Physics 111

Exam #2

February 9, 2011

Name_______________________________________

Multiple Choice	/16
Problem #1	/28
Problem #2	/28
Problem #3	/28
Total	/100

Part I: Multiple-Choice: *Circle the best answer to each question. Any other marks will not be given credit. Each multiple-choice question is worth 4 points for a total of 16 points.*

1. Two loops of wire of the same physical size are oriented parallel to one another and carry the same magnitudes of current but the current flow is in opposite directions in each of the wires. If the current flows counterclockwise in the bottom loop while the same magnitude of current flows clockwise in the upper loop, the force felt by the upper loop of wire due to the current flowing in the lower loop of wire would tend to

   a. make the upper loop grow and be attracted to the lower loop of wire.
   b. make the upper loop grow and be repelled from the lower loop of wire.
   c. make the upper loop shrink and be attracted to the lower loop of wire.
   d. make the upper loop shrink and be repelled from the lower loop of wire.

2. A plane flies at constant speed due south through the Earth's magnetic field that has components that point both north and vertically down. In this situation,

   a. the left side of the plane becomes positively charged.
   b. the right side of the plane becomes positively charged.
   c. the top of the plane becomes positively charged.
   d. the bottom of the plane becomes positively charged.

3. A circuit has a single battery (with constant potential) and some resistors in it. If the equivalent resistance of the circuit is increases by a factor of 4, what happens to the total current and power dissipated by the entire circuit?

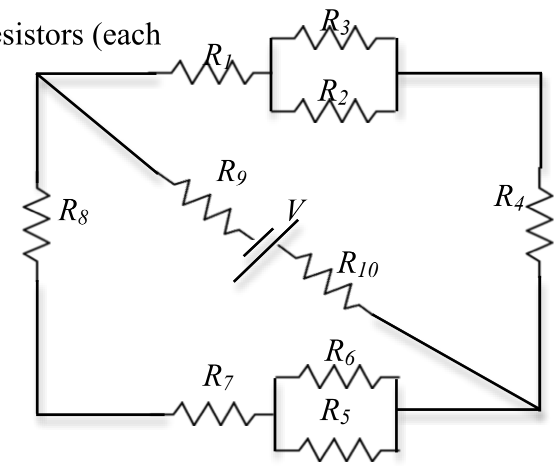
   a. Both decrease by a factor of 4.
   b. Both increase by a factor of 4.
   c. Both remain constant.
   d. Both decrease by a factor of 16.
   e. Both increase by a factor of 16.

4. A long straight wire is connected to a battery of constant potential and some resistors. This wire produces a magnetic field of strength B at a perpendicular distance r away from the wire. What happens to the equivalent resistance of the circuit and the magnetic field strength at the same perpendicular distance r if the current in the circuit were doubled?

   a. The equivalent resistance halves and the magnetic field strength halves.
   b. The equivalent resistance halves and the magnetic field strength doubles.
   c. The equivalent resistance doubles and the magnetic field strength halves.
   d. The equivalent resistance doubles and the magnetic field strength doubles.

Part II: Free Response Problems: *The three problems below are worth 84 points total and each subpart is worth 7 points each. Please show all work in order to receive partial credit. If your solutions are illegible or illogical no credit will be given. A number with no work shown (even if correct) will be given no credit. Please use the back of the page if necessary, but number the problem you are working on.*

1. You are given the circuit on the right that has 10 resistors (each with a resistance of 100Ω) that are wired to a 12.0V battery.



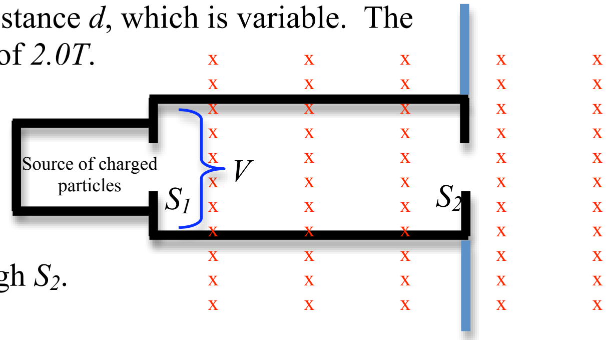
   a. What are the equivalent resistance R_{eq} of the circuit and total current I_{total} produced by the battery?

   b. What is the potential drop across resistors R_8 and R_{10}?

   c. What currents flow through resistors R_1 and R_7?

   d. Suppose that the circuit is powered up and allowed to run for one hour. How much energy has been dissipated across resistor R_2?

