the ring experiences no force due to electromagnetic induction.
   b. directed up at point A and up at point B.
   c. directed up at point A and down at point B.
   d. directed down at point A and up at point B.
   e. directed down at point A and down at point B.



4. Consider the situation below in which a bar of length $l = 0.05m$ and resistance $R = 2.3\Omega$ initially at rest is given a small kick to the right. As the bar moves to the right a current is induced to flow in the loop of wire due to the changing magnetic flux across the loop. Suppose that the initial velocity of the bar is $v = 3.2\frac{m}{s}$, the magnetic field is everywhere constant with strength $B = 2.7T$, what is the initial electric field induced across the movable bar? Assume that the magnetic field points perpendicular to the plane of the loop and points out of the page at you. Hint: Electric field is a vector, so be sure to calculate a magnitude and a direction for the electric field.



$$\varepsilon = Blv = 2.7T \times 0.05m \times 3.2\tfrac{m}{s} = 0.432V$$

$$E = \left| -\frac{\Delta V}{\Delta x} \right| = \frac{\varepsilon}{l} = \frac{0.432V}{0.05m} = 8.64\tfrac{V}{m}$$

To determine the direction of the electric field we need to know the direction of the current flow. Since the flux in increasing out of the page through the loop of wire as the bar moves, the current will flow CW to oppose the change in magnetic flux. Thus the current will flow down the bar from the top rail to the bottom rail and thus the electric field will point down the bar from the upper to the lower rail.

Physics 111 Equation Sheet

Electric Forces, Fields and Potentials

$$\vec{F} = k\frac{Q_1Q_2}{r^2}\hat{r}$$

$$\vec{E} = \frac{\vec{F}}{q}$$

$$\vec{E}_Q = k\frac{Q}{r^2}\hat{r}$$

$$PE = k\frac{Q_1Q_2}{r}$$

$$V(r) = k\frac{Q}{r}$$

$$E_x = -\frac{\Delta V}{\Delta x}$$

$$W = -q\Delta V_{f,i}$$

Magnetic Forces and Fields

$$F = qvB\sin\theta$$

$$F = ILB\sin\theta$$

$$\tau = NIAB\sin\theta = \mu B\sin\theta$$

$$PE = -\mu B\cos\theta$$

$$B = \frac{\mu_0 I}{2\pi r}$$

$$\varepsilon_{induced} = -N\frac{\Delta\phi_B}{\Delta t} = -N\frac{\Delta(BA\cos\theta)}{\Delta t}$$

Constants

$$g = 9.8\,\tfrac{m}{s^2}$$

$$1e = 1.6\times10^{-19}C$$

$$k = \frac{1}{4\pi\varepsilon_o} = 9\times10^9\,\tfrac{Nm^2}{C^2}$$

$$\varepsilon_o = 8.85\times10^{-12}\,\tfrac{C^2}{Nm^2}$$

$$1eV = 1.6\times10^{-19}J$$

$$\mu_o = 4\pi\times10^{-7}\,\tfrac{Tm}{A}$$

$$c = 3\times10^8\,\tfrac{m}{s}$$

$$h = 6.63\times10^{-34}Js$$

$$m_e = 9.11\times10^{-31}kg = \frac{0.511MeV}{c^2}$$

$$m_p = 1.67\times10^{-27}kg = \frac{937.1MeV}{c^2}$$

$$m_n = 1.69\times10^{-27}kg = \frac{948.3MeV}{c^2}$$

$$1amu = 1.66\times10^{-27}kg = \frac{931.5MeV}{c^2}$$

$$N_A = 6.02\times10^{23}$$

$$Ax^2+Bx+C=0 \rightarrow x = \frac{-B\pm\sqrt{B^2-4AC}}{2A}$$

Electric Circuits

$$I = \frac{\Delta Q}{\Delta t}$$

$$V = IR = I\left(\frac{\rho L}{A}\right)$$

$$R_{series} = \sum_{i=1}^{N} R_i$$

$$\frac{1}{R_{parallel}} = \sum_{i=1}^{N}\frac{1}{R_i}$$

$$P = IV = I^2R = \frac{V^2}{R}$$

$$Q = CV = \left(\frac{\kappa\varepsilon_0 A}{d}\right)V = (\kappa C_0)V$$

$$W = U = \tfrac{1}{2}QV = \tfrac{1}{2}CV^2 = \frac{Q^2}{2C}$$

$$Q_{\text{charge}}(t) = Q_{\max}\left(1-e^{-\frac{t}{RC}}\right)$$

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

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

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

Light as a Wave

$$c = f\lambda = \frac{1}{\sqrt{\varepsilon_o\mu_o}}$$

$$S(t) = \frac{energy}{time\times area} = c\varepsilon_o E^2(t) = c\frac{B^2(t)}{\mu_0}$$

$$I = S_{avg} = \tfrac{1}{2}c\varepsilon_o E_{\max}^2 = c\frac{B_{\max}^2}{2\mu_0}$$

$$P = \frac{S}{c} = \frac{Force}{Area}$$

$$S = S_o\cos^2\theta$$

$$v = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{c}{n}$$

$$\theta_{inc} = \theta_{refl}$$

$$n_1\sin\theta_1 = n_2\sin\theta_2$$

$$\frac{1}{f} = \frac{1}{d_o}+\frac{1}{d_i}$$

$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

$$M_{total} = \prod_{i=1}^{N} M_i$$

$$S_{out} = S_{in}e^{-\sum_i \mu_i x_i}$$

$$HU = \frac{\mu_w-\mu_m}{\mu_w}$$

Light as a Particle & Relativity

$$E = hf = \frac{hc}{\lambda} = pc$$

$$KE_{\max} = hf - \phi = eV_{stop}$$

$$\Delta\lambda = \frac{h}{m_e c}(1-\cos\phi)$$

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$p = \gamma mv$$

$$E_{total} = KE + E_{rest} = \gamma mc^2$$

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

$$E_{rest} = mc^2$$

$$KE = (\gamma-1)mc^2$$

Nuclear Physics

$$E_{binding} = (Zm_p + Nm_n - m_{rest})c^2$$

$$\frac{\Delta N}{\Delta t} = -\lambda N_o \rightarrow N(t) = N_o e^{-\lambda t}$$

$$A(t) = A_o e^{-\lambda t}$$

$$m(t) = m_o e^{-\lambda t}$$

$$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

Geometry

$$Circles:\ C = 2\pi r = \pi D \qquad A = \pi r^2$$

$$Triangles:\ A = \tfrac{1}{2}bh$$

$$Spheres:\ A = 4\pi r^2 \qquad V = \tfrac{4}{3}\pi r^3$$

Misc. Physics 110 Formulae

$$\vec{F} = \frac{\Delta\vec{p}}{\Delta t} = \frac{\Delta(m\vec{v})}{\Delta t} = m\vec{a}$$

$$\vec{F} = -k\vec{y}$$

$$\vec{F}_C = m\frac{v^2}{R}\hat{r}$$

$$W = \Delta KE = \tfrac{1}{2}m\left(v_f^2 - v_i^2\right) = -\Delta PE$$

$$PE_{gravity} = mgy$$

$$PE_{spring} = \tfrac{1}{2}ky^2$$

$$|\vec{A}| = \sqrt{A_x^2 + A_y^2}$$

$$\phi = \tan^{-1}\left(\frac{A_y}{A_x}\right)$$

$$\vec{v}_f = \vec{v}_i + \vec{a}t$$

$$v_f^2 = v_i^2 + 2a\Delta x$$

$$\vec{x}_f = \vec{x}_i + \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2$$