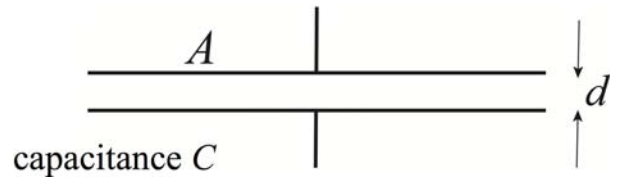


The next three questions pertain to the situation described below.

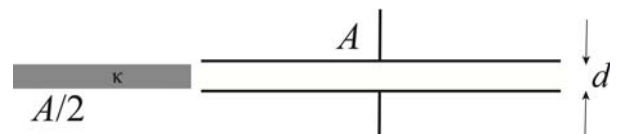
Illustrated below is a parallel plate capacitor with plate area  $A$  and plate spacing  $d = 0.2$  mm. After being charged, the capacitor is disconnected from the battery (hence, the terminals are open).



1) This capacitor stores  $Q = 3.2 \mu\text{C}$  when the voltage  $V$  across the spacing of this capacitor is 220 V. What is the area  $A$ ?

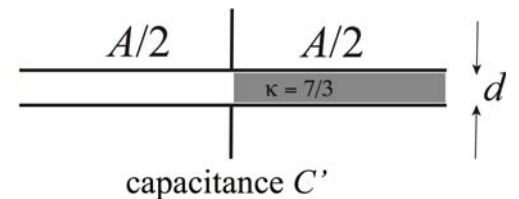
- a.  $A = 0.2 \text{ m}^2$
- b.  $A = 0.13 \text{ m}^2$
- c.  $A = 0.33 \text{ m}^2$
- d.  $A = 0.46 \text{ m}^2$
- e.  $A = 0.066 \text{ m}^2$

2) Now, you hold a slab of a dielectric material of thickness  $d$  with area  $A/2$  and dielectric constant  $\kappa = 7/3$  close to the capacitor gap as shown in the figure. Choose the correct statement from below.



- a. You feel no particular force due to the capacitor.
- b. You feel that the slab is pulled to the capacitor gap.
- c. You feel that the slab is repelled from the capacitor gap.

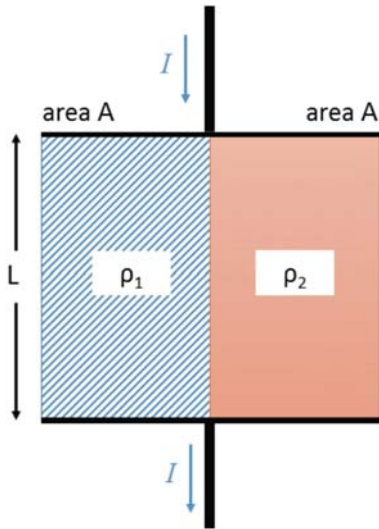
3) Before placing the dielectric slab discussed in the preceding question, the capacitance of the capacitor is  $C$ . After placing the slab as shown in the figure, what is the capacitance  $C'$  of this capacitor? The slab fits very closely to the gap. [Hint: consider the system as two capacitors connected in parallel.]



- a.  $C' = 5C/3$ .
- b.  $C' = 4C/3$ .
- c.  $C' = 7C/3$ .
- d.  $C' = 11C/6$ .
- e.  $C' = 3C/2$ .

4) A single resistor is made by attaching two blocks of different materials to two conducting plates, as shown in the figure.

What is the total resistance  $R$  of the combined element?



Cross Sectional Area of Each Block:

$$A = 1.6 \times 10^{-4} \text{ m}^2$$

Length of Blocks:

$$L = 0.2 \text{ m}$$

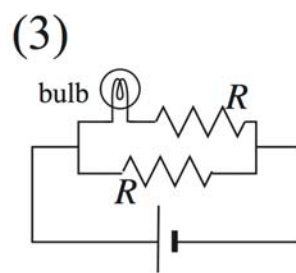
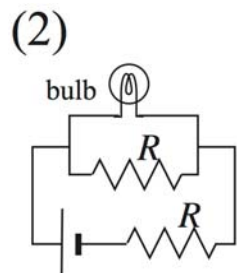
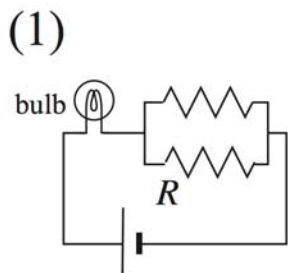
Resistivities:

