

Physics 111, Exam #3
Spring 2003

Name: KEY (1 point)

Multiple Choice: Choose the best answer (3 points each)

1. D Consider a cylindrical sample of a substance *that obeys Ohm's Law*. Its resistance depends on:
- the Electric field inside the sample.
 - the voltage across the sample.
 - the current density in the sample.
 - the length of the sample, the cross sectional area of the sample, and the material that the sample is made of.
 - all of the above

2. D You increase the voltage across a certain light bulb by a factor of two and measure the current to increase by a factor of three. What can you conclude?

- The resistance of the bulb has been increased in this process. *No*
- The power dissipated in the bulb has also tripled. *No*
- The bulb does not obey Ohm's law.
- None of the above.

$$V = IR$$

$$P = IV = (3I_0)(2V_0) = 6I_0V_0$$

3. A A current I flows through a resistor when it is connected to a battery of terminal voltage V . If another, identical resistor is added in *parallel* with the first, which is true?

- The voltage drop across each resistor is V . *Yes*
- The current through the new resistor is $I/2$. *No*
- The power supplied by the battery is IV . *No*
- The power dissipated in the new resistor is $IV/2$. *No*

4. D Which of the following would be true if energy conservation did not hold in electric circuits?

- Kirchhoff's junction (current) rule would not be valid.
- Resistors would not dissipate energy.
- Kirchhoff's loop (voltage) rule would not be valid.
- Charge could be created in the circuit.

5. C You have several identical resistors and several identical capacitors. Your boss wants you to design a circuit with the *shortest* time constant possible. What should you do?

- Put them all in series.
- Put them all in parallel.
- Put the resistors in parallel and the capacitors in series.
- Put the resistors in series and the capacitors in parallel.

$$\tau = RC$$

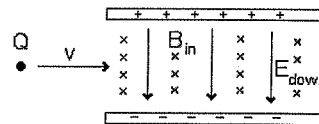
6. E A solenoid has N turns, a radius r , a length L and carries a current I . If we double the length of the solenoid (keeping everything else constant and assuming an ideal solenoid) the B-field inside of the solenoid will

- Increase by a factor of 4
- Increase by a factor of 2
- Remain the same
- Decrease by a factor of 2
- Decrease by a factor of 4

$$B = \mu_0 \frac{N}{L} I$$

7. C An positively charged ion with charge Q is found to pass straight through the velocity selector shown. If the magnitude of the Electric field is increased (keeping the direction the same) the ion will

- deflect in the upward direction.
- continue in a straight line.
- deflect in the downward direction.



$$\uparrow F_m = qvB$$

$$\downarrow F_e = qE$$

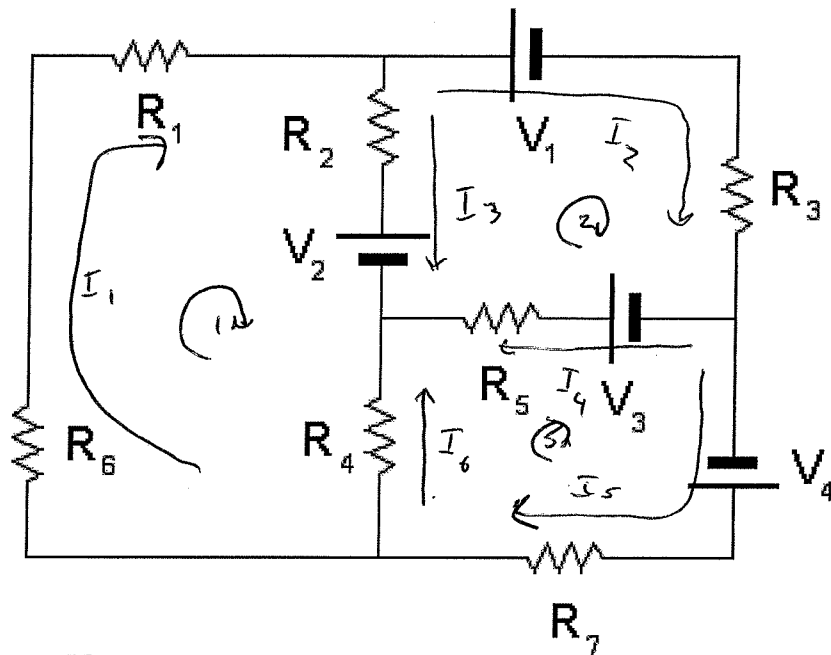
8. C Which of the following statements are true?

