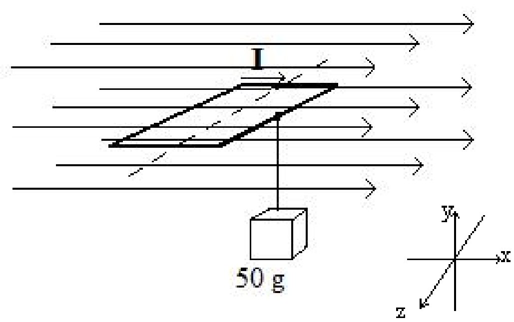
Phys 102 Spg. 2008

Exam No. 2 Solutions

I. (20 pts) A 10-turn wire loop measuring 8.0 cm by 16.0 cm carrying a current of 2.0 A lies in the horizontal plane and is free to rotate about a horizontal axis through its center as shown below. A 50-g mass hangs from one side of the loop. A uniform horizontal magnetic field is also present, as shown. What magnetic field strength is required to hold the loop in its horizontal position? (take g to be 9.8 m s^{-1}).



Answer:

The loop will remain in its horizontal position when the sum of the torque generated by the mass and the torque from the loop's magnetic moment interaction with the magnetic field is zero.

The loop's magnetic moment is a vector directed out of the page and is given by

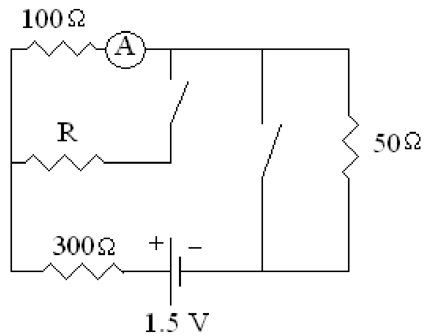
$$\vec{\tau}_B = \vec{\mu} \times \vec{B} = INAB\hat{z},$$

where I is the current, N is the number of turns in the loop, A is the area enclosed by the loop and B is the magnitude of the B field. Absent a counteracting torque, $\vec{\tau}_B$ will cause the loop to rotate counterclockwise with respect to the horizontal axis of rotation. The torque generated by the mass is $\vec{\tau}_m = -r_\perp F\hat{z}$, where $-r_\perp$ is the lever arm – the perpendicular distance from the force to the axis of rotation and $F = mg$ is the force applied by the mass. $\vec{\tau}_m$ will cause the loop to rotate clockwise with respect to the horizontal axis of rotation. Setting these torques equal yields –

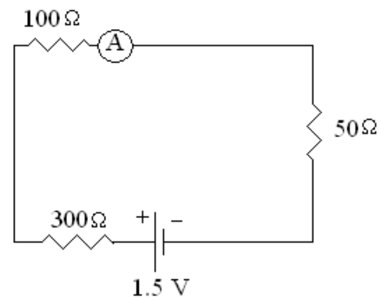
$$INAB = mgr_\perp \rightarrow B = mgr_\perp / INA =$$

$$B = \frac{(0.05kg)\left(9.8\frac{m}{s^2}\right)(0.04m)}{(2A)(10)(0.08 \times 0.16m^2)} = \mathbf{0.076T}$$

II. (25 pts) In the circuit shown below, the reading of the ammeter (which has negligible resistance) is the same with both switches open and both closed. Find the resistance R.



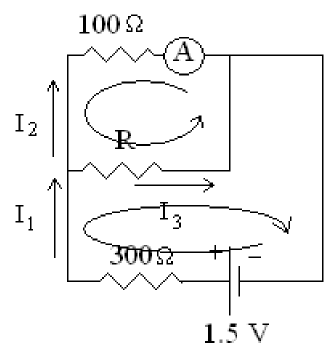
Answer: With the switches both open, the circuit can be redrawn as shown–



The current through the ammeter can now be determined using $I = \frac{V}{R_{eq}}$, where $R_{eq} = 100\Omega + 300\Omega + 50\Omega = 450\Omega$., which gives $I = \frac{1.5V}{450\Omega} = \mathbf{3.33mA}$.

With the switches closed, the circuit can be drawn as shown –

R can then be determined using Kirchhoff's Rules (with the currents shown to the right and using the value obtained for what is now I_2, obtained in the first part of this problem).



