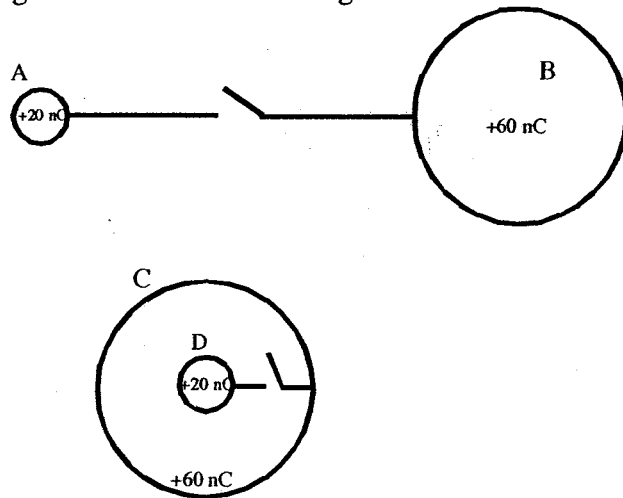


**Question 2 – Ranking Questions, use = signs where appropriate.**

**I – Charges on metal shells**

Two pairs of charged hollow, spherical conducting shells are connected with wires and switches. The system AB is very far from CD. The radius of each large shell is four times that of the small shell. Before the switches are closed the small shells have charges of +20 nC and the large ones +60 nC.



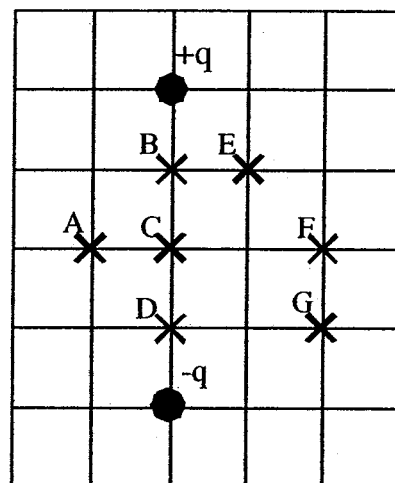
After the switches are closed, rank the net charge on each shell.

Greatest \_\_\_\_\_ Least

Briefly explain:

**II – Potential near two point charges**

Two equal magnitude but opposite sign charges are fixed in space at the locations shown in the diagram. Seven points A-G are near the two point charges.



Rank the electric potential at the points, remember to include the sign. Assume the usual definition that the electric potential is zero at large distances.

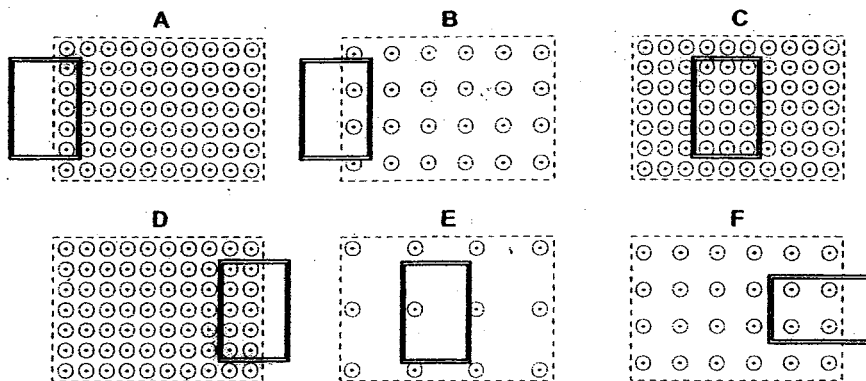
Greatest \_\_\_\_\_ Least

Briefly explain:

Handwritten explanation:  
 III)  $\Delta - V > R > F > C = E = 0$   
 I)  $C > B > A > D = 0$   
 II)  $B > E > A = C = F > G > D$

**III – Induced emf for rectangular loops moving in a uniform magnetic field**

Six identical rectangular loops are moving to the right at the same speed in the vicinity of a region of uniform magnetic field. The strengths of the magnetic fields vary as indicated. All loops contain a  $1 \Omega$  resistor that is **not** shown.