$$\rho_1 = 4.1 \times 10^{-8} \Omega \cdot \text{m}$$

$$\rho_2 = 5.1 \times 10^{-8} \Omega \cdot \text{m}$$

- a.  $R = 1.5 \times 10^{-6} \Omega$
- b.  $R = 4.8 \times 10^{-5} \Omega$
- c.  $R = 2.8 \times 10^{-5} \Omega$
- d.  $R = 1.2 \times 10^{-4} \Omega$
- e.  $R = 1.8 \times 10^{-5} \Omega$

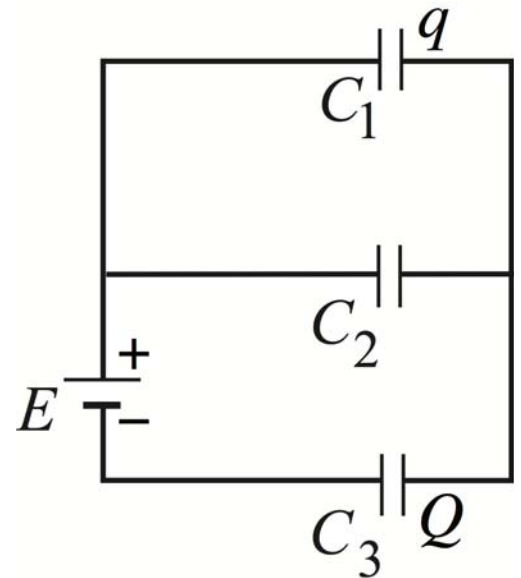
5) Consider circuits consisting of two identical resistors having resistance  $R = 10 \Omega$  and a light bulb whose resistance is  $1 \Omega$ . Among the following circuits, which gives the brightest bulb output? Assume that all the batteries are indistinguishable.



- a. Figure 2
- b. Figure 1
- c. Figure 3

The next two questions pertain to the situation described below.

In the following capacitor circuit,  $C_1 = 6 \mu\text{F}$ ,  $C_2 = 3 \mu\text{F}$  and the battery provides a positive voltage as shown in the figure.



6) The magnitude of charge  $q$  on capacitor  $C_1$  in the figure is  $35 \mu\text{C}$ . What is the charge  $Q$  on the right plate of capacitor  $C_3$  ?

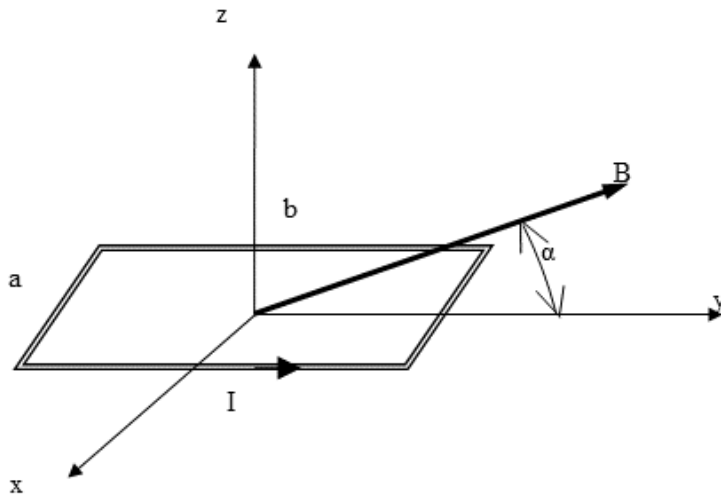
- a.  $Q = -11.2 \mu\text{C}$
- b.  $Q = 32.8 \mu\text{C}$
- c.  $Q = 52.5 \mu\text{C}$
- d.  $Q = -45.9 \mu\text{C}$
- e.  $Q = -32.8 \mu\text{C}$

7) Now, the battery voltage is reduced from  $E$  to  $E/3$ . Which of the following answers is closest to the magnitude of charge  $q$  now stored in  $C_1$  ?

