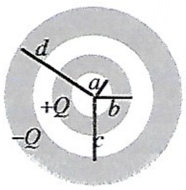
YOU MUST SHOW ALL THE STEPS TO GET CREDIT!

NO Credit for simply copying solutions from elsewhere.

0% For ANY level of cheating in ANY form!

1.



Consider the two cocentric conducting spherical shells withthe inner radii a and c, and the outer radii b and d as shown in the figure. The smaller shell has a net charge $+Q$ and the larger one $-Q$.

A. What is the electric field at the following locations, and ***why***? You must show all calculations.
   (i) $r<a$,
   (ii) $a<r<b$
   (iii) $b<r<c$
   (iii) $c<r<d$
   (iv) $r>d$

B. What is the electric potential at the following locations, and ***why***? You must show all calculations.
   (i) $r<a$,
   (ii) $a<r<b$
   (iii) $b<r<c$
   (iii) $c<r<d$
   (iv) $r>d$

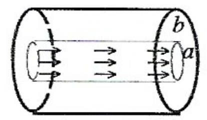
C. What is the capacitance of this arrangement?

D. Where is the smaller conductor's charge located?

E. Where is the larger conductor's charge located?

F. (i) What would happen to the electric potential if these two spherical shells are connected with a conducting wire?
   (ii) How would the electric charges redistribute?

2.



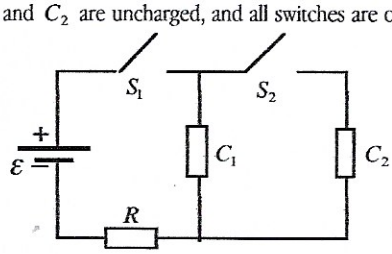
A cocentric wire has a core of radius a within which current density per unit area is constant J. The total current carried by the inner core is $I = JA = J\pi a^2$. The external conductor shell has a radius b and carries the same total current I in the reverse direction.

A. Obtain the magnetic field in the regions
   (i) $r<a$,
   (ii) $a<r<b$
   (iii) $r>b$

B. Obtain the magnetic flux in the region $a<r<b$

C. Obtain the inductense of this arrangment.

3. In the diagram, $\varepsilon = 200\text{ V}$, $R = 10\ \Omega$, $C_1 = 12\ \mu F$; $C_2 = 24\ \mu F$. Initially, C_1 and C_2 are uncharged, and all switches are open.



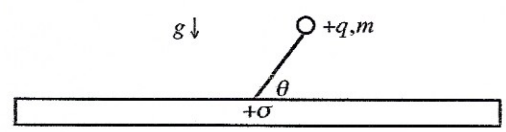
A. S_1 is closed. Determine Q on C_1 when equilibrium is reached.
   Next S_1 is opened, S_2 is closed. When equilibrium is reached

B. Determine Q on C_1.

C. Determine V across C_1.

D. Now S_2 remains closed, and now S_1 is also closed. How much additional charge flows from the battery?

4.



An infinite plane has a surface charge density $+\sigma$. A charge of $+q$ with mass m is tied to it with a massless string with tension F_T.

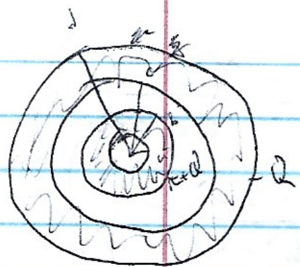
A. Use Gauss' Law to obtain the electric field produced by the charge density.

B. Draw a free body diagram for the charge showing all forces acting on it.

C. Obtain the net force on the charge in terms of the given quantities.

E/M Cumulative 2

neg 20 TA 12 Total 32/57

1) 

A) $\int E\cdot ds = \frac{Q_{enc}}{\varepsilon_0}$ +1

(i) if $r < a$, $\boxed{E=0}$ +1 b/c field is always 0 inside a conducting sphere or shell because charges accumulate on the surface, thus, $\boxed{Q_{enc}=0}$ +1

(ii) $a<r<b$

$\cancel{\int E \cdot 4\pi r^2 dr = \frac{Q_{enc}}{\varepsilon_0}}$

$\cancel{Q_{enc} = +Q\cdot\frac{r}{R} - Q\cdot\frac{r}{b}}$

$\cancel{E = \frac{1}{4\pi\varepsilon_0} Q\cdot\frac{r}{b}\cdot\frac{1}{r^2}}$

$\cancel{= \frac{kQ}{rb}}$

~~(ii)~~ (ii) b/c conducting sphere & all charge accumulating on the inner surface, $\boxed{E=0}$ if $a<r<b$ × TA 1

