PH 393 Physics II **Exam 2** **Fall 2011**

Name: Solutions **11/8/11**

Present neat and orderly answers for each question.
Clearly indicate your method of solution for each problem, including equations used.
Include appropriate units.
Show all work.

$\mu_0 = 1.26 \times 10^{-6}$ Tm / A $\quad$ $e = 1.6 \times 10^{-19}$ C $\quad$ $m_p = 1.67 \times 10^{-27}$ kg (proton mass)

Multiple Choice (2 pts each)

1. When a current flows through a wire it is possible for the temperature of the wire to increase. In order to accommodate the increase in temperature, with no changes to any other aspect of the circuit (including operation), how would you modify the magnitude of the electric field that travels along the length of the wire?

   $R \propto T$ → increasing T increases R
   $V \propto R$ → increasing R requires a greater V for the same current.
   $E \propto V$

   a. Turn off the electric field.
   b. Make no changes to the electric field.
   c. Increase the electric field.
   d. Decrease the electric field.

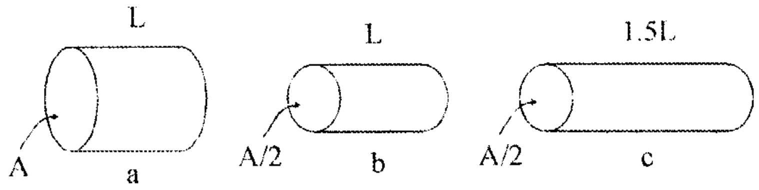
   Ans. C

2. A cathode ray tube (CRT) is a device which was used in television sets. Essentially a beam of electrons is redirected using electric and magnetic fields. If you have a CRT and want to deflect the beam of electrons upward you would have to have the directions of a magnetic field (B) and electric field (E) in which of the following configurations?

   a. B up and E up;
   b. B into the page and E up;
   c. B out of the page and E down;
   d. B down and E down;

   Ans. C

3. The figures below show three cylindrical copper conductors along with their cross-sectional areas and lengths. Rank them according to their resistances, greatest first.



   a. a, b, c;
   b. b, c, a;
   c. b, a, c;
   d. c, b, a.

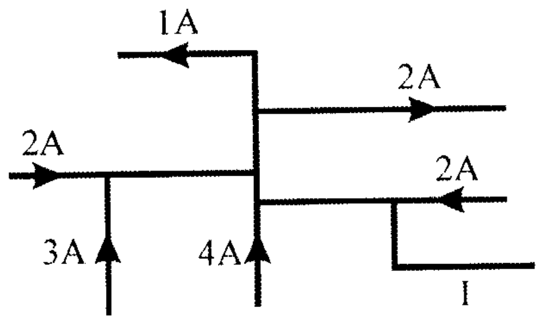
   Ans. D

4. A current carrying square loop of wire is placed in a sinusoidally varying magnetic field. The oscillating magnetic field is parallel to the plane containing the loop. Which of the following motions would be observed?

   a. There would be no motion.
   b. The loop would translate.
   c. The loop would rotate.
   d. The loop would vibrate (back and forth motion).

   Ans. D

5. A portion of a circuit shown below contains the currents shown. What is the magnitude and direction of the current I?



a. 4 A Left;
b. 4 A Right;
c. 8 A Left;
d. 8 A Right.

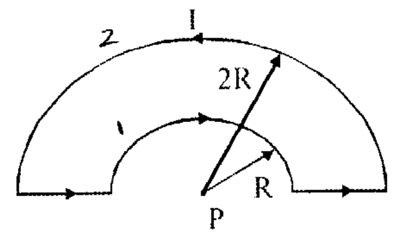
$\Sigma I_{in} = \Sigma I_{out}$

$2A + 3A + 4A + 2A = 1A + 2A + I$

$11A = 3A + I \Rightarrow I = 8A$ out

Ans. D

6. The following wire carries a current I producing a magnetic field at point P equaling:



$B = \frac{\mu_0 I}{4\pi r}\theta$

a. $\frac{\mu_0 I}{8R}$ out of the page;
b. $\frac{\mu_0 I}{8R}$ into the page;
c. $\frac{3\mu_0 I}{8R}$ out of the page;
d. $\frac{3\mu_0 I}{8R}$ into the page.

