Name____

Physics 111 Quiz #3, October 17, 2014

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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A long straight wire conducting a current is used to generate a magnetic field throughout a region of space. The wire lies in the plane of the page and the current is flowing through the wire from the bottom of the page to the top of the page. Suppose that over an interval of time $\Delta t = 10s$ that the current changes according to $I = 16.4 - 0.7t$, where t is in seconds and I is in Amperes.

a. For this particular time-varying current, what is the change in magnetic field over a point P (with coordinates $(x, y) = (0.25, y)$ in meters)? Hint: Take the center of the wire to be located at the origin.

$$\left|\Delta B\right| = B_f - B_i = \frac{\mu_0}{2\pi r}\left|I_f - I_i\right| = \frac{4\pi \times 10^{-7}\, \frac{Tm}{A}}{2\pi(0.25m)}\left|\left(16.4A - 0.7\tfrac{A}{s} \times 10s\right) - \left(16.4A\right)\right|$$ directed into the

$$\left|\Delta B\right| = 5.6 \times 10^{-7} T$$

page.

b. Suppose now that a circular loop with diameter $5cm$ was placed with its center at point P and that the current varied in the long straight wire while the circular loop of wire was at point P. Over this interval of time, what was the magnitude of the induced potential difference across the wire loop?

There are actually two solutions to this problem depending on how the wire loop is actually oriented.

If the wire loop were oriented with the plane of the loop in the plane of the page (the normal to the loop pointing perpendicular to the page say out at you) then the magnitude of the potential difference is given by Faraday's Law:

$$\left|\varepsilon\right| = \left|-NA\cos\theta\frac{\Delta B}{\Delta t}\right| = \left|\pi r^2\frac{\Delta B}{\Delta t}\right| = \left|\pi\left(0.025m\right)^2\frac{5.6 \times 10^{-7}T}{10s}\right| = 1.1 \times 10^{-9}V.$$

The second way of solving the problem involves the wire loop oriented perpendicular to the plane of the page (with it's normal parallel to the wire.) In this case no magnetic field lines pass through the wire loop, so there is no change in magnetic flux and then the induced potential difference would be zero.

c. If the circular loop of wire were made out of copper ($\rho_{Cu} = 1.7 \times 10^{-8}\,\Omega m$) and has a cross sectional area of $A = 7.9 \times 10^{-7}\,m^2$, what are the magnitude and direction of the induced current in the circular loop of wire?

Again, there are two solutions to this problem, based on the results for part b.

If the normal the loop were parallel to the wire, then the current would be zero by Ohm's law.

If the wire loop were oriented in the plane of the page (normal pointing say out of the page at you) then the current (by Ohm's law) is

$$I = \frac{V}{R} = \frac{V}{\rho L / A} = \frac{VA}{\rho L} = \frac{1.1 \times 10^{-9} V \times 7.9 \times 10^{-7} m^2}{1.7 \times 10^{-8}\,\Omega m \times (2\pi \times 0.025 m)} = 3.25 \times 10^{-7} A$$

with the direction of the current ***clockwise*** to undo the decrease in the magnetic flux (due to the decreasing current in the wire.)

d. Suppose that you had a wire that was oriented in front of you with a constant current flowing from the floor to the ceiling. Suppose that the circular loop of wire used in the previous parts was dropped from the ceiling and allowed to fall to the floor, parallel to the wire at a fixed distance r from the wire. The loop of wire, as it falls, remains at the same fixed distance away from the wire. The force on the wire loop as it falls through the magnetic field is

1. $F = ILB$ in magnitude and the direction of the force is towards the ceiling always.
2. $F = ILB$ in magnitude and the direction of the force is towards the floor always.
3. $F = ILB$ in magnitude and the direction of the force is towards the ceiling until the loop passes the half-way point between the ceiling and the floor at which point the force changes direction and points towards the floor.
4. $F = ILB$ in magnitude and the direction of the force is towards the floor until the loop passes the half-way point between the ceiling and the floor at which point the force changes direction and points towards the ceiling.
5. is zero always.

Since the current is constant and the loop falls parallel to the wire from the ceiling to the floor the magnetic flux through the wire loop is constant and thus there is no force due to electromagnetic induction. Here too, the orientation of the loop doesn't matter, the magnetic flux will be constant either way.

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

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

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

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

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

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

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

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

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

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

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

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

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

$N_A = 6.02\times10^{23}$

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

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

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

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

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

Light as a Wave

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

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

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

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

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

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

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

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

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

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

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

$$d\sin\theta = m\lambda \text{ or } \left(m+\tfrac{1}{2}\right)\lambda$$

$$a\sin\phi = m'\lambda$$

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

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

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

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

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

$$PE_{gravity} = mgy$$

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