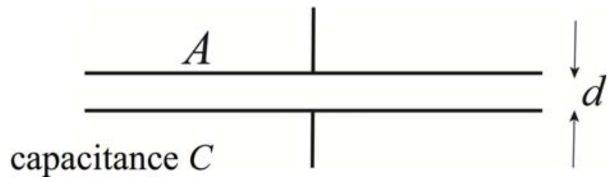
The next three questions pertain to the situation described below.

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).



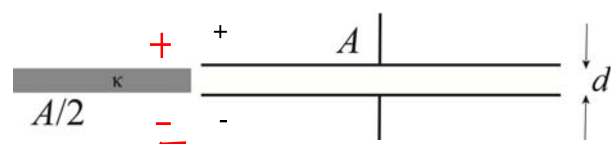
1) This capacitor stores $Q = 3.2\ \mu$C when the voltage V across the spacing of this capacitor is 220 V. What is the area A?

Q = CV
C = e0 A/d
or
E = Q/e0A

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

```
C = Q/V = 3.2/220 microF
A = dC/e0 = 0.2x10^{-3}x(3.2/220)x10^{-6}/8.85x10^{-12}
  = (0.2x3.2/2.2x8.85) x 10^{-3-2-6+12}
  = 0.03287 x 10^{1} = 0.33 m^2
or
A = Q/e0E = Qd/e0V = the same as above.
```

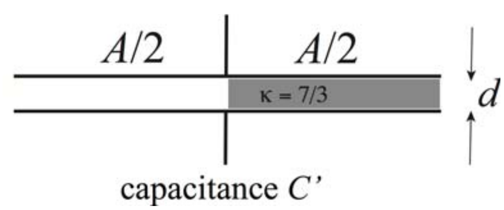
2) Now, you hold a slab of a dielectric material of thickness d with area $A/2$ and dielectric constant $\kappa = 7/3$ close to the capacitor gap as shown in the figure. Choose the correct statement from below.



induced charges attracted to the metal plates

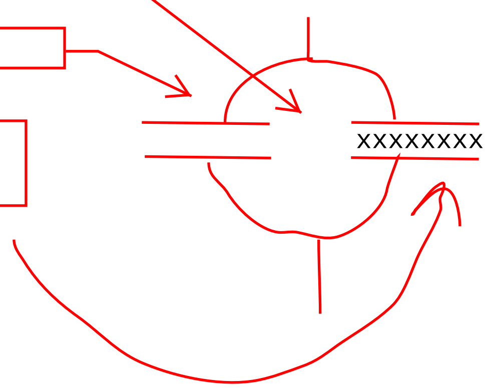
a. You feel no particular force due to the capacitor.
b. You feel that the slab is pulled to the capacitor gap.
c. You feel that the slab is repelled from the capacitor gap.

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.]



C/2

C is proportional to kappa



kappa C/2

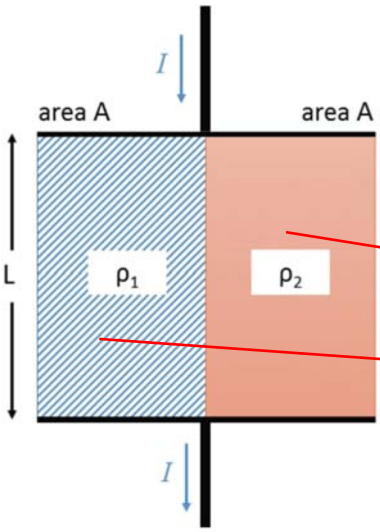
a. $C' = 5C/3$.
b. $C' = 4C/3$.
c. $C' = 7C/3$.
d. $C' = 11C/6$.
e. $C' = 3C/2$.

parallel connection is C + C'

```
C' = C/2 + (7/3)C/2 = C(1/2 + 7/6) = 5C/3.
```

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

R in parallel
RR'/(R+R')