$B_1 = \frac{\mu_0 I}{4\pi R}(\pi)$ into page

$B_2 = \frac{\mu_0 I}{4\pi(2R)}\pi$ out of page

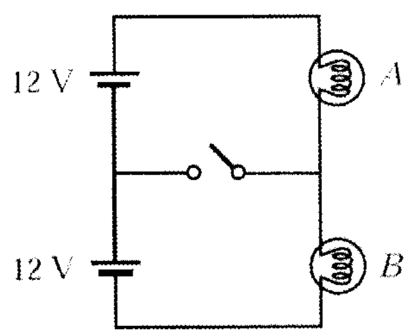
$\vec{B} = \vec{B}_2 - \vec{B}_1 = \frac{\mu_0 I}{R}\left[\frac{1}{8} - \frac{1}{4}\right]$

$= \frac{\mu_0 I}{R}\left[-\frac{1}{8}\right]$

$= \frac{\mu_0 I}{8R}$ into Page

Ans. B

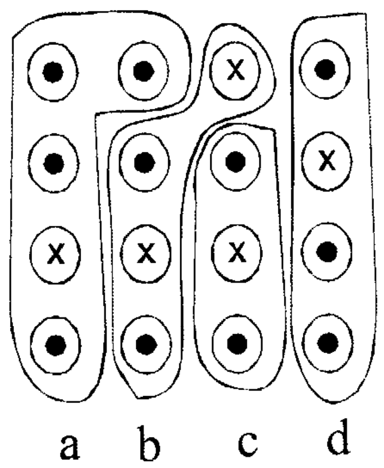
7. Consider the circuit below which contains two identical light bulbs. What happens when the switch is closed?



e. Nothing;
f. The intensity of bulb A increases;
g. The intensity of bulb A decreases;
h. Both bulbs go out.

Ans. E

8. Sixteen long parallel wires carry equal currents I in the directions shown. Rank the amperian loops according to the magnitude of $\oint \vec{B} \cdot d\vec{s}$ along each, greatest first.



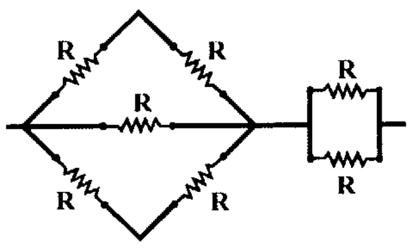
$\oint \vec{B} \cdot d\vec{s} = \mu_0 I_{encl}$

$I_{encl} =$ 3I 0 I 2I

a. d, b, a, c;
b. a, d, c, b;
c. d, a, c, b;
d. a, b, d, c.

Ans. B

9. The circuit below contains two groups of resistors. Group 1 is the group of 5 resistors on the left and group 2 is the group of two resistors on the right. Which of the two groups of resistors can store more energy?



Resistors do not store energy !!

a. Group 1;
b. Group 2;
c. Both groups store zero energy.
d. There is not enough information to decide.

Ans. C

10. A positive charge is fired perpendicular to a long straight wire. How does the magnitude of the magnetic force on the charge change as it moves away from the wire?