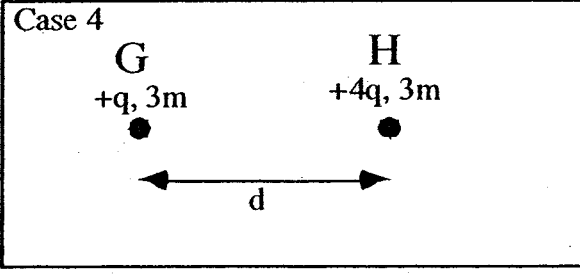
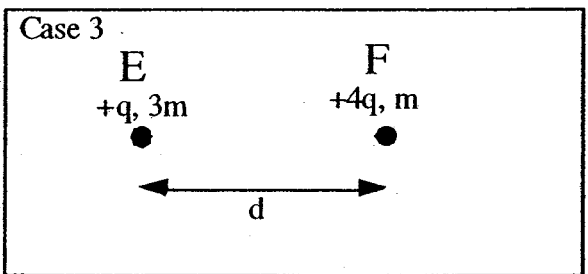
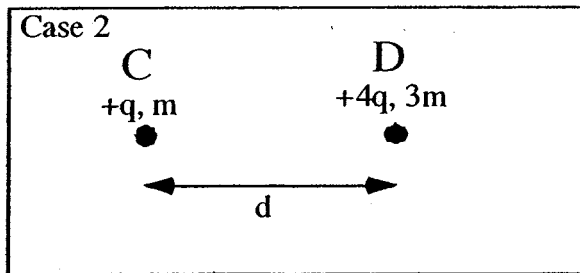
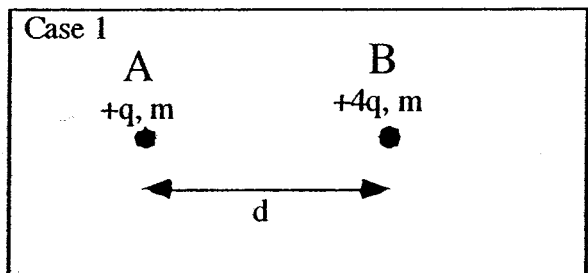
Rank the magnitude of the potential across each resistor in the loops at the instant shown.

Greatest \_\_\_\_\_ Least

Briefly explain:

**IV – Initial acceleration of two charged objects**

In each case shown below a particle of charge  $+q$  is placed a distance  $d$  from a particle of charge  $+4q$ . The particles (A-H) are released simultaneously. The masses of the particles are indicated in the diagram.



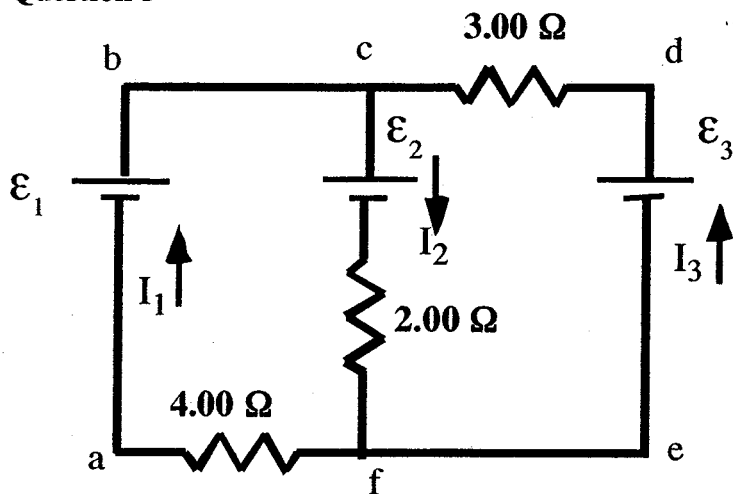
Rank the magnitude of the acceleration of each particle just after it is released.