Length of Blocks:
$L = 0.2\ \mathrm{m}$

R = rho L/A

can be interpreted as

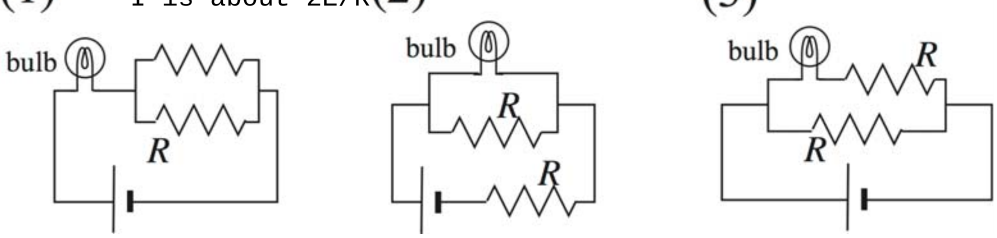
Resistivities:
$\rho_1 = 4.1 \times 10^{-8}\ \Omega \cdot \mathrm{m}$
$\rho_2 = 5.1 \times 10^{-8}\ \Omega \cdot \mathrm{m}$

```
total R = (L/A) rho1 x rho2/(rho1 + rho2)
        = (0.2/1.6 x 10^{-4}) x (4.1x5.1/9.2)x10^{-8}
        = (0.2x4.1x5.1/1.6x9.2)x 10^{4-8}
        = 0.284 x 10^{-4} ohms
```

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.

(1) I is about 2E/R (2) I is about E/R (3) I is about E/R



P = I^2R

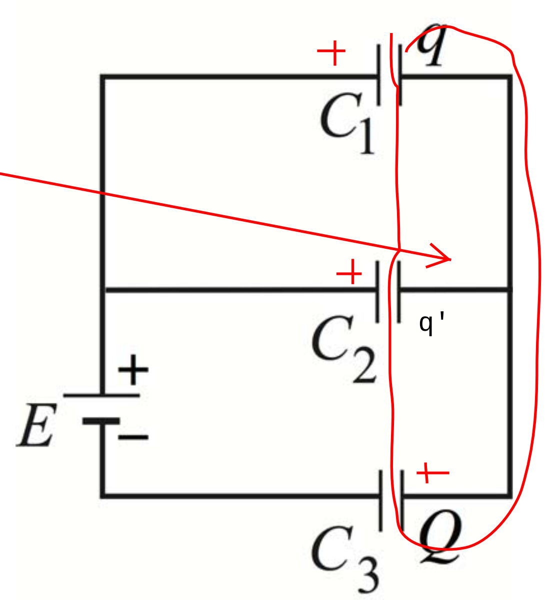
Therefore, the largest I -> the brightest

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

In this case crude estimates are enough as noted above the figures.

The next two questions pertain to the situation described below.

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



Conservation of charge implies

Total charge here must be zero.

q + q'+ Q = 0.

C1 and C2 are in parallel, so the voltages across them are identical.

q/C1 = q'/C2 -> q' = (C2/C1)q

6) The <u>magnitude</u> of charge q on capacitor C_1 in the figure is $35\ \mu$C. What is the charge Q on the <u>right plate</u> of capacitor C_3 ?

Therefore, |Q| = q + (C2/C1)q = (C1+C2)q/C1
= (9/6)35 = 105/2 microC

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

Q is on the higher voltage side, so it must be positive

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?

Every charge is proportional to E.

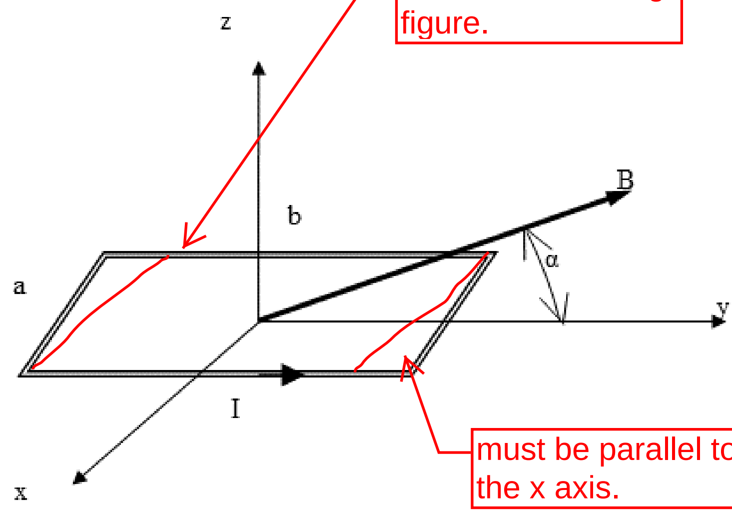
a. $|q| = 11.7\ \mu$C
b. $|q| = 8\ \mu$C
c. $|q| = 24\ \mu$C