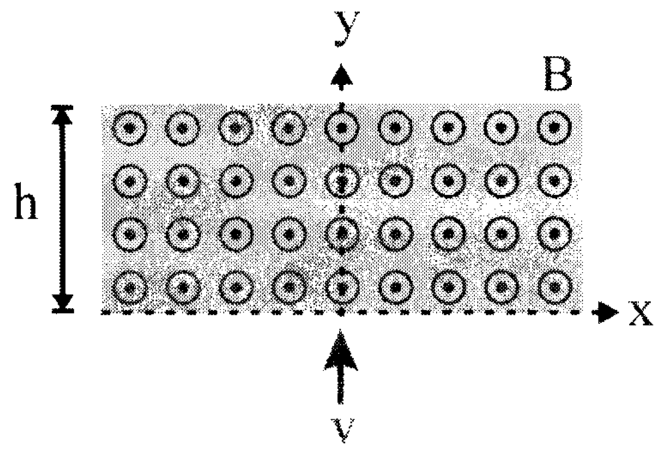
a. Zero force;
b. Constant force;
c. Decreases as 1/r;
d. Decreases as $1/r^2$.

$B = \frac{\mu_0 I}{2\pi r}$

$F \propto B \rightarrow F \propto \frac{1}{r}$

Ans. C

Problem 1 (20 pts)



The diagram above depicts a region of magnetic field that is infinitely long, but only h = 20 cm wide. The magnetic field strength is given by **B** = 1200 mT $\hat{k}$. Charges are fired into the magnetic field region with a velocity **v** = v $\hat{j}$.

a) If a proton is fired into the magnetic field, determine the initial velocity of the proton required such that it just reaches the top boundary of the magnetic field region at y = h. (5 pts)

b) Determine the initial velocity of the proton required such that it exits the lower boundary of the magnetic field region at x = ±h. State the deflection direction, relative to the original velocity, of the path of the proton. (5 pts)

c) Two atoms are fired into the magnetic field region with the same initial velocity **v** = 1.5 Mm/s $\hat{j}$. One atom is iron (Fe^{3+}, 55.845 u) and the other is oxygen (O^{2-}, 15.999 u). *The symbol, charge valence and atomic weights (1 u ≈ 1.67x10^{-27} kg) are given in parentheses.* Determine the exit location from the magnetic field region for each atom and plot the trajectory that each atom follows. Clearly show the expression used to define each of the trajectories. (6 pts)

d) If you had two unknown atoms that you fired, with the same initial velocity, into this magnetic field region, how could you determine what atoms they were? Specify what you would measure and what you would calculate. (4 pts)

a) $F_B = m\frac{v^2}{r}$, $F_B = q\vec{v}\times\vec{B} = qvB$ } $qvB = m\frac{v^2}{r} \Rightarrow r = \frac{mv}{qB}$

If $y = h$ then $r = h$, so → $v = \frac{qBr}{m} = \frac{qBh}{m} = \frac{(1.6\times10^{-19}C)(1200\times10^{-3}T)(0.2m)}{(1.67\times10^{-27}kg)}$

$\Rightarrow \boxed{v = 2.3\times10^{7}\ \frac{m}{s}}$

b) A proton is deflected to the right

for $x = +h$, $y = \frac{h}{2}$ → $d = h$ $\Rightarrow r = \frac{h}{2}$

$v = \frac{qBr}{m} = \frac{qB(\frac{h}{2})}{m} = \frac{(1.6\times10^{-19}C)(1200\times10^{-3}T)(\frac{0.2m}{2})}{(1.67\times10^{-27}kg)} = \frac{2.3\times10^{7}\frac{m}{s}}{2} = \boxed{1.15\times10^{7}\ \frac{m}{s}}$

c) <u>For Iron (Fe):</u>

$$r = \frac{mv}{qB} = \frac{(55.845)(1.67\times10^{-27}\,kg)(1.5\times10^{6}\,\frac{m}{s})}{30.6\times10^{-19}\,C)(1200\times10^{-3}\,T)} = 0.243\ m$$

$0.243\ m > 0.2\ m$ so it does not complete $\frac{1}{4}$ circle.

