DO ALL SIXTEEN PROBLEMS. THE WORTH OF EACH PROBLEM IS MARKED BESIDE THE PROBLEM. SHOW YOUR WORK FOR PARTIAL CREDIT. USE MKS UNITS IN ALL ANSWERS UNLESS OTHERWISE SPECIFIED.

For problems 1 through 3, consider the following situation: point C located at (0 m, +12 m); q_A = +18 µC located at (-5 m, 0 m); q_B = -12 µC located at (+8 m, 0 m).

Specify **directions** as angles measured counterclockwise from the positive x axis.
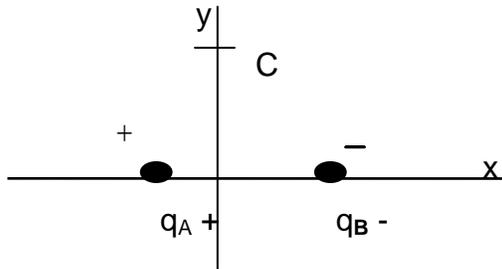
1)   a) What is the force on q_A due to the presence of q_B ?

Magnitude: Direction: See note above to answer direction

        [3] __**0.012 Nt**_____   [3] _____**0°**_____ .

b) Is the magnitude of the force on q_B due to the presence of q_A [smaller than, the same as, or larger than] the magnitude of the force on q_A due to the presence of q_B ?

                                                                [1] __**same**_____ .

c) Is the direction of the force on q_B due to the presence of q_A [the same as, opposite to, or other than] the direction of the force on q_A due to the presence of q_B ?

                                                        [1] ____**opposite**_____ .

2) a) What is the electric field at point C due to q_A ONLY ?

Magnitude: Direction:

        [2] __**958.6 Nt/C**_____   [2] __**67.4°**_____ .

b) What is the total electric field at point C due to both q_A and q_B ?

Magnitude: Direction:

        [1] __**799 Nt/C**_____   [1] __**30.2°**_____ .

c) What would be the electric force on an electron placed at position C ?

Magnitude: Direction:

        [1] __**1.27 x 10⁻¹⁶ Nt**_____   [1] __**210.2°**_____ .

3) Consider the same two charges at the same locations as in prob #1. a) What is the voltage at the point C due to the presence of the two charges q_A and q_B (assuming that the voltage at infinity is zero) ?

[3] **4,973 V**   . b) How much energy would it take to bring a third charge of +15 nCoul from very far away and place it at the point C ?

[1] **7.46 x 10^{-5} J**   .

 c) Would this process take energy or would it give up energy?

[1] **take energy**   .

For problems 4 and 5, consider the following situation: two parallel plates, each of area 49 cm^2 (7 cm x 7 cm) are separated by 2 mm with vacuum initially between the plates. One plate is directly above the other plate. A voltage of 30 volts is placed across the two plates with the top plate having the higher voltage.

4) a) What will the **electric field** be 1.5 mm above the bottom plate (0.5 mm below the top plate)?
magnitude: direction:

[2] **15,000 V/m**   ,   [2] **down**   .

b) Will the electric field [get stronger, get weaker, or stay the same in magnitude] as you **approach the top plate** (go from 1.5 mm above the bottom plate to more than 1.5 mm above the bottom plate)?

[1] **same**   .   c) What is the **electric field** at a distance of 0.5 mm above the top plate ?   magnitude: direction:

[1] **0**   [1] **none**   .

5) a) How much charge is on the top plate? [2] **6.5 x 10^{-10} C**   .
b) Does the top plate or does the bottom plate have the positive charge?

[1] **top**   .

c) What is the capacitance of this parallel plate system?

[2] **2.17 x 10^{-11} F**   .

d) How much energy does this capacitor store with this charge and voltage on it?
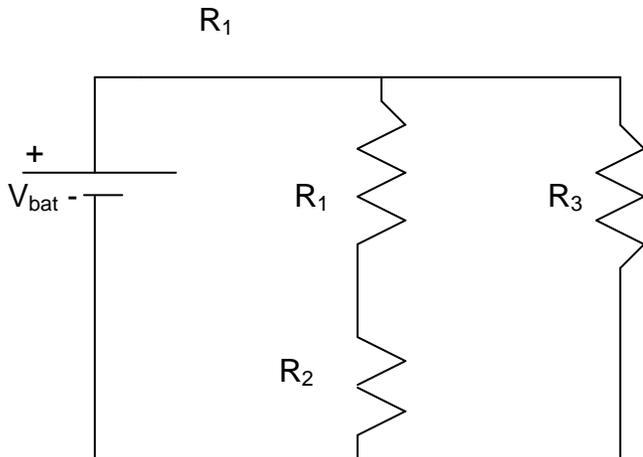
[2] **9.75 x 10^{-9} J**.

6) Consider the three resistors in the diagram below.

a) What is the effective resistance of the three resistors given that $R_1 = 6\ \Omega$, $R_2 = 9\ \Omega$ and $R_3 = 15\ \Omega$?