- a.  $|q| = 11.7 \mu\text{C}$
- b.  $|q| = 8 \mu\text{C}$
- c.  $|q| = 24 \mu\text{C}$

The next three questions pertain to the situation described below.

A rectangular single wire loop with dimensions  $a = 4$  cm and  $b = 5$  cm lies in the  $xy$ -plane. It carries a current of  $I = 3.7$  A with the direction of current flow indicated in the figure. The loop is in a uniform magnetic field of strength  $B = 3.5 \times 10^{-4}$  T pointing along a direction lying in the  $yz$ -plane and making an angle of  $\alpha = 30^\circ$  from the  $y$  axis.



8) What is the magnitude of the torque on the loop?

- a.  $2.2 \times 10^{-6}$  N m
- b.  $4.7 \times 10^{-6}$  N m
- c.  $1.3 \times 10^{-6}$  N m

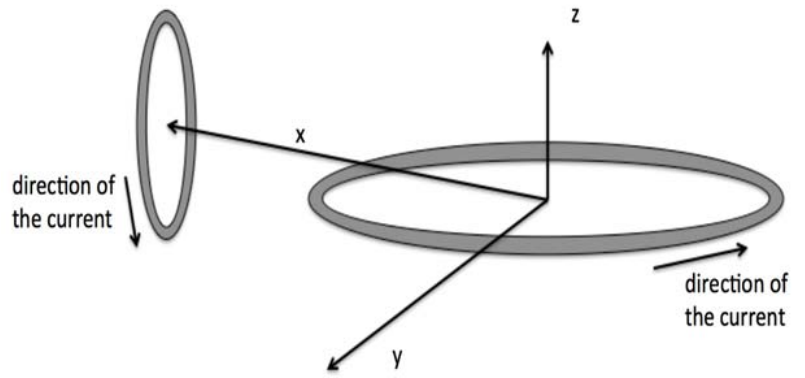
9) About which axis does the torque try to rotate the loop?

- a. z-axis
- b. x-axis
- c. y-axis

10) What is the magnitude of the force on the left side of the loop labeled a in the figure?

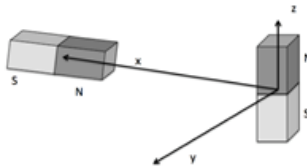
- a.  $5.18 \times 10^{-5}$  N
- b.  $4.45 \times 10^{-5}$  N
- c.  $3.06 \times 10^{-5}$  N

11) In the  $xy$ -plane, there is a giant metal ring that is centered at the origin and carries a constant current that flows in the direction specified in the figure below. Away from the giant ring, there is a smaller ring centered on the  $x$ -axis that carries a constant current as well (the direction is also drawn). Assume that both rings are held fixed in space as shown in the figure and that there is zero gravity.

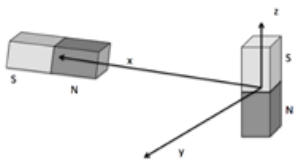


Which of the following configurations of bar magnet bars produces magnetic field lines that are most similar to those generated by the rings?

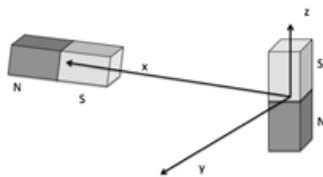
**Figure 1**



**Figure 2**



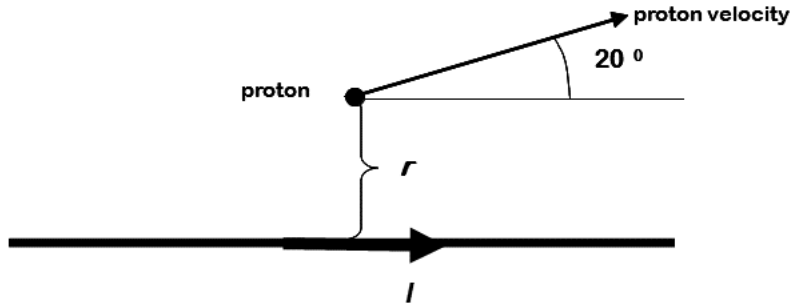
**Figure 3**



- a. Figure 3
- b. Figure 1
- c. Figure 2

The next two questions pertain to the situation described below.