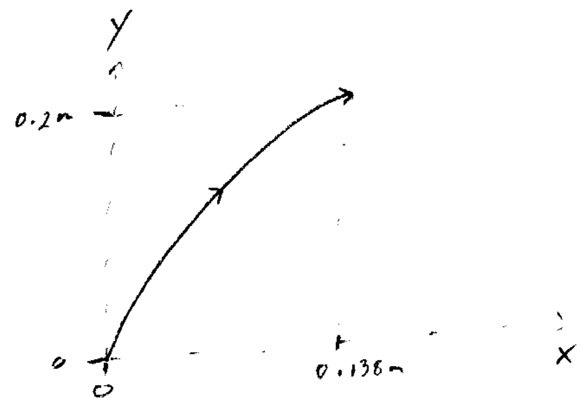
$y = 0.2\ m$ and $r = 0.243\ m$ $\Rightarrow$ $x_c = \sqrt{r^2 - y^2} = \sqrt{(0.243\,m)^2 - (0.2\,m)^2}$

$\Rightarrow x_c = 0.138\ m$ measured from center of circle

$x = r - x_c = 0.243\ m - 0.138\ m = 0.105\ m$

Positive charge deflects to the right.

exits at $(0.105\ m, 0.2\ m)$



<u>For Oxygen (O):</u>

$$r = \frac{mv}{qB} = \frac{(15.999)(1.67\times10^{-27}\,kg)(1.5\times10^{6}\,\frac{m}{s})}{2(1.6\times10^{-19}\,C)(1200\times10^{-3}\,T)} = 0.1044\ m$$

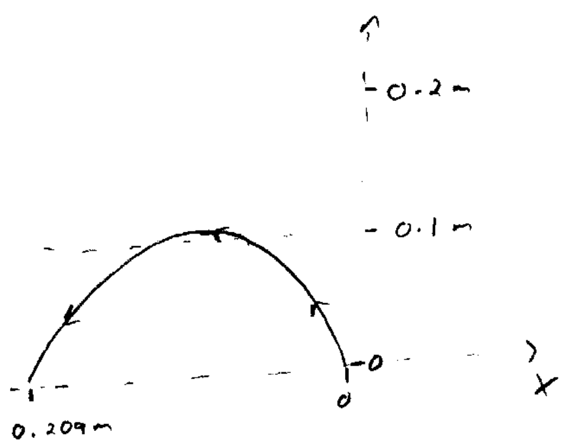
$0.1044\ m < 0.2\ m$, so it completes $\frac{1}{2}$ circle

