Name_____

Physics 111 Quiz #4, February 6, 2015

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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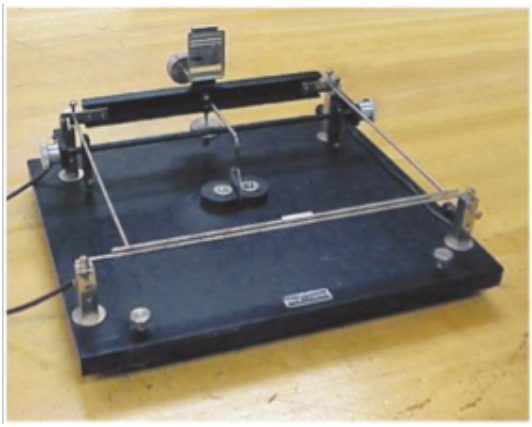
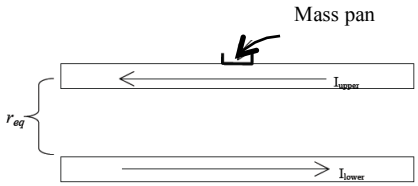
A current balance is a device with two sets of bars through which a current I can pass. The lower bar is fixed, while the upper bar is able to pivot about the back edge (with the mirror) as shown in the picture below on the left. The separation distance between the bars is fixed and this is called the equilibrium separation r_{eq}.

When the upper bar is perturbed from equilibrium the experimenter needs to bring the system of bars back into equilibrium (meaning the bars are again separated by r_{eq}) by adding masses to the pan attached to the upper bar.





1. The schematic of the experimental setup is above on the right and shows the upper and lower bars of the current balance. Given the directions of the currents in the upper and lower bars, the direction of the magnetic force on the upper bar, due to the current flowing in the lower bar is

   a. pointing up the plane of the paper.

   b. pointing down the plane of the paper.

   c. pointing into the paper.

   d. pointing out of the paper.

2. The current in the circuit is produced from a $120V$ battery (not shown, but the leads are on the left side of the picture) connected to a variable resistor (also not shown, where a variable resistor is a resistor whose resistance can be changed – just like the one you used in the RC circuits experiment a few weeks ago.) Suppose that you set the resistance in this circuit at 20Ω. What mass (in milligrams) would be required to be added to the pan on the upper bar to return the system to an equilibrium separation of $r_{eq} = \frac{1}{2}cm$ if each of the bars has a length $L = 30cm$?

The current in the bars: $V = IR \rightarrow I = \frac{V}{R} = \frac{120V}{20\Omega} = 6A$.

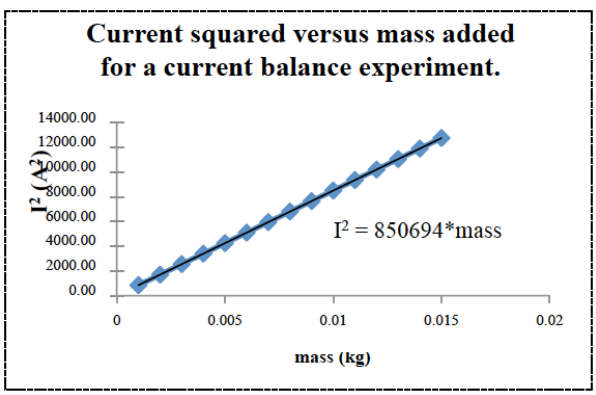
The forces that act on the upper bar can be used to determine the mass needed. We have

$$\sum F_y : F_B - F_W = ma_y = 0 \rightarrow F_B = F_W \rightarrow ILB = mg$$

$$m = \frac{ILB}{g} = \frac{IL}{g}\left(\frac{\mu_0 I}{2\pi r_{eq}}\right) = \frac{\mu_0 L I^2}{2\pi r_{eq} g} = \frac{4\pi \times 10^{-7}\,\frac{Tm}{A} \times 0.3m \times (6A)^2}{2\pi \times 0.5 \times 10^{-2} m \times 9.8\,\frac{m}{s^2}} = 4.4 \times 10^{-5} 5kg$$

$$m = 4.4 \times 10^{-5} 5kg \times \frac{1000g}{1kg} \times \frac{1000mg}{1g} = 44mg$$

3. Suppose that you were to go into the lab and use a current balance to perform an experiment involving magnetic forces and fields. You take data on the current through the bars versus the mass added to the pan needed to return the system to its equilibrium separation and construct the graph below. The range of currents on the y-axis would be determined using the $120V$ power supply and the range of variable resistances you choose during the experiment. What is the experimental value of the permeability of free space, μ_0?



$$I^2 = \left(\frac{2\pi r_{eq} g}{\mu_0 L}\right) m \rightarrow \frac{2\pi r_{eq} g}{\mu_0 L} = 850694$$

$$\therefore \mu_0 = \frac{2\pi r_{eq} g}{850694\,\frac{A^2}{kg} \times L} = \frac{2\pi \times 0.5 \times 10^{-2} m \times 9.8\,\frac{m}{s^2}}{850694\,\frac{A^2}{kg} \times 0.3m} = 3.84\pi \times 10^{-7}\,\frac{Tm}{A}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$PE_{gravity} = mgy$$

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

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

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