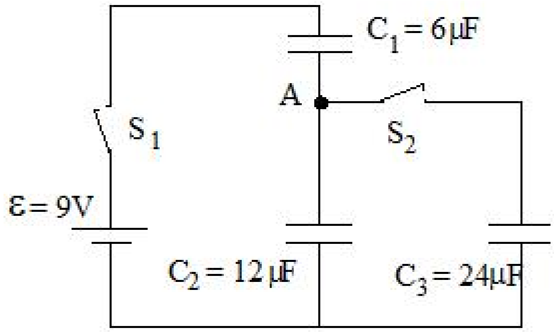
$$I_1 - 3.33 \times 10^{-3} - I_3 = 0$$
$$1.5 - 300 I_1 - R I_3 = 0$$
$$(100)(3.33 \times 10^{-3}) - R I_3 = 0$$

R can be derived from these equations in a number of different ways. One way is to note that the third equation directly gives the value for RI_3 which can then be plugged into the second equation to find I_1, which can then be used to find I_3 by the first equation, and finally that result plugged into the value for RI_3 to obtain R.

So, RI_3 equals 0.333V, which means $I_1 = \frac{1.5 - RI_3}{300} = \frac{1.5 - .333}{300} = 3.89 \times 10^{-3} A$. Therefore, $I_3 = I_1 - I_2 = 3.89 \times 10^{-3} A - 3.33 \times 10^{-3} A = 0.56 \times 10^{-3} A$ and so

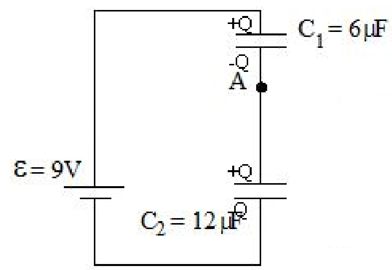
$$R = \frac{0.333V}{0.56 \times 10^{-3} A} = \mathbf{594\Omega}.$$

III. (25 pts) Consider the circuit shown below, where switches S_1 and S_2 are open and C_1, C_2 and C_3 are uncharged.



(a) If S_1 is now closed how much charge flows through it as C_1 and C_2 charge up?

Answer: The circuit with just S_1 closed is as shown to the right (with S_2 open, no current can flow and therefore C_3 can be ignored.) The amount of charge Q that will flow through S_1 will be sufficient to satisfy the loop rule that the voltage of the emf source will be divided among the potential drops across the 2 capacitors according to the equation –



$$\varepsilon - \frac{Q}{C_1} - \frac{Q}{C_2} = 0 \rightarrow \varepsilon = \frac{(C_1 + C_2)Q}{C_1 C_2} \rightarrow Q = \frac{\varepsilon C_1 C_2}{C_1 + C_2}$$

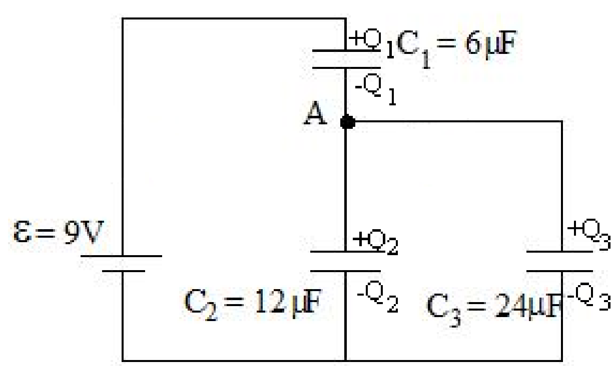
$$Q = \frac{(9V)(6 \times 10^{-6}F)(12 \times 10^{-6}F)}{(6 \times 10^{-6}F + 12 \times 10^{-6}F)} = \mathbf{3.6 \times 10^{-5}C}$$

(b) What is now the potential at point A? (Take the potential on the negative terminal of the source of emf to be 0V).

Answer: The potential at point A with respect to the negative terminal of the source of the emf is simply the potential across C_2, which is

$$V_2 = \frac{Q}{C_2} = \frac{3.6 \times 10^{-5}C}{12 \times 10^{-6}F} = \mathbf{3V}.$$

When C_1 and C_2 are fully charged, S_2 is closed.



The answers to the last 3 parts can be determined by analyzing the circuit shown at right, after it reaches steady state. Part (c) is asking for the amount of charge, Q_3, which will accumulate on C_3. Since $Q_3 = C_3V_3$, the voltage across C_3 must be determined, which is the answer to part (d). This can be solved for by first determining the equivalent capacitance, C', for C_2 and C_3, then determining the amount of charge, Q' which will accumulate on the 2 capacitors, C_1 and C', and then determining the potentials across those capacitors, similar to the approach used in parts (a) and (b). Part (e) then asks for the difference between the amount of charge that accumulated on C_1 before and after switch S_2 is closed, or the difference between Q determined in part (a) and Q_1 determined here.

(c) How much charge flows through S_2?