A long straight wire carries a current of  $I = 30$  A as shown in the figure. A proton (with charge  $q = 1.602 \times 10^{-19}$  C) is moving with velocity  $v = 200$  m/s as shown below. The velocity lies fully in the plane of the figure. The velocity makes an angle of  $20^\circ$  with the direction of the wire. At the instant considered in this problem, the proton is  $r = 0.25$  m away from the wire.



12) What is the direction of the magnetic field due to the wire at the position of the proton?

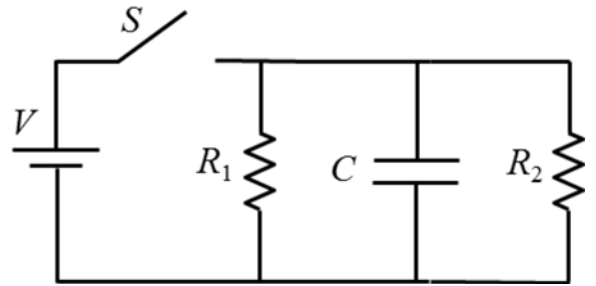
- a. It is parallel to the wire.
- b. It is pointing out of the plane of paper.
- c. It is pointing into the plane of the paper.

13) What is the magnitude of the magnetic force on the proton?

- a.  $3.7 \times 10^{-22}$  N
- b.  $6.2 \times 10^{-22}$  N
- c.  $9.5 \times 10^{-22}$  N
- d.  $7.7 \times 10^{-22}$  N
- e.  $4.9 \times 10^{-22}$  N

The next four questions pertain to the situation described below.

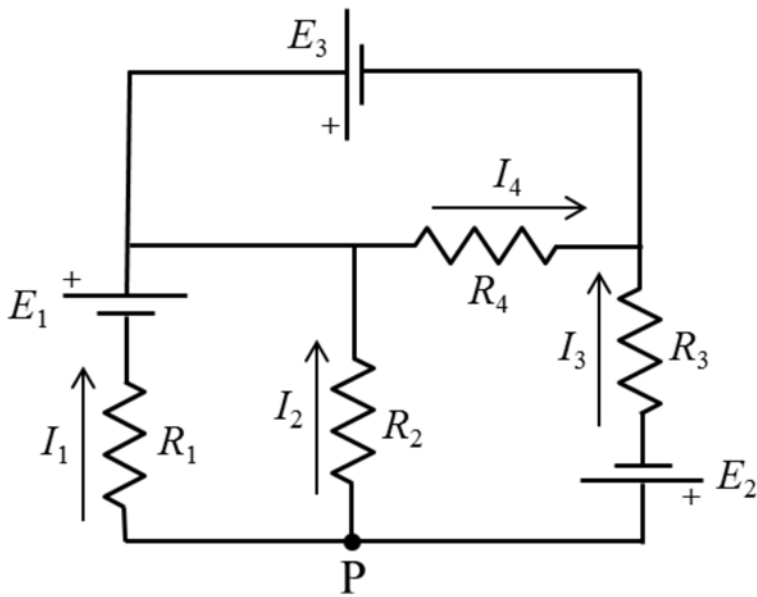
A circuit is constructed with two resistors and one capacitor as shown. The values for the resistors are:  $R_1 = R_2 = 3 \Omega$ . The capacitance is  $C = 40 \mu\text{F}$  and the battery voltage is  $V = 10 \text{ V}$ . The capacitor is initially uncharged. At time  $t = 0$  the switch  $S$  is closed.



- 14) What is the magnitude of the current through  $R_1$  immediately after the switch is closed?
- 6.7 A
  - 3.3 A
  - 0 A
- 15) What is the current through the battery  $I_b$  a long time ( $t \rightarrow \infty$ ) after closing switch  $S$ ?
- $|I_b| = 13.4 \text{ A}$
  - $|I_b| = 6.7 \text{ A}$
  - $|I_b| = 0 \text{ A}$
  - $|I_b| = 20 \text{ A}$
  - $|I_b| = 3.3 \text{ A}$
- 16) After being closed for a long time the switch is opened again. How much time does it take for the capacitor to drop to  $1/4$  of its initial charge?
- 0.026 s
  - 0.0034 s
  - $4.2 \times 10^{-5} \text{ s}$
  - $8.3 \times 10^{-5} \text{ s}$
  - $2.5 \times 10^{-4} \text{ s}$
- 17) After the switch has been open a long time ( $t \rightarrow \infty$ ), energy  $U_0$  has been dissipated over the two resistors. If the value of the resistors  $R_1$  and  $R_2$  had been doubled (so each was  $6 \Omega$ ), how would the energy dissipated,  $U$ , compare to  $U_0$ ? Assume every other parameter in the problem stayed the same.
- $U = U_0$
  - $U > U_0$
  - $U < U_0$ .