[3] _____**7.5 Ω**_____. b) If the resistors were replaced by capacitors with $C_1 = 6$ nF, $C_2 = 9$ nF and $C_3 = 15$ nF, what would the effective capacitance of the three capacitors be for this hookup?

[3] _____**18.6 nF**_____.

7) Consider the situation below: The resistor has a resistance of 18,000 Ω and the capacitor has a capacitance of 47 nF, and the battery has a voltage of 30 volts. a) How long will it take the capacitor to lose half (50%) of its charge after the switch to the battery is opened?

[2] _____**5.86 x 10^{-4} sec**_____.
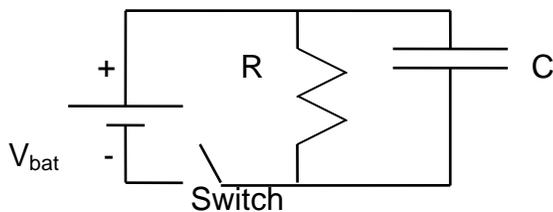
b) How long will it take for the capacitor to lose 95% of its charge (have 5% left)?

[2] _**2.53 x 10^{-3} s**_ .

c) If the capacitance were decreased, would the times for parts a and b above [increase, stay the same, or decrease]?

[1] _____**decrease**_____ .

IN ALL CASES INVOLVING DIRECTIONS, EXPRESS YOUR ANSWER AS ONE OF THE FOLLOWING: {UP, DOWN, NORTH, EAST, SOUTH, OR WEST}. (DO NOT EXPRESS IT AS INTO THE PAPER OR OUT OF THE PAPER!)

N
↑   ⊙up
W←   →E
↓   ⊗down
S

USE MKS UNITS IN YOUR ANSWERS UNLESS OTHERWISE SPECIFIED.

8) a) An electron is moving toward the East→ with a speed of 4×10^5 m/s in a magnetic field of strength 0.123 T directed down⊗. What is the magnetic force on the electron:

magnitude: direction:

[2] __**7.87 x 10^{-15} Nt**__   ,   [2] ___**South**___. b) If the particle were a proton moving at the given speed in the same magnetic field, would the magnetic force on the proton be more (>), the same (=), or less (<) in magnitude than on the electron?

[1] __**same**__.

c) Would the direction of the magnetic force on the proton be the same or different (if different, specify the new direction) than on the electron?

[1] ___**North**___. d) Assuming the field were constant, the electron would: [move in a straight line and begin to **go faster**, move in a straight line and start to **slow down**, move in a circle with the **same radius** as the proton, move in a circle with a **smaller radius** than the proton, move in a circle with a **bigger radius** than the proton]?

[1] ___**smaller radius**___.

9) A solenoid has a length of 30 cm, a radius of 4 cm, and 2,000 windings wound around it. A current of 3.3 amps flows through the solenoid.   a) What is the magnitude of the magnetic field at the center of the solenoid?   ≈ **.0276 T**

[2] __**= .0267 T**__.   b) Is this an "exact" or "approximate" calculation?

[1] _____. c) Is the "approximate" value higher, the same, or lower than the "exact" value?

[1] ___**higher**___.   d) In this case, by what percent does the "approximate" value differ from the "exact" value?

[1] __**3.4 %**__.

10) A rectangular loop of wire of width (↔) 68 cm and length (↕) 34 cm is placed in a region where the magnetic field is .123 Teslas in strength as shown in the figure below (the North and South poles of the magnet are indicated in the figure by the N and S letters). A current of 3.3 Amps flows counter-clockwise (as viewed from above) through the wire. Use the direction convention indicated on the previous page (N↑, E→, S↓, W←, up⊙, down⊗)   a) What will be the magnetic force on the North side of the loop?

Magnitude: Direction:

[1] _____**0**_____,   [1] __**none**_____.

b) What will be the magnetic force on the West side of the loop?

Magnitude: Direction:

[1] __**0.138 Nt**_____   [1] _**up ⊙**_____.   c) Will the force on the East side be equal and opposite to that on the West side (yes or no)?

[1] _**Yes**____.   d) Which direction will the TOTAL magnetic FORCE on the rectangular current loop be? (specify direction or answer none if force is zero)