q -> 35/3 = 11.7

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 × 10^{-4} T pointing along a direction lying in the yz-plane and making an angle of $\alpha = 30^{\circ}$ from the y axis.

This is a confusing figure.



must be parallel to the x axis.

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

The magnetic moment points in the z direction; its magnitude is IA

Torque = mu x B sin (90-alpha)

a. 2.2 × 10^{-6} N m
b. 4.7 × 10^{-6} N m
c. 1.3 × 10^{-6} N m

```
torque = 3.7 x 20x10^{-4} x 3.5x10^{-4} x sin 60
       = 224x10^{-8} Nm
```

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

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

This does not depend on the orientation of the loop in the xy-plane.

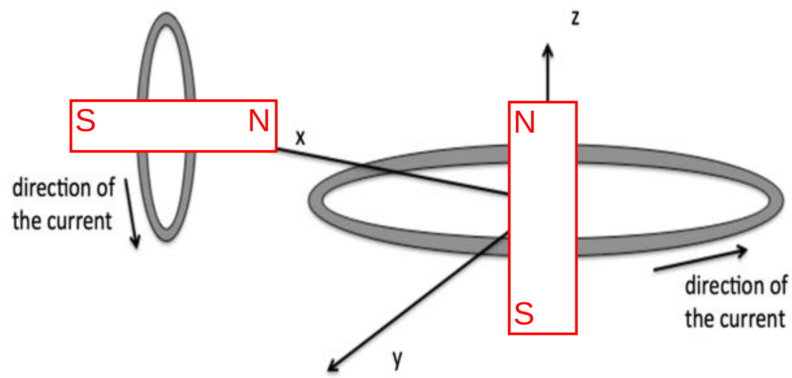
10) What is the magnitude of the force on the left side of the loop labeled a in the figure?

a. 5.18 × 10^{-5} N
b. 4.45 × 10^{-5} N
c. 3.06 × 10^{-5} N

```
If the figure is reasonable, then theta = 90,
so F = 3.7 x 0.04 x 3.5 x 10^{-4}
     = 0.518 x 10^{-4}
However, the angle theta is actually not very clear due to the bad figure.
```

F = ILB sin theta

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.



RH screw rule

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

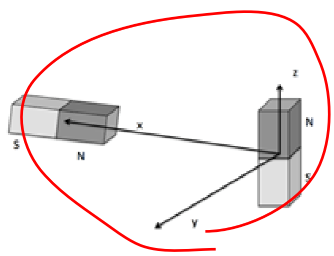


Figure 2

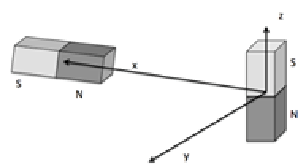
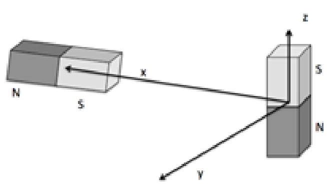


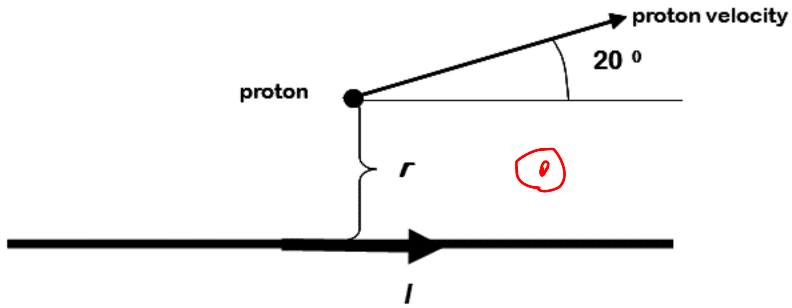
Figure 3



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° 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?