Greatest \_\_\_\_\_ Least

Briefly explain:

Handwritten explanation: (III)  $A = D > B > F > C = E = 0$   
 (II)  $A = B = C = F > D = E = G = H$

## Question 3



For the above circuit,  $\mathcal{E}_1 = 64.0 \text{ V}$ ,  $\mathcal{E}_2 = 54.0 \text{ V}$  and  $\mathcal{E}_3 = 66.0 \text{ V}$ , assume the batteries are ideal.

a) Write the equations for the changes in potential around loop  $abcf$  and loop  $cdef$ , and the currents at point  $c$ .

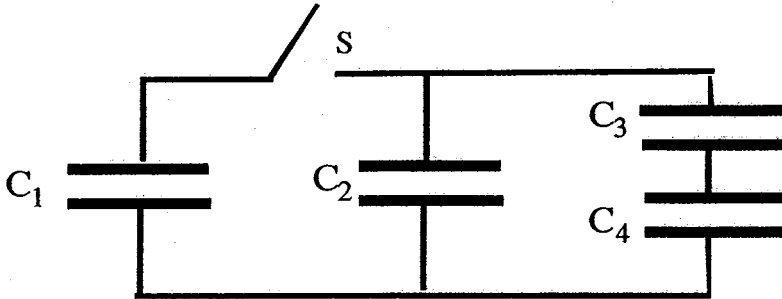
b) Determine the values for  $I_1$ ,  $I_2$ , and  $I_3$ .

c) What is the potential difference between points  $c$  and  $f$  i.e.  $V_f - V_c =$

$$\begin{aligned}
 \text{a)} \quad & 64 - 54 - 2I_2 - 4I_1 = 0 \\
 & +3I_3 - 66 + 2I_2 + 54 = 0 \\
 & I_1 + I_3 = I_2 \\
 \text{b)} \quad & I_1 = 1.0 \text{ A}, I_2 = 3.0 \text{ A}, I_3 = 2.0 \text{ A} \\
 \text{c)} \quad & V_f - V_c = -60 \text{ V}
 \end{aligned}$$

**Question 4**

A capacitor,  $C_1$ , is charged to a potential difference of 20.0 V by a battery. The battery is then removed and then  $C_1$  is connected to three uncharged capacitors,  $C_2$ ,  $C_3$  and  $C_4$  as shown in the figure. The switch  $S$  is then closed.



Given  $C_1 = 40.0 \mu\text{F}$ ,  $C_2 = 30.0 \mu\text{F}$ ,  $C_3 = 20.0 \mu\text{F}$  and  $C_4 = 20.0 \mu\text{F}$ ,

a) When the system comes to equilibrium, what are the charges on each capacitor and the potential difference across each capacitor?

$q_1 = \underline{\hspace{2cm}}$       $\Delta V_1 = \underline{\hspace{2cm}}$   
 $q_2 = \underline{\hspace{2cm}}$       $\Delta V_2 = \underline{\hspace{2cm}}$   
 $q_3 = \underline{\hspace{2cm}}$       $\Delta V_3 = \underline{\hspace{2cm}}$   
 $q_4 = \underline{\hspace{2cm}}$       $\Delta V_4 = \underline{\hspace{2cm}}$

b) What is the change in potential energy of the four capacitor system between the time just before the switch is closed and the time when equilibrium is reached? Comment on your findings.

(9)  $8.0 \text{ mJ} \leftarrow 4.0 \text{ mJ}$   
 $C_1$   $400 \mu\text{C}$ ,  $10\text{V}$   
 $C_2$   $300 \mu\text{C}$ ,  $10\text{V}$   
 $C_3$   $100 \mu\text{C}$ ,  $5\text{V}$   
 $C_4$   $100 \mu\text{C}$ ,  $5\text{V}$

**Question 5**

A series LCR circuit consists of, a 30.0 mH inductor, a 12.0  $\mu$ F capacitor and a 25.0  $\Omega$  resistor plus a variable frequency AC generator.

a) Calculate the resonance frequency of the circuit.

The AC generator is set to 500 Hz with  $V_{rms} = 9.00$  V. At this frequency:

b) What is the impedance of the circuit?

c) What is the rms current?