(iii) $b<r<c$

$Q_{enc} = +Q$

$E\cdot 4\pi r^2 = \frac{Q_{enc}}{\varepsilon_0} = \frac{+Q}{\varepsilon_0}$ +1

$E = \frac{kQ}{r^2}$ +1

(iv) $c<r<d$ Q_{enc} is still $+Q$, so $E = \frac{kQ}{r^2}$ ~

~

4, TA 1

(v) $r>d$ $\int E\cdot ds = \frac{Q_{enc}}{\varepsilon_0}$

$Q_{enc} = +Q - Q = 0$ +1

$E=0$ if $r>d$ +1

B) at $r<a$, $\Delta V = -\int_i^f E\cdot dr$

(i) At all points inside a conducting sphere,

$V = \frac{kQ}{R}$ at $r<a$, $V_a = \frac{kQ}{b}$ +1

$V_d = \frac{-kQ}{d}$

$V = \frac{kQ}{b} - \frac{kQ}{d}$ ~

(ii) $a<r<b$, V is still $V = \frac{kQ}{b} - \frac{kQ}{d}$ ~

(iii) $b<r<c$ $V_a = \frac{kQ}{r}$, $V_d = \frac{-kQ}{d}$

$V = \frac{kQ}{r} - \frac{kQ}{d}$ ~

(iv) $c<r<d$; no change

$V = \frac{kQ}{r} - \frac{kQ}{d}$ ~

(v) $r>d$; $V_a = \frac{kQ}{r}$, $V_d = -\frac{kQ}{r}$

$V_{Total} = 0$ +1

C) $C = \frac{|Q|}{|V|} = \frac{Q}{kQ\left(\frac{1}{r}-\frac{1}{d}\right)}$ TA 1

$= \frac{4\pi\varepsilon_0}{\left(\frac{1}{r}-\frac{1}{d}\right)}$ r=c $= \frac{4\pi\varepsilon_0}{\left(\frac{1}{c}-\frac{1}{d}\right)}$ TA 1

4, TA 2

D) on its outer surface +1

E) on its outer surface ~

F)(i) The electric potential would become 0 as the charge ~ moves between the shells and neutralizes

(ii) each sphere would have an equal charge & be neutral. +1

2) A)(i) $r < a$ $\quad B = \frac{\mu_0}{4\pi} I \int \frac{dl \times \hat{r}}{r^2}$

~~$B = \frac{\mu_0 I l}{4\pi r^2}$~~ $\quad \oint B \cdot d\vec{l} = \mu_0 I_{enc}$ +1

$I_{enc} = \frac{J \pi r^2}{\pi a^2}$

$B \cdot 2\pi r = \mu_0 \cdot J \cdot \frac{r^2}{a^2}$ ~

~~$B = \frac{\mu_0 J a^2}{2\pi r^3}$~~ $\quad B = \frac{\mu_0 I r}{2\pi a^2}$ ~

(ii) $a < r < b$ $\quad \oint B \cdot dr = \mu_0 I_{enc}$

~~$I_{enc} = I - I \cdot \frac{\pi r^2}{\pi b^2}$~~

~~$B \cdot 2\pi r = \mu_0 I - \mu_0 I \frac{r^2}{b^2}$~~

~~$B = \frac{\mu_0 I}{2\pi r}\left(1 - \frac{r^2}{b^2}\right)$~~

~~(iii) $I_{enc} = I - I = 0$~~ ~

$I_{enc} = -I \frac{(\pi r^2 - \pi a^2)}{(\pi b^2 - \pi a^2)} + I$

3

$B \cdot 2\pi r = \mu_0 I \left(1 - \frac{\pi r^2 - \pi a^2}{\pi b^2 - \pi a^2}\right)$

$B = \frac{\mu_0 I}{2\pi r}\left(1 - \frac{\pi r^2 - \pi a^2}{\pi b^2 - \pi a^2}\right)$ ~

(iii) $r > b$ $\quad I_{enc} = I - I = 0$ +1

$B = 0$ +1

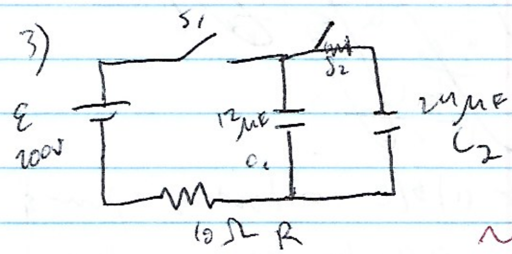
B) $\Phi = \vec{B} \cdot \vec{A}$

$= \ell r \cdot \frac{\mu_0 I}{2\pi}\left(1 - \frac{\pi r^2 - \pi a^2}{\pi b^2 - \pi a^2}\right)$ ~

$= \frac{\mu_0 I r}{2}\left(1 - \frac{\pi r^2 - \pi a^2}{\pi b^2 - \pi a^2}\right)$