Ampere and RH screw

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?

B = mu0I/2pi r
F = qvB sin theta

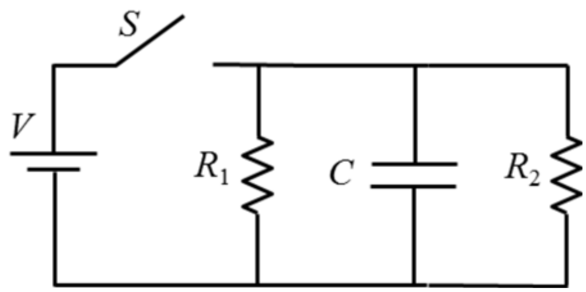
a. 3.7×10^{-22} N
b. 6.2×10^{-22} N
c. 9.5×10^{-22} N
d. 7.7×10^{-22} N
e. 4.9×10^{-22} N

```
B = mu0I/2pi r
= 4pix10^{-7}x 30 /2 pi x 0.25
= (2x30/0.25)x10^{-7} = 240x10^{-7} = 2.4x10^{-5}

F = qvB, because v and B are perpendicular
  = 1.6x10^{-19} x 200 x 2.4x10^{-5}
  = 7.68 x 10^{-19+2-5} 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 $C = 40\ \mu$F and the battery voltage is $V = 10$ V. The capacitor is initially uncharged. At time $t = 0$ the switch S is closed.



The voltage across C cannot change instantaneously.

14) What is the magnitude of the current through R_1 <u>immediately after the switch is closed</u>?

a. 6.7 A
b. 3.3 A
c. 0 A

No voltage across R1 -> no current.

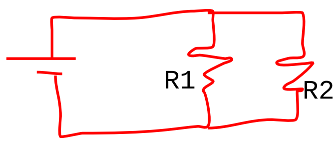
Remark:
Note that there is an infinite current through C.
In reality, this causes a lot of trouble due to Faraday's effect.

15) What is the current through the battery I_b a long time ($t \to \infty$) after closing switch S?

Long after -> C is full -? no current through C.

a. $|I_b| = 13.4$ A
b. $|I_b| = 6.7$ A
c. $|I_b| = 0$ A
d. $|I_b| = 20$ A
e. $|I_b| = 3.3$ A

The effective circuit looks as



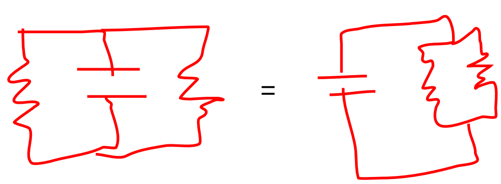
Ib = V/(R1R2/(R1+R2)
= (R1+R2)V/R1R2
= 10(6/9)= 20/3 A

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?

The effective circuit is

tau = C x (R seen from C)

a. 0.026 s
b. 0.0034 s
c. 4.2×10^{-5} s
d. 8.3×10^{-5} s
e. 2.5×10^{-4} s



tau = 40x(3/2)= 60 micro sec.

Q(t) = Q0e^{-t/tau} -> 1/4 = e^{-t/tau} ->t = tau x log 4
= 60 x 1.386 = 83.177 micro sec

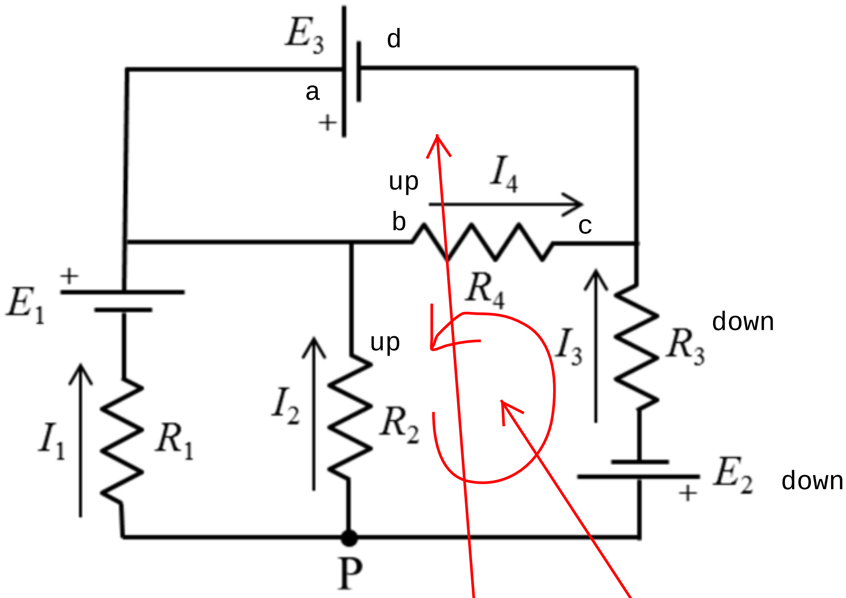
17) After the switch has been open a long time ($t \to \infty$), energy U_0 has been dissipated over the two resistors. If the value of the resistors R_1 and R_2 had been doubled (so each was 6 Ω), how would the energy dissipated, U, compare to U_0? Assume every other parameter in the problem stayed the same.