- The net magnetic force on any closed current loop in a uniform magnetic field depends on the strength of the magnetic field. *No* $F = 0$
- A uniform magnetic field does NO WORK on a charged particle moving in it. *Yes* $F \cdot v = 0$
- The angular frequency of a particle moving in a constant magnetic field depends on the energy of the particle. *No*
- All of the above.
- None of the above.

$$\omega = \frac{qB}{m}$$

if C →
then -2

2. Consider the circuit shown. Use Kirchhoff's rules to determine enough independent equations to determine the current in each leg of the circuit. **Make sure that you indicate the currents that you assume on the diagram.** (25 points)



$$I_1 = I_2 + I_3$$

$$I_2 = I_4 + I_5$$

$$I_5 = I_6 + I_1$$

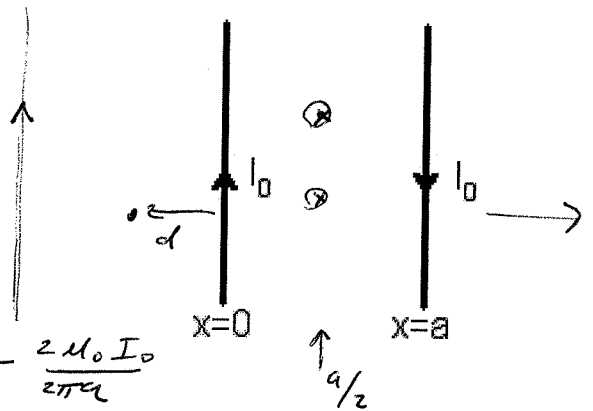
$$-I_1 R_6 - I_1 R_1 - I_3 R_2 - V_2 + I_6 R_4 = 0$$

$$V_2 + I_3 R_2 - V_1 - I_2 R_3 + V_3 - I_4 R_5 = 0$$

$$-I_6 R_4 + I_4 R_5 - V_3 + V_4 - I_5 R_7 = 0$$

3. Two long wires are located at $x=0$ and $x=a$ and each carries a current of magnitude, I_0 in opposite directions as shown. Let $a=0.1$ m and $I_0=3$ A.

a) Calculate the magnetic field at a point midway between the wires. (take out of the page to be the positive direction)(6 points)



$$\underline{B} = -\frac{\mu_0 I_0}{2\pi a/2} - \frac{\mu_0 I_0}{2\pi a/2} = -\frac{2\mu_0 I_0}{2\pi a} - \frac{2\mu_0 I_0}{2\pi a}$$

$$\underline{B} = -\frac{4\mu_0 I_0}{2\pi a} = \frac{-(4)(4\pi \times 10^{-7})3}{2\pi 0.1} = \cancel{240 \times 10^{-7}} \frac{-24 \times 10^{-7}}{0.1}$$

$$\boxed{B = -240 \times 10^{-7} \text{ T}} = \boxed{-2.4 \times 10^{-5} \text{ T}} = \boxed{-24 \mu\text{T}}$$

b) Calculate the magnetic field at a point 0.05 m to the left of the wire at $x=0$. (6 points)

$$\underline{B} = +\frac{\mu_0 I_0}{2\pi d} - \frac{\mu_0 I_0}{2\pi(a+d)} = \frac{\mu_0 I_0}{2\pi} \left[\frac{1}{d} - \frac{1}{d+a} \right]$$