C) $L = \frac{\Phi}{I} = \frac{\mu_0 r}{2}\left(1 - \frac{\pi r^2 - \pi a^2}{\pi b^2 - \pi a^2}\right)$ ~

3)



~

A) S_1 closed $\quad \tau = RC$

$Q(t) = V_0 C\left[1 - e^{t/RC}\right]$

$Q = CV = (12\,\mu F)(200\,V)$

+1 $= 2400\,\mu C$ TA1

B) S_1 open, S_2 closed

disconnected from battery

$Q_1 = C_1 V_1 \quad Q_2 = C_2 V_2$

$V_2 = V_1 = V = 200\,V$

$\frac{Q_1}{C_1} = \frac{Q_2}{C_2} \quad \frac{Q_1}{Q_2} = \frac{C_1}{C_2}$ TA1

3, TA2

3B) $\frac{Q_1}{Q_2} = \frac{C_1}{C_2} = 0.5$ TA1

$Q_{total} = Q_1 + Q_2 = 240\ \mu C$ TA1

$Q_1 = \frac{1}{3} Q_{total} = 80\ \mu C$ TA1

$Q_2 = \frac{2}{3} Q_{total} = 160\ \mu C$

$C = \frac{Q}{V}$ $V = \frac{Q}{C} = \frac{80\ \mu C}{12\ \mu F} = 6.7\ V$

TA2

D) $V_1 = V_2 = 200V$

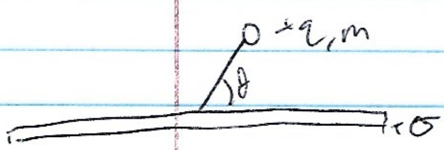
~~~

$Q_1 = C_1 V_1 = (12\ \mu F)(200V) = 240\ \mu C$

$Q_2 = C_2 V_2 = (24\ \mu F)(200V) = 480\ \mu C$

$\Delta Q = 480\ \mu C$ TA2

4)



A) $\oint E \cdot dS = \frac{Q}{\varepsilon_0}$ disc with $R \to \infty$

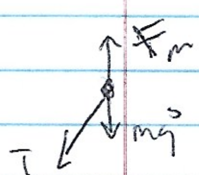
$\cancel{E = \frac{1}{4\pi\varepsilon_0} \cdot 2\pi\sigma\left(1 - \frac{z}{\sqrt{z^2+R^2}}\right)}$

$\cancel{E A = \frac{Q}{\varepsilon_0}}$

~

$E = \frac{\sigma}{2\varepsilon_0}$ $E = \frac{\sigma}{2\varepsilon_0}$ +1

B)



+1 +1 +1

C)

oscillating back & forth

4, TA 7 ~~
~~~

57 total

1.

A. $\oint \vec{E}\cdot d\vec{A} = \frac{Q}{\varepsilon_o} = 4\pi kQ$ (or $\vec{E}\bullet\vec{A} = 4\pi kQ$) **[1 pt]**

(i) $r<a$, $\vec{E}=0$ because **[1 pt]**
$Q_{enc}=0$, Gauss'Law **[1 pt]**

(ii) $a<r<b$ $\vec{E}=0$ because **[1 pt]**
$Q_{enc}=0$, Gauss'Law **[1 pt]** /5

All the charge is on the outer surface of the conductor to ensure zero electric field within it.

(iii) $b<r<c$ $E4\pi r^2 = 4\pi kQ$ **[1 pt]** $E=\frac{kQ}{r^2}$ **[1 pt]**

(iii) $c<r<d$ $\vec{E}=0$ **[1 pt]**
$Q_{enc}=0$ *Gauss'Law* **[1 pt]**

All the $-Q$ is on the inner surface of the conductor to shield the positive $+Q$ charge to ensure zero electric field within it.

(iv) $r>d$ $\vec{E}=0$ **[1 pt]**
$Q_{enc}=+Q+(-Q)=0$ Gauss'Law **[1 pt]** /6

B. You can solve this problem in two ways: by using $V=\int_i^f \vec{E}\cdot d\vec{r}$ as was done in chapter 16-17 test in problem 8 or by superpositon and reasoning.
We will use the principle of superposition.
If we had only the inner shell, for $r\leq b$, the electric potential would have been $V_1 = k\frac{Q}{b}$ **[1 pt]** throughout the region and $V_1 = k\frac{Q}{r}$ **[1 pt]** for $r>b$. If we had only the outer shell with its current charge disbribution, the electric potential would have been $V_2=-k\frac{Q}{c}$ **[1 pt]** throughout the region $r\leq d$ Now we use hte superpostion fo these voltages in each region.

