Name____

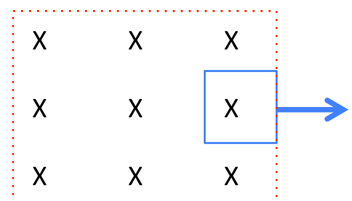
Physics 111 Quiz #5, February 15, 2019

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 magnetic field of constant strength $B = 2.5T$ is oriented perpendicular to the plane of the page and points down into the page. The magnetic field exists only in the region bounded by the red dashed box. A square loop of wire (the blue box) is placed in the plane of the page with the normal to the loop parallel to the magnetic field. As shown in the figure below, the loop is pulled from the field at a constant speed of $v = 0.2\frac{m}{s}$ in the direction of the arrow. What are the magnitude and direction of the current induced in the loop of wire? Assume that the resistance of the loop of wire is 10Ω and the wire loop has sides of length $L = 15cm$.



$$I = \frac{\varepsilon}{R} = \left| -\frac{N}{R}\frac{\Delta\left(BA\cos\theta\right)}{\Delta t} \right| = \left| \frac{B}{R}\frac{\Delta A}{\Delta t} \right| = \frac{Blv}{R} = \frac{2.5T \times 0.15m \times 0.2\frac{m}{s}}{10\Omega} = 0.0075A = 7.5mA$$

The direction is CW to undo the change in magnetic flux.

2. What magnitude of force is needed to pull the wire loop in the figure above from the magnetic field at a constant speed of $v = 0.2\frac{m}{s}$?

$$F_{me} - F_B = ma_x = 0 \rightarrow F_{me} = F_B = ILB = 0.0075A \times 0.15m \times 2.5T = 0.0028N = 28mN$$

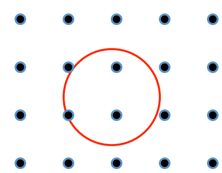
The direction is to the right in the direction of the velocity.

3. How much energy is dissipated as heat in the wire as it pulled completely from the magnetic field?

Since the velocity is constant, it takes a time $t = \frac{x}{v} = \frac{0.15m}{0.2\frac{m}{s}} = 0.75s$ to pull the loop from the magnetic field. The energy dissipated is given by

$$P = \frac{\Delta E}{\Delta t} \rightarrow \Delta E = P\Delta t = I^2 R\Delta t = \left(0.0075A\right)^2 \times 10\Omega \times 0.75s = 0.00042J = 0.42mJ\ .$$

4. A 200 turn circular loop of copper wire, the red circle shown below, is placed in a magnetic field whose direction is parallel to the normal to the loop. The magnetic field varies in time according to $B(t) = B_{\max} e^{-at}$, where $B_{\max} = 4T$ and $\alpha = 0.04 s^{-1}$. The loop has diameter of $15cm$, resistance 2.6Ω and the magnetic field varies over a time interval $0s \le t \le 10s$. What are the magnitude and direction of the current induced in the loop of wire?



$$I = \frac{\varepsilon}{R} = \left| -\frac{N}{R}\frac{\Delta(BA\cos\theta)}{\Delta t} \right| = \left| -\frac{200}{2.6\Omega} \times \pi (0.075m)^2 \left(\frac{4T\left(e^{-0.04s^{-1}\times 10s} - 1\right)}{10s} \right) \right| = 0.17A = 170mA$$ and

the direction is CCW by the right-hand-rule to undo the change in magnetic flux.

5. If the intensity of an electromagnetic wave doubles which of the following may occur?
   a. The electric field must double.
   b. The magnetic field must double.
   c. Both the electric and magnetic fields must double.
   d. Both the electric and magnetic field must increase by a factor of $\sqrt{2}$.
   e. Both the electric and magnetic field must decrease by a factor of $\sqrt{2}$.
   f. Both the electric and magnetic fields remain constant.

