Name____

Physics 111 Quiz #4, October 12, 2018

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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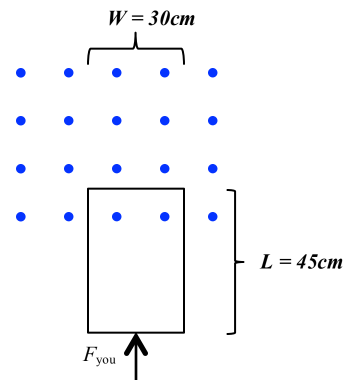
A lightweight metal loop is pushed up the plane of the page through a $|\vec{B}| = 2T$ magnetic field that is oriented perpendicular to the loop of the wire and points up, out of the plane of the page as shown on the right.



a. The wire moves into the field at a constant speed by you exerting a force, $|\vec{F}_{you}| = 20mN$. At what constant speed were you pushing the wire into the magnetic field? Assume that the wire has a resistance of 100Ω.

Constant speed means the acceleration is zero. Thus, the net force has to be zero. We have: $F_{you} - F_B = ma_y = 0 \rightarrow F_{you} = F_B = IWB$. The current in the wire is determined from Ohm's law and the potential difference induced over the wire by Faraday's law. Thus,

$I = \frac{\varepsilon}{R} = \frac{1}{R}\left|-N\frac{\Delta(BA\cos\theta)}{\Delta t}\right| = \frac{B}{R}\left|\frac{\Delta A}{\Delta t}\right| = \frac{B}{R}\left|\frac{W\Delta y}{\Delta t}\right| = \frac{BWv}{R}$. The magnetic force

$$F_{you} = IWB = \frac{W^2B^2v}{R} \rightarrow v = \frac{RF_{you}}{W^2B^2} = \frac{100\Omega \times 20\times10^{-3}T}{(0.3m\times 2T)^2} = 5.6\tfrac{m}{s}$$

b. What is the magnitude of the induced current that flows in the wire loop?

$$I = \frac{\varepsilon}{R} = \frac{BWv}{R} = \frac{2T\times 0.3m\times 5.6\frac{m}{s}}{100\Omega} = 0.034A = 34mA$$

c. What is the direction of the induced current that flows in the loop? To earn full credit you need to explain how the magnetic flux is changing and how the current is produced in response to this changing magnetic flux.

The magnetic flux is increasing through the wire loop. To oppose the increase the magnetic field produced by the wire would need to point into the plane of the paper and this would produce a clockwise current flow.

d. What are the magnitude and direction of the electric field produced in the section of the bar labeled ***W***?

$\left|\vec{E}\right| = \left|-\frac{\Delta V}{\Delta x}\right| = \frac{\varepsilon}{W} = \frac{BWv}{W} = Bv = 2T \times 5.6\tfrac{m}{s} = 11.2\tfrac{V}{m}$ and the direction of the induced electric field in the section marked ***W*** is from left to right in the direction of the current flow.

e. How much energy per unit time is generated as heat by you pushing the wire loop into the magnetic field at the constant speed in part a?

$$P = I^2 R = \left(0.034A\right)^2 \times 100\Omega = 0.113W = 113mW$$

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

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

Electric Circuits

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

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

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

Misc. Physics 110 Formulae

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