a. $U = U_0$
b. $U > U_0$
c. $U < U_0$.

The energy is conserved, so only the stored energy can be dissipated.

The next three questions pertain to the situation described below.

In the following figure, $E_1 = 12$ V, $E_3 = 7$ 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. $I_2R_2 + I_4R_4 + I_3R_3 + E_2 = 0$
b. $I_2R_2 - I_4R_4 - I_3R_3 + E_2 = 0$
c. $I_2R_2 + I_4R_4 - I_3R_3 + E_2 = 0$
d. $I_2R_2 + I_4R_4 + I_3R_3 - E_2 = 0$
e. $I_2R_2 + I_4R_4 - I_3R_3 - E_2 = 0$

For this loop
I2R2 -E2 - I3R3 + I4R4 = 0

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

a. $I_4 = 3$ A
b. $I_4 = 0$ A
c. $I_4 = -3$ A
d. $I_4 = 1.75$ A
e. $I_4 = -1.75$ A

The voltages at a and b must be the same (higher);
The voltages at c and d must be the same (lower);
BECAUSE there are no resistor between these pairs of points.
Hence, the voltage across R4 is E3. -> E3/R4 = 7/4 = 1.75 A.

You could use a loop, but do not do such a stupid approach.

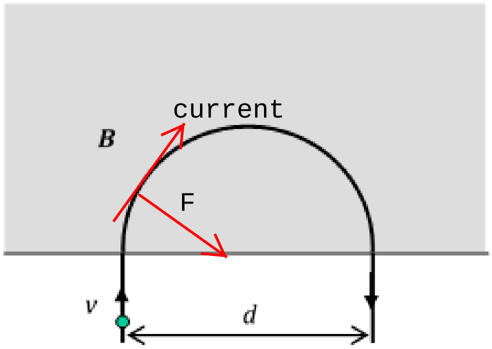
20) At junction P three currents I_1, I_2, and I_3 meet. Given the labels in the figure, which of the following describes the correct relation among them?

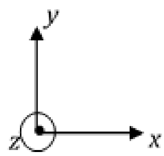
a. $I_1 - I_2 - I_3 = 0$
b. $I_1 - I_2 + I_3 = 0$
c. $-I_1 + I_2 - I_3 = 0$
d. $I_1 + I_2 + I_3 = 0$
e. $I_1 + I_2 - I_3 = 0$

All leaving P. Steadiness + charge conservation imply
I1 + I2 + I3 = 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.





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

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

RE rule

Fingers point yourself.

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.

cyclotron motion r = mv/qB
d = 2r

a. $d = 6$ mm
b. $d = 25$ mm
c. $d = 45$ mm
d. $d = 925$ mm
e. $d = 112$ mm

d = 2mv/qB = 2x1.2x10^{-27}x5x10^6/1.6x10^{-19}x3
= (12/4.8)x 10^{-27+6+19} = 2.5 x 10^{-2} m

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

Increasing B -> decreasing d

The energy is conserved, so v is the same.

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