Answer: Using the approach outlined above, $C' = C_2 + C_3 = 36\mu F$.

$$Q' = \frac{\varepsilon C_1 C'}{C_1 + C'} = \frac{(9V)(6\times 10^{-6}F)(36\times 10^{-6}F)}{(6\times 10^{-6}F + 12\times 10^{-6}F)} = 4.63\times 10^{-5}C$$

$$V' = V_3 = {Q'}/{C'} = \frac{4.63\times 10^{-5}C}{36\mu F} = 1.29V$$

The amount of charge flowing through S_2, therefore, will be

$$Q_3 = C_3 V_3 = (24\times 10^{-6}F)(1.29V) = \mathbf{3.1\times 10^{-5}C}$$

(d) What is the final potential at point A?

Answer: The final potential at point A will be $V_3 = V' = \mathbf{1.29V}$

(e) How much additional charge passed through S_1 after closing S_2 and in what direction did it flow?

Answer: $\Delta Q_1 = Q_{1_f} - Q_{1_i} = Q'(from\ part\ (c) - Q\ (from\ part\ (a) =$

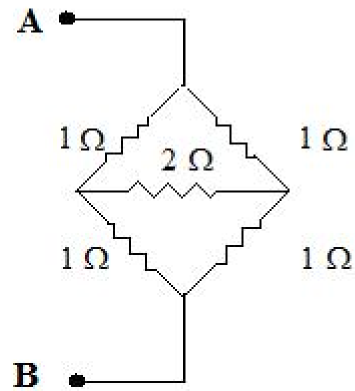
$$= 4.63\times 10^{-5}C - 3.6\times 10^{-5}C = \mathbf{1.03\times 10^{-5}C}.$$

Since the final charge on C_1 is greater than the initial charge, the charge flow is to the right.

Last Name: First Name:

Physics 102 Spring 2008: Exam #2 – Multiple-Choice Questions

1. Consider the arrangement of resistors shown below. The equivalent resistance between A and B is



(a) ¼ Ω

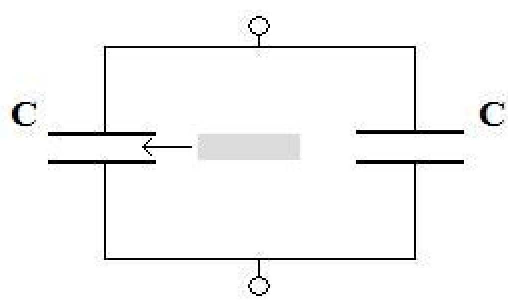
(b) ½ Ω

(c) 1 Ω ✓

(d) 2 Ω

(e) 4 Ω

2. Consider parallel plate capacitors of identical capacitance C that are connected in parallel as shown. They are initially charged such that they store a total energy U and are then isolated.



A dielectric of dielectric strength κ is now inserted to entirely fill the gap between the plates of one capacitor. The energy shared by the pair of capacitors is –

(a) Unchanged

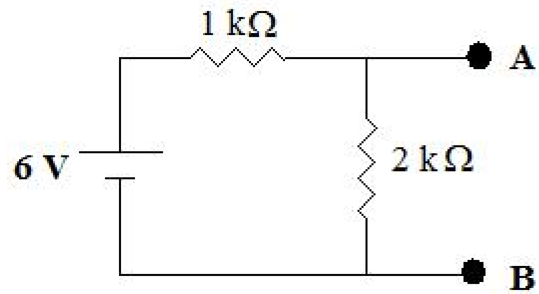
(b) $2U/(1 + \kappa)$ ✓

(c) $U(1 + \kappa)/2$

(d) $4U/(1 + \kappa)^2$

(e) $U(1 + \kappa)^2/4$

3. A capacitor is charged to 12 V and then connected between points A and B in the figure below, with the positive plate connected to point A. What is the current through the 2 kΩ resistor a long time after the capacitor is connected?



