PHYS 232 QUIZ 1

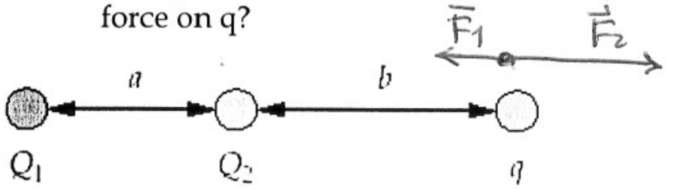
02-18-2005

50 minutes.

This quiz has 3 questions. Please show all your work. If your final answer is not correct, you will get partial credit based on your work shown. You are allowed to have one hand-written, one-sided page of equations.

Question I. (40 points)

1. If a = 3.0 mm, b = 4.0 mm, Q1 = –60 nC, Q2 = 80 nC, and q = 30 nC in the figure, what is the magnitude and the direction of the total electric force on q?

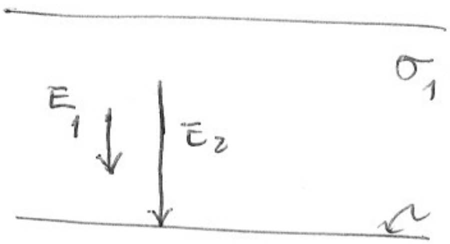


$\vec{F}_q = \vec{F}_2 + \vec{F}_1$

$\vec{F}_1 = k_e \cdot \frac{q_1 q}{r^2}$ $\vec{F}_2 = k_e \frac{q_2 q}{r^2}$

$\therefore F_q = 1.02\ N$ to the right.

2. Two infinite parallel surfaces carry uniform charge densities (σ) of +0.20 nC/m² and -0.60 nC/m² respectively. What is the magnitude of the electric field at a point between the two surfaces?



$\sigma_1 = +0.2\ \frac{nc}{m^2}$

$\sigma_2 = -0.6\ \frac{nc}{m^2}$

$\vec{E}_1 = \frac{\sigma_1}{2\varepsilon_0}$ downwards

$\vec{E}_2 = \frac{\sigma_2}{2\varepsilon_0}$ downwards

$\vec{E} = \vec{E}_1 + \vec{E}_2 = 45.2\ N/c$

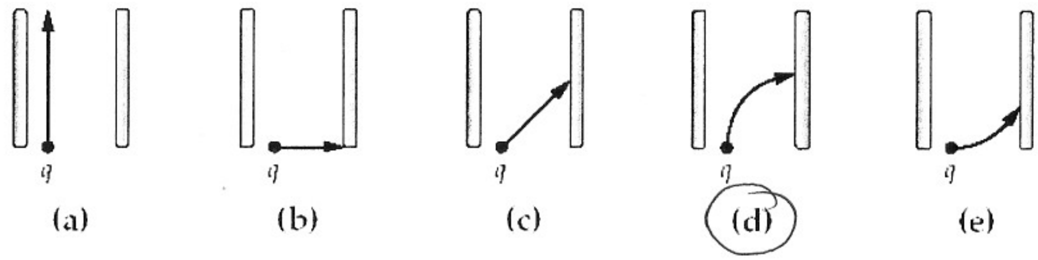
3. A particle (m = 2.0 μg, q = –5.0 nC) has a speed of 30 m/s at point A and moves (with only electric forces acting on it) to point B where its speed is 80 m/s. Determine the electric potential difference $\Delta V = V_B - V_A$.

$q\,\Delta V = \frac{1}{2} m v_A^2 - \frac{1}{2} m v_B^2$

$\Delta V = 1.1 \times 10^3\ V$

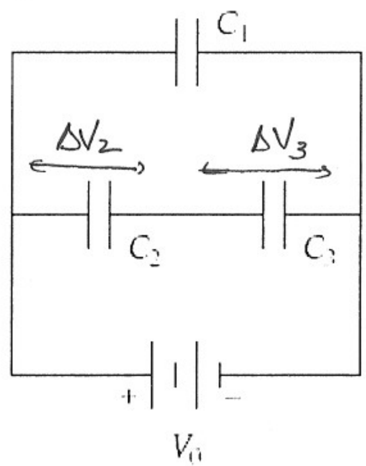
(08)

4. A positively charged particle is moving in the +y-direction when it enters a region with a uniform electric field pointing in the +x-direction. Which of the diagrams below shows its path while it is in the region where the electric field exists. The region with the field is the region between the plates bounding each figure. The field lines always point to the right. The x-direction is to the right; the y-direction is up.