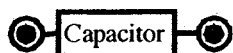
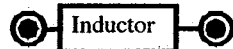
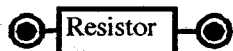
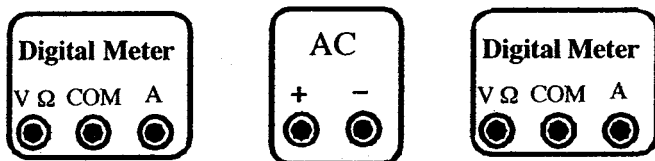
d) What is the average power dissipated in the circuit?

e) What is the phase angle between the voltage and current?

f) What is the rms voltage across the capacitor, and does this voltage lead or lag the current?

Shown below are diagrams showing the different components of the circuit.

g) Sketch in how you would connect them to measure the rms current in the series LCR circuit and the potential across the capacitor. Draw lines between the components to indicate a connecting wire. Ensure that you have the correct polarity for the meters.



Handwritten calculations for part (a):

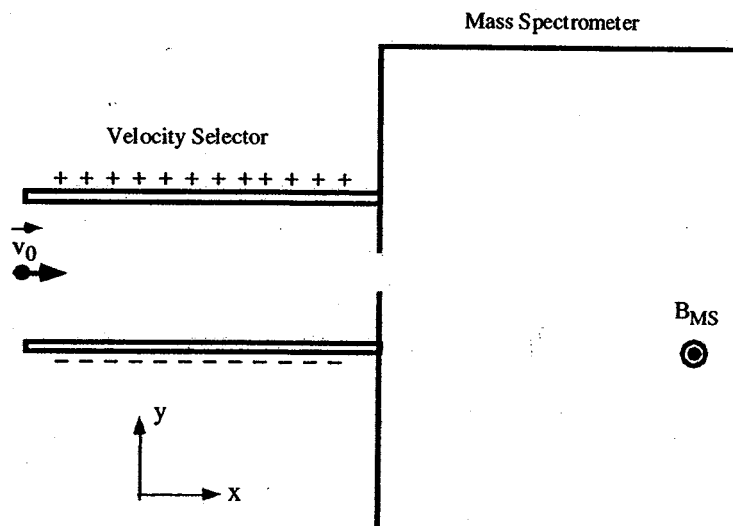
$$f = \frac{1}{2\pi\sqrt{LC}}$$

$$= \frac{1}{2\pi\sqrt{(30 \times 10^{-3})(12 \times 10^{-6})}}$$

$$= 265 \text{ Hz}$$

**Question 6**

Positively charged ions with a velocity along the x-axis enter a velocity selector. The velocity selector selects a beam of ions with a given velocity,  $v_0$ , by adjusting the magnitudes of perpendicular electric ( $E$ ) and magnetic ( $B$ ) fields. After leaving the velocity selector, the beam of ions enters a mass spectrometer, where due to a uniform magnetic field,  $B_{MS}$ , the ions follow semicircular paths.



- On the above diagram, show the direction of the electric and magnetic fields in the velocity selector. Also draw a free-body diagram showing the forces acting on an ion, ignore gravity and friction forces.
- On the above diagram, sketch and identify the path of an ion entering the velocity selector with  $v < v_0$  and with  $v > v_0$ .

A Sodium ion with kinetic energy,  $KE = 1.87 \times 10^{-14} \text{ J}$  leaves the velocity selector and enters the Mass Spectrometer – the uniform magnetic field,  $B_{MS}$  ( $B_{MS} \neq B$ ), is directed out of page.

( $\text{Na}^+$   $q = 1.60 \times 10^{-19} \text{ C}$   $m = 23 \text{ u}$   $1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$ )

- Sketch the ion's path in the region of  $B_{MS}$ .
- What is the change in the KE in the region of  $B_{MS}$ ?
- Calculate the magnetic field,  $B$  in the velocity selector, if the potential difference between the plates of velocity selector is 350 V and the plate separation is 5.00 mm.
- Calculate the magnetic field,  $B_{MS}$  in the MS, if the sodium ion follows a path with radius 14.0 cm.

Handwritten notes:

$\Delta$  1.697  
 1 0.0707 T  
 350  
 semicircle  
 $E \uparrow$   $B \otimes$