(a) 0 mA

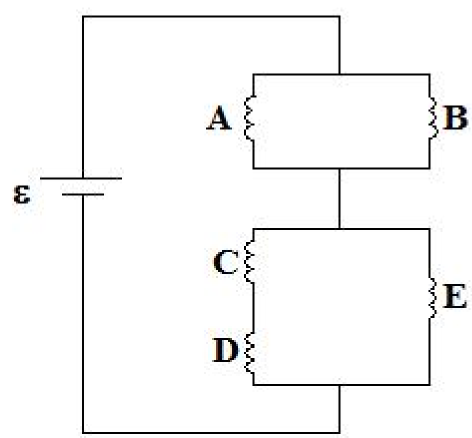
(b) 2 mA ✓

(c) 4 mA

(d) 6 mA

(e) 8 mA

4. Five identical bulbs are connected as shown to a source of emf ε. Which bulb is brightest?



(a) A

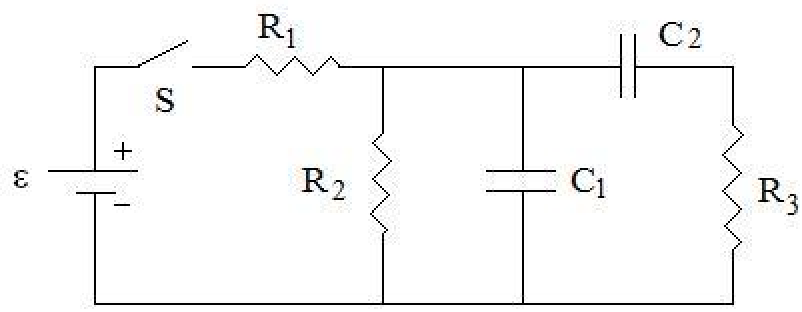
(b) B

(c) C

(d) D

(e) E ✓

For the next two questions, consider the circuit shown below where C_1 and C_2 are initially uncharged and switch S is open.



5. The current through the source of emf immediately after S is closed is

(a) ε/R_1 ✓

(b) ε/R_2

(c) $\varepsilon/(R_1 + R_2)$

(d) $\varepsilon/(R_1 + R_3)$

(e) ε/R_2C_1

6. Following closure of the switch, the current through R_3

(a) immediately jumps up before decreasing to zero.

(b) immediately jumps up before decreasing to a steady equilibrium value.

(c) builds up to a steady, non-zero equilibrium value.

(d) initially builds up but then decreases to zero. ✓

(e) remains zero.

7. A static magnetic field CANNOT do which of the following?

(a) exert a force on a charged particle

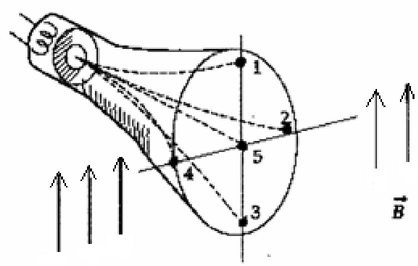
(b) accelerate a charged particle

(c) change the momentum of a charged particle

(d) change the kinetic energy of a charged particle ✓

(e) reverse the direction of motion of a charged particle.

8. When a cathode-ray tube (television picture-tube) with a horizontal axis is placed in a magnetic field directed vertically up, the electrons emitted from the cathode follow one of the paths shown and strike the screen at one of the numbered points.



The spot that most nearly represents the correct path is

(a) 1

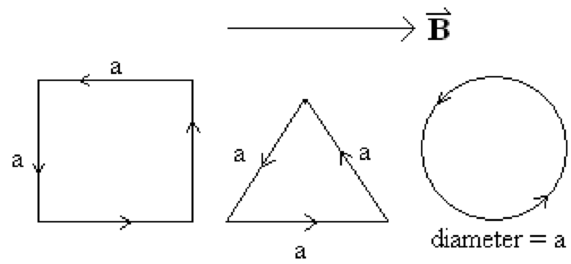
(b) 2 ✓

(c) 3

(d) 4

(e) 5

9. Three current loops are depicted below, along with their dimensions and current direction. If a uniform magnetic field is pointing to the right of the page, which current loop has the greatest magnetic potential energy compared to its minimal value of magnetic potential energy?



(a) The rectangular current loop. ✓

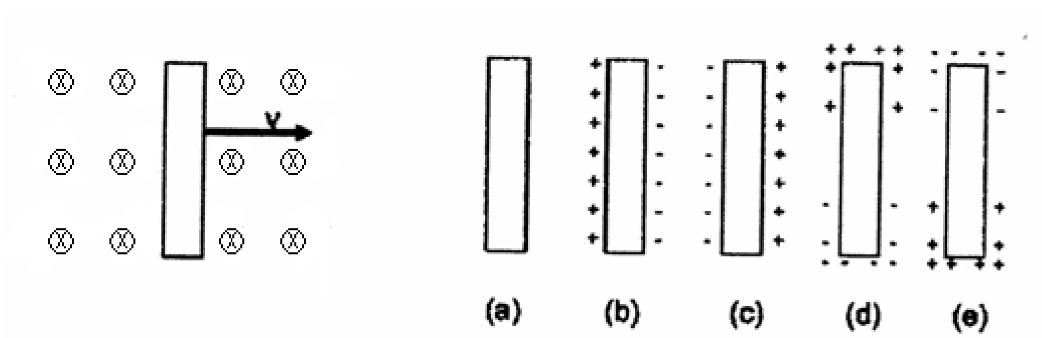
(b) The triangular current loop.

(c) The circular current loop.

(d) They all have the same magnetic potential energy relative to their minimal magnetic potential energy.

(e) More information is required.

10. An initially uncharged metal bar is moved at constant velocity to the right through a region where there is a uniform magnetic field pointing into the page.



Which of the above diagrams best describes the charge distribution on the surface of the metal bar?

(a) a

(b) b

(c) c

(d) d ✓

(e) e