$$= \frac{(4\pi \times 10^{-7})3}{2\pi} \left[\frac{1}{0.05} - \frac{1}{0.15} \right] = (6 \times 10^{-7}) \left[\frac{3}{0.15} - \frac{1}{0.15} \right]$$

$$= (6 \times 10^{-7}) \left(\frac{2}{0.15} \right) = \boxed{80 \times 10^{-7} \text{ T}} = \boxed{8 \mu\text{T}}$$

c) Calculate the force per unit length on the wire at $x=a$ due the wire at $x=0$ (6 points)

$$\frac{\underline{F}}{l} = \left(\frac{\mu_0 I_1 I_2}{2\pi a} \right) = \frac{(4\pi \times 10^{-7})(3)(3)}{(2\pi)(0.1)} \text{ N/m (repulsive)}$$

$$\boxed{180 \times 10^{-7} \text{ N/m repulsive}}$$

d) If a third wire is placed at $x=-0.1$ m, what is the current in that wire if it makes the magnetic field at $x=-0.05$ m equal to zero. (6 points)

~~←~~ B field due to 3rd wire must be $-8 \mu\text{T}$ to cancel field due to other 2 wires.

Must flow upward with

$$|B| = (8 \mu\text{T}) = \frac{\mu_0 I_3}{2\pi(0.05)}$$

$$\frac{(4\pi \times 10^{-7}) I_3}{2\pi(0.05)} = 8 \times 10^{-6}$$

$$4 \times 10^{-6} I_3 = 8 \times 10^{-6}$$

$$\boxed{I_3 = 2 \text{ Amps (up)}}$$

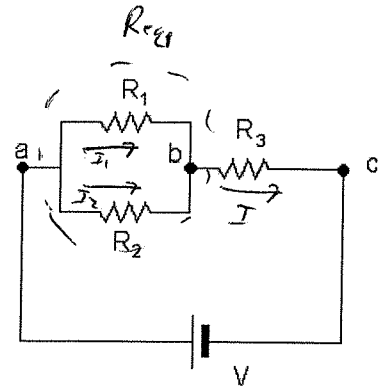
4. Three resistors $R_1 = 10\Omega$, $R_2 = 30\Omega$, $R_3 = 5\Omega$, are hooked across a battery $V=25\text{ V}$ as shown.

a) What is the equivalent resistance of the three resistors in combination? (5 points)

$$\frac{1}{R_{eq1}} = \frac{1}{10} + \frac{1}{30} = \frac{3}{30} + \frac{1}{30} = \frac{4}{30}$$

$$R_{eq1} = \frac{30}{4} = 7.5$$

$$R_{eq} = 5\Omega + 7.5\Omega = \boxed{12.5\Omega}$$



b) What is the current through each of the resistors? (i.e. find the current in R_1 , R_2 and R_3 .) (9 points)

Current through $R_3 = I R_{eq} = 25\text{ V}$

$$I = \frac{25}{12.5} = \boxed{2\text{ A}} \leftarrow \text{through } R_3$$

$$I_1 + I_2 = 2\text{ A}$$

$$I_1 R_1 = I_2 R_2$$

$$\Rightarrow I_1 = I_2 \frac{R_2}{R_1} = 3I_2$$

$$3I_2 + I_2 = 2\text{ A}$$

$$4I_2 = 2\text{ A}$$

$$\boxed{I_2 = 0.5\text{ A}}$$

$$\boxed{I_1 = 1.5\text{ A}}$$

c) How much power is dissipated by the combination of resistors? (5 points)

$$P = I^2 R_{eq} = (2\text{ A})^2 (12.5\Omega)$$

$$\boxed{P = 50\text{ W}}$$

d) If point c is taken to be zero potential, what is the potential at the points a and b? (6 points)

$$\text{If } c = 0 \Rightarrow \boxed{a = +25\text{ V}}$$

$$b = I_3 R_3 = (2)(5) = \boxed{+10\text{ V}}$$