Physics 111 Equation Sheet

Electric Forces, Fields and Potentials

$$\vec{F} = k\frac{Q_1 Q_2}{r^2}\hat{r}$$
$$\vec{E} = \frac{\vec{F}}{q}$$
$$\vec{E}_Q = k\frac{Q}{r^2}\hat{r}$$
$$PE = k\frac{Q_1 Q_2}{r}$$
$$V(r) = k\frac{Q}{r}$$
$$E_x = -\frac{\Delta V}{\Delta x}$$
$$W = -q\Delta V_{f,i}$$

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

$$I = \frac{\Delta Q}{\Delta t}$$
$$V = IR = I\left(\frac{\rho L}{A}\right)$$
$$R_{series} = \sum_{i=1}^{N} R_i$$
$$\frac{1}{R_{parallel}} = \sum_{i=1}^{N}\frac{1}{R_i}$$
$$P = IV = I^2R = \frac{V^2}{R}$$
$$Q = CV = \left(\frac{\kappa\varepsilon_0 A}{d}\right)V = (\kappa C_0)V$$
$$PE = \tfrac{1}{2}QV = \tfrac{1}{2}CV^2 = \frac{Q^2}{2C}$$
$$Q_{\text{charge}}(t) = Q_{\max}\left(1-e^{-\frac{t}{RC}}\right)$$
$$Q_{\text{discharge}}(t) = Q_{\max}e^{-\frac{t}{RC}}$$
$$C_{parallel} = \sum_{i=1}^{N} C_i$$
$$\frac{1}{C_{series}} = \sum_{i=1}^{N}\frac{1}{C_i}$$

Light as a Particle & Relativity

$$E = hf = \frac{hc}{\lambda} = pc$$
$$KE_{\max} = hf - \phi = eV_{stop}$$
$$\Delta\lambda = \frac{h}{m_e c}(1-\cos\phi)$$
$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$
$$p = \gamma mv$$
$$E_{total} = KE + E_{rest} = \gamma mc^2$$
$$E_{total}^2 = p^2c^2 + m^2c^4$$
$$E_{rest} = mc^2$$
$$KE = (\gamma - 1)mc^2$$

Geometry

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

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

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

Light as a Wave

$$c = f\lambda = \frac{1}{\sqrt{\varepsilon_o\mu_o}}$$
$$S(t) = \frac{energy}{time\times area} = c\varepsilon_o E^2(t) = c\frac{B^2(t)}{\mu_0}$$
$$I = S_{avg} = \tfrac{1}{2}c\varepsilon_o E_{\max}^2 = c\frac{B_{\max}^2}{2\mu_0}$$
$$P = \frac{S}{c} = \frac{Force}{Area}$$
$$S = S_o\cos^2\theta$$
$$v = \frac{1}{\sqrt{\varepsilon\mu}} = \frac{c}{n}$$
$$\theta_{inc} = \theta_{refl}$$
$$n_1\sin\theta_1 = n_2\sin\theta_2$$
$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$
$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$
$$M_{total} = \prod_{i=1}^{N} M_i$$
$$S_{out} = S_{in}e^{-\sum_i \mu_i x_i}$$
$$HU = \frac{\mu_w - \mu_m}{\mu_w}$$

Nuclear Physics

$$E_{binding} = (Zm_p + Nm_n - m_{rest})c^2$$
$$\frac{\Delta N}{\Delta t} = -\lambda N_o \rightarrow N(t) = N_o e^{-\lambda t}$$
$$A(t) = A_o e^{-\lambda t}$$
$$m(t) = m_o e^{-\lambda t}$$
$$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

Misc. Physics 110 Formulae

$$\vec{F} = \frac{\Delta\vec{p}}{\Delta t} = \frac{\Delta(m\vec{v})}{\Delta t} = m\vec{a}$$
$$\vec{F} = -k\vec{y}$$
$$\vec{F}_C = m\frac{v^2}{R}\hat{r}$$
$$W = \Delta KE = \tfrac{1}{2}m\left(v_f^2 - v_i^2\right) = -\Delta PE$$
$$PE_{gravity} = mgy$$
$$PE_{spring} = \tfrac{1}{2}ky^2$$
$$|\vec{A}| = \sqrt{A_x^2 + A_y^2}$$
$$\phi = \tan^{-1}\left(\frac{A_y}{A_x}\right)$$
$$\vec{v}_f = \vec{v}_i + \vec{a}t$$
$$v_f^2 = v_i^2 + 2a\Delta x$$
$$\vec{x}_f = \vec{x}_i + \vec{v}_i t + \tfrac{1}{2}\vec{a}t^2$$