2. Consider the mass spectrometer shown below where there is a source of charged particles and these particles are incident at S_1, travel through the velocity selector and exit at S_2. All of the particles that are incident at S_1 have the same charge ($+q$) but may differ in mass. There is a $50kV$ potential difference across the capacitor (located between S_1 and S_2 and with the upper plate at charge $+Q$ and the lower plate at charge $-Q$) and the plates are separated by a distance d, which is variable. The magnetic field everywhere has a value of $2.0T$.



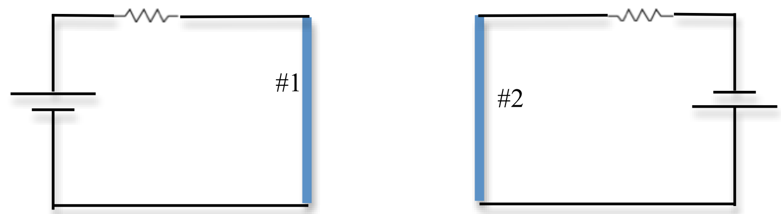
   a. Derive an expression for the orbital trajectory r of a particle as a function of the stated parameters and the mass of the particle, m, after it passes out through S_2.

   b. Suppose that you have two singly ionized isotopes of sodium, $^{22}_{11}Na$ and $^{24}_{11}Na$, that are the source of charged particles, by what amount would the two isotopes be separated when they strike the detector (either one of the blue plates) if the separation between the capacitor plates is $5mm$? Will the isotopes strike the detector above or below the exit at S_2?

   c. What is the time of flight for each of the two isotopes of in the magnetic field?

   d. Suppose instead you have the nuclear decay of barium ($^{137}_{56}Ba^* \rightarrow {}^{137}_{56}Ba + {}^{0}_{0}\gamma$) in which a gamma ray (${}^{0}_{0}\gamma$) is produced at the source and these are incident at S_1 and emerge at S_2. Where would the gamma ray, a form of electromagnetic radiation, strike the detector?

3. Consider the circuit shown below in which a long straight wire #1 is connected to a battery rated at *12.0V* and a *125Ω* resistor, while another long straight wire #2 is connected to a *10.0V* battery and a *275Ω* resistor and the two wires (#1 & #2) are separated by *0.5m* and that each blue segment of wire has a length of 0.25m.



   a. What magnetic force would wire #1's feel due to the current flowing in wire #2? Suppose that this force were strong enough to accelerate and actually move the entire circuit #1 assumed to have total mass *m*, would the circuit experience a constant acceleration and would its velocity after it has been displaced by a distance Δx be given by $v_f^2 = 2a\Delta x$? Justify your answer.

   b. Assuming that the wires are in their original configuration and remain stationary, what is the net magnetic field at the midpoint between the two wires?

   c. Suppose a square loop of wire with sides of length *10cm* were oriented with its face perpendicular to the net magnetic field and the center of the loop at the midpoint between the two wires. What would the net force be on the loop if there was a current $I_{loop} = 25mA$ flowing clockwise? (Hint: Assume that the net magnetic field is taken as being constant across the face of the loop of wire and the value of that field is your calculated value in part b.)

   d. Suppose that you made the same *25*-turn loop of wire exactly as in part c, what would the net torque be on the loop if there was a current $I_{loop} = 25mA$ flowing clockwise? In what direction would the loop of wire rotate?

Physics 111 Equation Sheet

Electric Forces, Fields and Potentials

$$\vec{F} = k\frac{Q_1Q_2}{r^2}\hat{r}$$
$$\vec{E} = \frac{\vec{F}}{q}$$
$$\vec{E}_Q = k\frac{Q}{r^2}\hat{r}$$
$$PE = k\frac{Q_1Q_2}{r}$$
$$V(r) = k\frac{Q}{r}$$
$$E_x = -\frac{\Delta V_{B,A}}{\Delta x}$$
$$W_{A,B} = q\Delta V_{A,B}$$

Magnetic Forces and Fields

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

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 Wave

Constants

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

$G = 6.67\times10^{-11}\,\frac{Nm^2}{kg^2}$

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

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

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

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

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

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

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

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

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

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

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

$N_A = 6.02\times10^{23}$

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

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

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

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

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

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

$$\vec{F} = \frac{\Delta\vec{p}}{\Delta t} = \frac{\Delta(m\vec{v})}{\Delta t} = m\vec{a}$$
$$\vec{F} = -k\vec{y}$$
$$\vec{F}_C = m\frac{v^2}{R}\hat{r}$$
$$W = \Delta KE = \tfrac{1}{2}m(v_f^2 - v_i^2) = -\Delta PE$$
$$PE_{gravity} = mgy$$
$$PE_{spring} = \tfrac{1}{2}ky^2$$
$$x_f = x_i + v_{ix}t + \tfrac{1}{2}a_xt^2$$
$$v_{fx} = v_{ix} + a_xt$$
$$v_{fx}^2 = v_{ix}^2 + 2a_x\Delta x$$