$x = 2r = 0.209\ m$ and $r = 0.1044$ $\qquad y_{max} = r = 0.1044\ m$

$\Rightarrow y = 0\ m$

exits at $(-0.209\ m, 0\ m)$

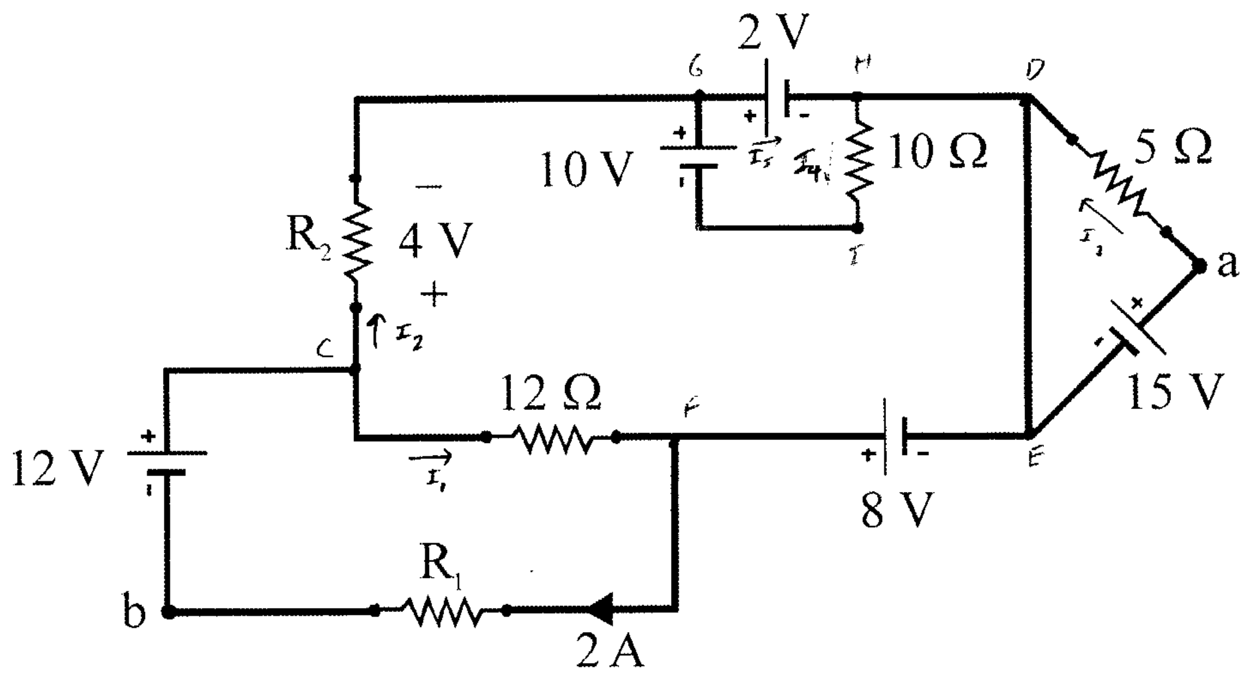
Negative charge deflects to the left.



d) You would set up a screen and measure the radius of the path, from which you could determine the charge to mass ratio ($\frac{q}{m}$), which would allow you to distinguish between different atoms.

Problem 1 (20 pts)

Consider the following circuit:



a) Determine the resistances R_1 and R_2. (8 pts)
b) Determine the voltage from point a to point b ($\Delta V = V_a - V_b$). (5 pts)
c) Determine the rate that thermal energy appears in the 5 Ω resistor. (2 pts)
d) Determine the power associated with the 2V battery. Is the battery supplying or absorbing power? (5 pts)

All loops clockwise!

a) Loop BCDEF:

$12V - 4V - 2V + 8V - (2A)R_1 = 0 \Rightarrow 14V = 2A\,R_1 \Rightarrow \boxed{R_1 = 7\,\Omega}$

Loop BCF:

$12V - I_1(12\Omega) - (2A)R_1 = 0 \Rightarrow I_1 = \frac{12V - 14V}{12\Omega} = -0.167\,A$

Node C:

$2A = I_2 + I_1 \Rightarrow I_2 = 2A - I_1 = 2A - (-0.167A) = 2.167A$

$V_2 = I_2 R_2 \Rightarrow R_2 = \frac{V_2}{I_2} = \frac{4V}{2.167A} = \boxed{1.85\,\Omega}$

b) Loop DAE:

$I_3(5\Omega) - 15V = 0 \Rightarrow I_3 = \frac{15V}{5\Omega} = 3A \Rightarrow V_3 = I_3(5\Omega) = 15V$

Branch BCDA:

$\Delta V = 12V - 4V - 2V + 15V = \boxed{21V}$

c) $P = \frac{V^2}{R} = \frac{(15V)^2}{5\Omega} = \boxed{45W}$

d) <u>loop GHI:</u>

$10V - 2V - I_4(10\Omega) = 0 \Rightarrow I_4 = \frac{8V}{10\Omega} = 0.8A$

<u>Node G:</u>

$I_2 + I_4 = I_5 \Rightarrow I_5 = 2.167A + 0.8A = 2.967A$

$P = VI = (2V)(2.967A) = \boxed{5.934W}$ $\boxed{\text{Absorbing}}$

Current enters positive terminal of battery, therefore battery is being charged.