[1] ____**none**_____. e) Which direction will the total magnetic TORQUE on the rectangular current loop be? (specify direction or answer none if torque is zero)
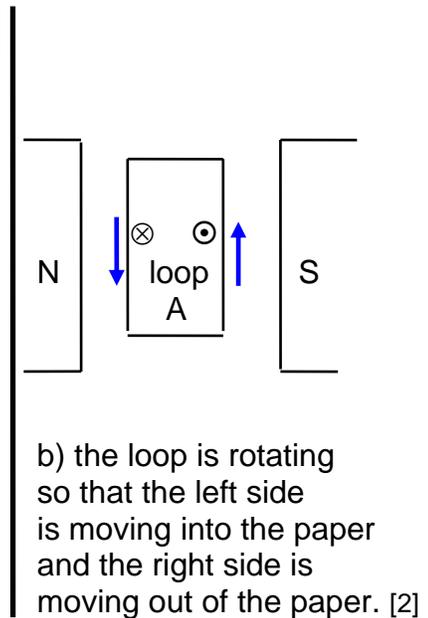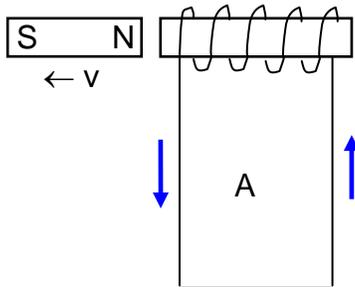
[1] _**North**___.
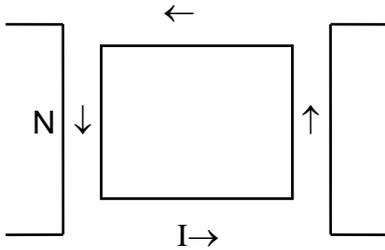
11) DESIGN an electric generator that will provide an rms voltage of 220 volts. Both DRAW A DIAGRAM and indicate the values for all parameters. [6]

12) Clearly draw in the **direction** of the induced current in circuit A in each of the three diagrams, or write NONE if there is no induced current.

a) the North magnetic
   pole is moving away from
   the solenoid of circuit A [2]

S   N

← v

A

N   ⊗ ⊙   S
    loop
     A

b) the loop is rotating
   so that the left side
   is moving into the paper
   and the right side is
   moving out of the paper. [2]

c) consider the induced
   current in the circuit
   labeled A due to the
   switch being opened in
   the circuit labeled B. [2]

B   A

S

+ ‖ -

V_{bat} R
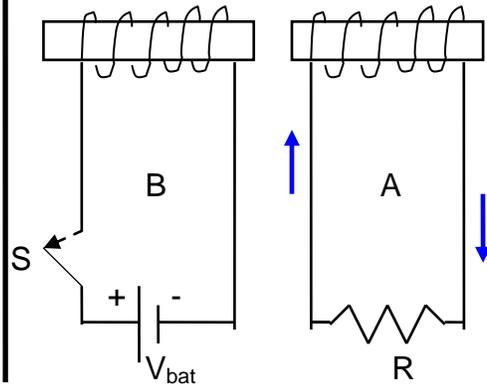
13) Consider a series LRC circuit with an oscillating voltage source of 30 volts (rms) at 300 Hz. The resistance is 40 Ω, the capacitance is 3 μF, and the inductance is 850 mH.   What is the:
a) capacitive reactance (X_C)?

[2] __**176.8 Ω**__.

b) inductive reactance (X_L)?

[2] __**1,602.2 Ω**__.

c) impedance (Z) of the circuit?

[1] __**1,426 Ω**__.

d) rms current in the circuit?

[1] __**0.021 A**__.

e) What is the rms voltage across the capacitor ($V_{C\text{-rms}}$)?

[1] __**3.72 V**__.

14.   a) Given that the intensity of a sound wave of frequency 1,440 Hz is 3.0×10^{-7} W/m² , what will its intensity be if the frequency of the sound wave is increased by a factor of 5 and the amplitude stays constant: (in Watts/m²)?   (in dB)?

[1] __**7.5 x 10^{-6} W/m^2**__   [1] ___**68.75 dB**___ .

b) Given that the intensity of a sound wave of frequency 185 Hz is 55 dB at a distance of 2 meters from the speaker, what will its intensity be at a distance of 8 meters from the speaker:

  (in W/m²)?   (in dB)?

[1] __**1.98 x 10^{-8} W/m^2**__   [1] __**42.96 dB**___ .

15)   Assume the speed of sound in this room is 345 m/s. Consider a speaker that produces a sound of frequency 3,000 Hz. (In parts a and b, consider the air to be still - no wind.)
a) Suppose that the speaker is held stationary, and you head away from the speaker at a speed of 32 m/s. What frequency will you measure for the sound?

[2] _____**2,722 Hz**_____ .

b) Suppose that you are stationary and the speaker goes toward you at a speed of 25 m/s. What frequency will you now measure for the sound?

[2] ____**3,234 Hz**____ .

c) Suppose that the speaker of frequency 3,000 Hz is mounted on a train that is leaving the station going East at 25 m/s, you are approaching the station (and the back of the train) going East at a speed of 35 m/s, and there is a wind blowing West (from the East) at a speed of 15 m/s (relative to the station). What will you measure for the frequency of the sound [you must be precise: answer to the closest Hz]?

[2] ____**3,078 Hz**____ .

16) a) Write down the one-dimensional wave equation for an electric field wave: [2]

b) Where did this equation come from (that is, is it basic, or is it derived from more basic principles - and if so, what is that basic principle or principles)? [2]

c) Show that $E_y(x,t) = E_o \sin(kx - \omega t)$ is a solution of the one-dimensional wave equation for Electric Field as long as $\omega/k = v = \sqrt{1/\varepsilon_o \mu_o)}$: [2]