Name____

Physics 111 Quiz #4, October 13, 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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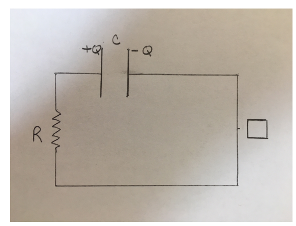
1. Suppose that you have a circuit in which a $0.01F$ capacitor is connected to a 10Ω resistor. The capacitor is allowed to fully charge using a $12V$ battery at which point the battery is removed from the system. The capacitor is connected to the resistor and subsequently allowed to discharge through the resistor as shown below. If the current in the circuit follows $I = I_{\max} e^{-\frac{t}{RC}}$ what is the current induced (magnitude and direction) in the 1000 turn, square loop of wire after one time constant? Assume that the magnetic field is constant over the square loop of wire (of area $1\times10^{-4}m^2$) and that the center of the square loop of wire has a resistance of 12.5Ω and is located $\frac{1}{2}cm$ to the right of the circuit.



$$I = \frac{\varepsilon}{R_{loop}} = \left(\frac{NA}{R_{loop}}\right)\frac{\Delta B}{\Delta t}$$

The change in time is one time constant $\Delta t = RC = 10\Omega \times 0.01F = 0.1s$.

The change in magnetic field across the wire loop is given from the change in the current. The final magnetic field will be zero at zero current (when the capacitor is fully discharged.) Thus the change in magnetic field is

$$|\Delta B| = |B_f - B_i| = \left|\left(\frac{\mu_0 I_{\max}}{2\pi r} e^{-\frac{t_f}{RC}}\right) - \left(\frac{\mu_0 I_{\max}}{2\pi r} e^{-\frac{t_i}{RC}}\right)\right| = \left|\frac{\mu_0 V_{\max}}{2\pi r R_{circuit}}\left[e^{-\frac{RC}{RC}} - e^0\right]\right|$$

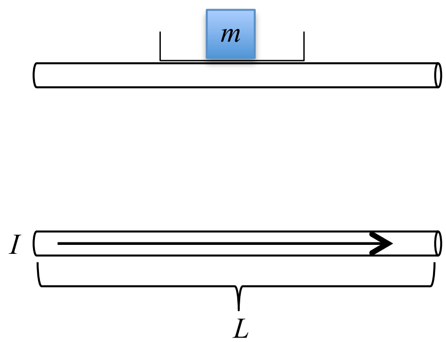
$$|\Delta B| = \left|\frac{\mu_0 V_{\max}}{2\pi r R_{circuit}}\left[e^{-1} - 1\right]\right| = \left|\left(\frac{4\pi\times10^{-7}\,\frac{Tm}{A}\times12V}{2\pi\times0.005m\times10\Omega}\right)\left[\frac{1}{e} - 1\right]\right| = 3.0\times10^{-5}T$$

The current induced in the wire loop is clockwise by the RHR with magnitude

$$I = \frac{\varepsilon}{R_{loop}} = \left(\frac{NA}{R_{loop}}\right)\frac{\Delta B}{\Delta t} = \left(\frac{1000\times1\times10^{-4}m^2}{12.5\Omega}\right)\frac{3\times10^{-5}T}{0.1s} = 2.4\times10^{-6}A = 2.4\mu A$$

2. Suppose instead of the experiment above you do the following experiment. As the capacitor is discharging through the resistor you give the square loop a small kick to the left (towards the circuit) at a speed v. In this situation the current induced in the square loop of wire would
   a. increase since the magnetic flux through the square loop is increasing with time.
   b. increase since the magnetic flux through the square loop is decreasing with time.
   c. decease since the magnetic flux through the square loop is increasing with time.
   d. decease since the magnetic flux through the square loop is decreasing with time.
   e. be unable to be determined since we don't know how the flux is changing with time.

3. Two long parallel wires each with length $L = 30cm$ and current I flowing in them are shown below. The bottom wire is fixed in space and cannot move and has the current flowing left-to-right. The upper bar can either move up or down the plane of the page, but does not because a $2.0g$ mass had been added to the pan on the upper wire. If the separation between the wires is $r = 1.0cm$, what is the magnitude and direction of the current flow in the upper wire? Ignore the mass of the wires.



The current flowing in the bottom bar produces a magnetic field at the upper wire that points out of the page. The force on this upper wire due to the magnetic field the wire is interacting with has to point up the page to balance the downward force of the weight of the added mass. Thus by the RHR the current has to flow from *right-to-left.* To determine the magnitude of the current we examine the forces that act on the upper wire. We have:

$$F_{net} = 0 = F_B - F_W \to F_B = F_W \to ILB = IL\left(\frac{\mu_0 I}{2\pi r}\right) = mg$$

$$I = \sqrt{\frac{2\pi rmg}{\mu_0 L}} = \sqrt{\frac{2\pi \times 0.01m \times 0.002kg \times 9.8\,\frac{m}{s^2}}{4\pi \times 10^{-7}\,\frac{Tm}{A} \times 0.3m}} = 57.2A$$

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

$$F = qvB\sin\theta$$
$$F = IlB\sin\theta$$
$$I = nAv_dq$$
$$\tau = NIAB\sin\theta = \mu B\sin\theta$$
$$PE = -\mu B\cos\theta$$
$$B = \frac{\mu_0 I}{2\pi r}$$
$$\varepsilon_{induced} = -N\frac{\Delta\phi_B}{\Delta t} = -N\frac{\Delta(BA\cos\theta)}{\Delta t}$$

Constants

$$g = 9.8\,\tfrac{m}{s^2}$$
$$1e = 1.6\times10^{-19}\,C$$
$$k = \frac{1}{4\pi\varepsilon_o} = 9\times10^9\,\tfrac{C^2}{Nm^2}$$
$$\varepsilon_o = 8.85\times10^{-12}\,\tfrac{Nm^2}{C^2}$$
$$1eV = 1.6\times10^{-19}\,J$$
$$\mu_o = 4\pi\times10^{-7}\,\tfrac{Tm}{A}$$
$$c = 3\times10^8\,\tfrac{m}{s}$$
$$h = 6.63\times10^{-34}\,Js$$
$$m_e = 9.11\times10^{-31}\,kg = \frac{0.511MeV}{c^2}$$
$$m_p = 1.67\times10^{-27}\,kg = \frac{937.1MeV}{c^2}$$
$$m_n = 1.69\times10^{-27}\,kg = \frac{948.3MeV}{c^2}$$
$$1amu = 1.66\times10^{-27}\,kg = \frac{931.5MeV}{c^2}$$
$$N_A = 6.02\times10^{23}$$
$$Ax^2 + Bx + C = 0 \rightarrow x = \frac{-B\pm\sqrt{B^2-4AC}}{2A}$$

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

$$Circles: \quad C = 2\pi r = \pi D \qquad A = \pi r^2$$
$$Triangles: \quad A = \tfrac{1}{2}bh$$
$$Spheres: \quad A = 4\pi r^2 \qquad V = \tfrac{4}{3}\pi r^3$$

Light as a Wave

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

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

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