(i) $r<a$, $V=kQ\left(\frac{1}{b}-\frac{1}{c}\right)$ **[1 pt]**

(ii) $a<r<b$, $V=kQ\left(\frac{1}{b}-\frac{1}{c}\right)$ **[1 pt]** /5

(iii) $b<r<c$ $V=kQ\left(\frac{1}{r}-\frac{1}{c}\right)$ **[1 pt]**

(iii) $c<r<d$ $V=0$ **[1 pt]**
since $Q_{enc}=+Q+(-Q)=0$

(iv) $r>d$ $V=0$ **[1 pt]**
since $Q_{enc}=+Q+(-Q)=0$

C. $\Delta V = V_{in}-V_{out} = kQ\left(\frac{1}{b}-\frac{1}{c}\right)-0$ **[1 pt]**

$C=\frac{Q}{\Delta V}=\frac{bc}{k(b-c)}=\frac{4\pi\varepsilon bc}{(b-c)}$ **[1 pt]** /5

D. At the outer surface, $r=b$. *See part A* **[1 pt]**

E. At the inner surface $r=c$. *See part A* **[1 pt]**

F. (i) They will reach an equal electric potential.
$\Delta V = kQ\left(\frac{1}{b}-\frac{1}{c}\right)$ will be equally distributed. **[1 pt]**

(ii) The charges will move from inner shell to outer shell until the electric potential difference becomes zero between the shells. **[1 pt]** /4

2. $\oint \vec{B}\bullet d\vec{\ell} = \mu_o I_{enc}$ (or $B2\pi r = \mu\pi r^2 J$) **[1 pt]**

A. Obtain the magnetic field in the following regions

(i) $r<a$, $B2\pi r = \mu\pi r^2 J$ **[1 pt]** $B=\frac{\mu}{2}rJ$ **[1 pt]**

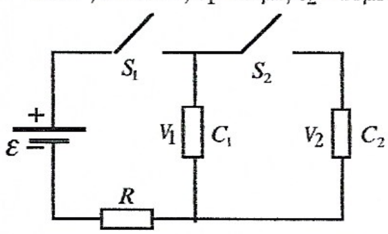
(ii) $a<r<b$ $B2\pi r = \mu\pi a^2 J$ **[1 pt]** $B=\frac{\mu}{2r}a^2 J = \frac{\mu I}{2\pi r}$ **[1 pt]** /5

(iii) $r>b$ $B=0$ **[1 pt]** *since* $I_{enc}=0$ **[1 pt]**

B. $\Phi = \int \vec{B}\cdot d\vec{A} = \int_a^b \frac{\mu I}{2\pi r}\ell dr = \frac{\mu I\ell}{2\pi}\ln\left(\frac{b}{a}\right)$ **[1+1+1 pts]**

C. $L=\frac{\Phi}{I}=\frac{\mu\ell}{2\pi}\ln\left(\frac{b}{a}\right)$ **[1 pt]** 6

3. $\mathcal{E}=200$ V, R = 10 Ω, $C_1 = 12\,\mu$F; $C_2 = 24\,\mu$F.



A. The equilibrium is reached when $V_1=\varepsilon$ **[1 pt]**
when S_1 is closed and S_2 is open.
$Q=V_1C_1=200V12\mu F=2.4\,$mC **[1+1 pts]**
Next S_1 is opened, S_2 is closed. When equilibrium is reached

B. The equlibrium is reached when $V_1=V_2$ **[1 pt]** /4
Since the total charge does not change, we also have to have
$\Rightarrow Q_1+Q_2=2.4$mC **[1 pt]**
$\frac{Q_1}{C_1}=\frac{Q_2}{C_2}\Rightarrow Q_1=\frac{C_1(2.4\text{mC}-Q_1)}{C_2}$ **[1 pt]**
$Q_1=0.8$mC, $Q_2=1.6$mC **[1 pt]** /3

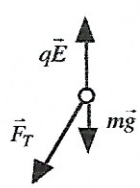
C. $V_1=\frac{Q_1}{C_1}=66.7V$ **[1+1 pts]**

D. $C_{eq}=C_T=C_1+C_2=36\mu$F **[1+1 pts]**
$Q_T=\varepsilon C_T=7.2$mC **[1 pt]**
$\Delta Q=Q_T-Q_o=7.2\text{mC}-2.4\text{mC}=4.8\text{mC}$ **[1+1 pts]** /7

4.

A. Remember that there are two surfaces: up and down. Therefore,
$\vec{E}\bullet\vec{A}=2EA=4\pi kQ$ **[1 pt]**
$E=2\pi k\frac{Q}{A}=2\pi k\sigma$ **[1 pt]**

B.



[1+1 +1 pts]

C. $\vec{F}_{net}=\vec{F}_T+\vec{F}_E+\vec{F}_g$ or any equivalent exression. **[1 pt]**
$\vec{F}_{net}=\vec{F}_T+2\pi kq\sigma\uparrow+mg\downarrow$ **[1 pt]** /7