(08)

5. What is the potential difference across C2 when C1 = 5.0 μF, C2 = 15 μF, C3 = 30 μF, and V0 = 24 V?



$C = \frac{Q}{\Delta V} \Rightarrow \Delta V = \frac{Q}{C}$

$\Rightarrow \frac{\Delta V_2}{\Delta V_3} = \frac{Q_2}{C_2} \Big/ \frac{Q_3}{C_3}$ But $Q_2 = Q_3$ (series)

$\Rightarrow \frac{\Delta V_2}{\Delta V_3} = \frac{C_3}{C_2} = \frac{30\ \mu F}{15\ \mu F}$

$\Rightarrow \Delta V_2 = 2\Delta V_3$

$\Delta V_3 = \frac{\Delta V_2}{2}$

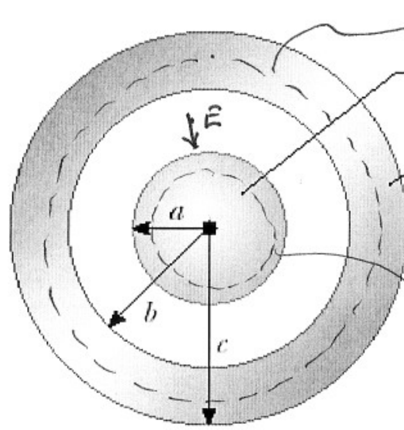
but $\Delta V_2 + \Delta V_3 = 24\ V$

$\Rightarrow \frac{3\Delta V_2}{2} = 24\ V$

$\Rightarrow \Delta V_2 =$ ~~8V~~ $16\ V$

Question II. (30 points)

A Solid conducting sphere of radius ***a*** carries a net negative charge **-*Q***. Concentric with this sphere is a conducting spherical shell with inner radius ***b*** and outer radius **c**, having a net positive charge +***Q***.



(05)

1. Describe how the charges are distributed in the sphere and in the conducting shell. Show how you arrived at your answers.

* -Q charges distributed on the surface of the sphere: for a Gauss' surface inside sphere $\Phi = 0$ since there is no $\vec{E}$ inside a conductor.

* +Q charges distributed on the inside surface of the shell. a Gauss' surfae inside the shell: $\phi = 0 \Rightarrow Q^{in}_{net} = 0$

(05)

2. What is the electric field (direction and magnitude) in the regions: (Show how you arrive at your answers)

   a. r < a $\Rightarrow$ $E = 0$
   b. a < r < b $\Rightarrow$ use a Gauss' surfae at r
   c. b < r < c
   d. r > c.

$$\phi = \oint \vec{E} \cdot d\vec{a} = \frac{Q_{in}}{\varepsilon_0}$$

for spherical symmetry, $E \cdot 4\pi r^2 = \frac{-Q}{\varepsilon_0}$

$$\Rightarrow E = -\frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$

* radially inward.

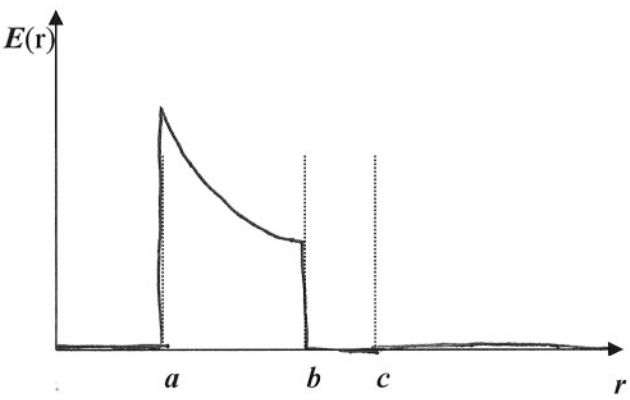
(c) for $b < r < c$, inside conductor

$\Rightarrow E = 0$

(d) for $r > c$, $E \cdot 4\pi r^2 = \frac{Q_{in}}{\varepsilon_0}$, but $Q_{in} = 0$ $\Rightarrow E = 0$

3. Sketch the variation of the Electric Field as a function of ***r*** on the axes here

(05)



(05) 4. What is the Electric potential just outside the conducting shell ?