The next three questions pertain to the situation described below.

In the following figure,  $E_1 = 12\text{ V}$ ,  $E_3 = 7\text{ V}$ ,  $R_1 = R_2 = R_3 = R_4 = 4\ \Omega$ .  $E_2$  is not known.



18) Given the currents depicted in the diagram, which of the following formulas correctly describes a Kirchhoff loop rule for this circuit?

- a.  $I_2 R_2 + I_4 R_4 + I_3 R_3 + E_2 = 0$
- b.  $I_2 R_2 - I_4 R_4 - I_3 R_3 + E_2 = 0$
- c.  $I_2 R_2 + I_4 R_4 - I_3 R_3 + E_2 = 0$
- d.  $I_2 R_2 + I_4 R_4 + I_3 R_3 - E_2 = 0$
- e.  $I_2 R_2 + I_4 R_4 - I_3 R_3 - E_2 = 0$

19) What is the current  $I_4$ ? Pay attention to the direction of the current arrow in the figure.

- a.  $I_4 = 3\text{ A}$
- b.  $I_4 = 0\text{ A}$
- c.  $I_4 = -3\text{ A}$
- d.  $I_4 = 1.75\text{ A}$
- e.  $I_4 = -1.75\text{ A}$

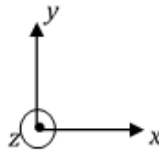
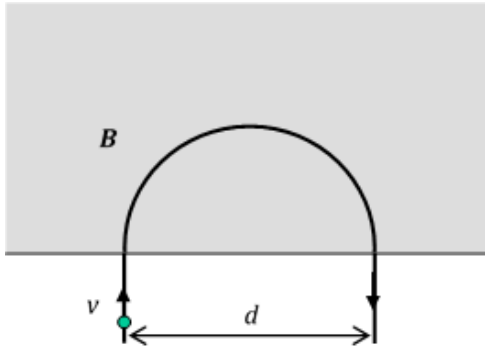
20) At junction P three currents  $I_1$ ,  $I_2$ , and  $I_3$  meet. Given the labels in the figure, which of the following describes the correct relation among them?

- a.  $I_1 - I_2 - I_3 = 0$
- b.  $I_1 - I_2 + I_3 = 0$
- c.  $-I_1 + I_2 - I_3 = 0$
- d.  $I_1 + I_2 + I_3 = 0$
- e.  $I_1 + I_2 - I_3 = 0$



The next three questions pertain to the situation described below.

A positively charged particle enters a region of uniform magnetic field as shown in the figure. The direction of the magnetic field is unspecified. After completing a semicircular path in the  $xy$ -plane, as shown below, the particle exits the field.



$$q = 1.6 \times 10^{-19} \text{ C}$$
$$m = 1.2 \times 10^{-27} \text{ kg}$$
$$v = 5 \times 10^6 \text{ m/s}$$
$$B = 3 \text{ T}$$

21) What is the direction of the magnetic field? (Note the axis orientation in the figure.)

- a. +  $x$  direction
- b. +  $z$  direction
- c. -  $z$  direction

22) Determine the distance  $d$  between the entrance and exit points on the particle's trajectory. Note that the particle makes a complete semicircle in the field region.

- a.  $d = 6 \text{ mm}$
- b.  $d = 25 \text{ mm}$
- c.  $d = 45 \text{ mm}$
- d.  $d = 925 \text{ mm}$
- e.  $d = 112 \text{ mm}$

23) If the magnitude of the magnetic field is increased, then the amount of time which the particle spends inside the region of magnetic field

- a. decreases.
- b. remains unchanged.
- c. increases.