Name________________________________________

Physics 111 Quiz #4, October 16, 2020

*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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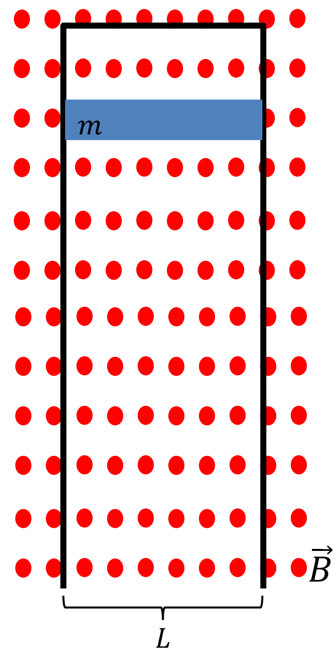
1. A platinum bar of mass $m = 250g$ is released from rest on a vertical set of wires shown below. The platinum bar has length $L = 10cm$, resistance $R$, and falls through a constant magnetic field pointing out of the page with magnitude $B = 2T$. As the bar falls, current is produced in the circuit, and the direction of the induced current flows




   a. clockwise around the circuit.

   b. counterclockwise around the circuit.

   c. clockwise at first then flows counterclockwise producing an alternating current.

   d. counterclockwise at first then flows clockwise producing an alternating current.

   e. in a manner that cannot be predicted.

2. If the platinum bar is circular with a diameter of $d = 1.2mm$, what is the resistance of the bar? Hint, the resistivity of platinum is $\rho = 1.06 \times 10^{-7}\Omega m$.

$$R = \frac{\rho L}{A} = \frac{1.06\times10^{-7}\Omega m\times0.1m}{\pi(0.6\times10^{-3}m)^2} = 0.0094\Omega$$

3. As the platinum bar falls it accelerates and its speed increases. However, after it attains a certain speed, called the terminal speed, the bar doesn't fall any faster but falls at the terminal speed for the remainder of its motion. What terminal speed does the platinum bar attain?

$$F_y\text{: } F_w - F_B = mg - ILB = mg - \frac{B^2L^2v}{R} = ma_y = 0 \rightarrow v = \frac{Rmg}{B^2L^2} = \frac{0.0094\Omega\times0.25kg\times9.8\frac{m}{s^2}}{(2T\times0.1m)^2} = 0.58\frac{m}{s}$$

Where, $\varepsilon = IR = \frac{\Delta\phi_B}{\Delta t} = B\frac{\Delta A}{\Delta t} = B\frac{L\Delta y}{\Delta t} = BLv \rightarrow I = \frac{Blv}{R}$

4. What is the energy dissipated, per unit time, as heat as the bar falls at its terminal speed?

$$P = I^2 R = \left(\frac{BLv}{R}\right)^2 R = \frac{B^2L^2v^2}{R} = \frac{\left(2T \times 0.1m \times 0.58\frac{m}{s}\right)^2}{0.0094\Omega} = 1.4W$$

5. What it the magnitude and direction of the induced electric field in the platinum bar? Be sure to explain your choice for the direction.

Since the current flows to the right in the bar (clockwise), the direction of the electric field must point to the right.

The magnitude of the electric field is:

$$E = \left|-\frac{\Delta V}{\Delta x}\right| = \frac{BLv}{L} = Bv = 2T \times 0.58\frac{m}{s} = 1.2\frac{N}{C}$$

# 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

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

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

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

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

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

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

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

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

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

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

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

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

$N_A = 6.02\times10^{23}$

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

## Electric Circuits

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

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

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

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

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

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

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

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

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

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

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

## Light as a Wave

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

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

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

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

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

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

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

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

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

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

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

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

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

## 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

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

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

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

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

$$PE_{gravity} = mgy$$

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

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

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

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

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

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