$V_{(r)} = -\int_{\infty}^{r} \vec{E} \cdot d\vec{s}$

But $\vec{E} = 0$ outside $\therefore$ V at $r=c = 0$

(05) 5. What is the potential difference between a point on the surface of the conducting sphere (at ***r=a***) and a point on the inside surface of the shell (at ***r=b***)

$\vec{E} = -E\,\hat{r}$

and $d\vec{s} = dr\,\hat{r}$

and $\hat{r} \cdot \hat{r} = 1$

$\Delta V_{ab} = -\int_{a}^{b} \vec{E} \cdot d\vec{s} = +\int_{a}^{b} k_e \frac{Q}{r^2}\, dr = -\left[\frac{k_e Q}{r} \right]_a^b$

$\Delta V_{ab} = -k_e Q \left[\frac{1}{b} - \frac{1}{a} \right] = +k_e Q \left[\frac{1}{a} - \frac{1}{b} \right]$

[illegible]

(05) 6. We now fill the space between the sphere and the shell (space between ***a*** and ***b***) with a dielectric material ($\kappa = 3.0$). What now is your answer for part 5. above.

with a dielectric

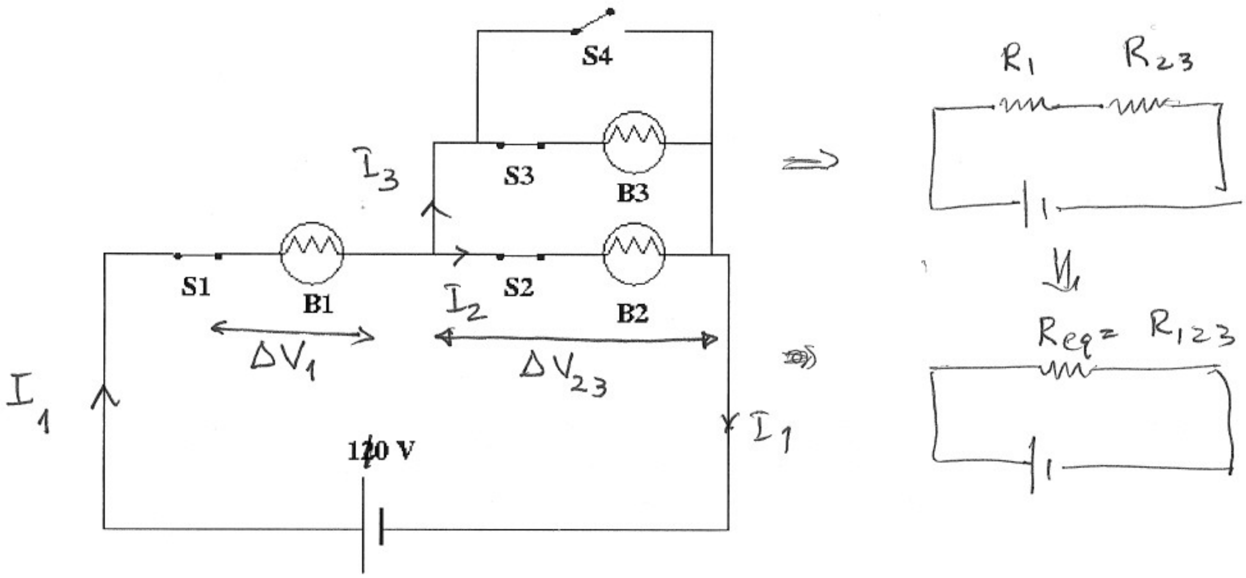
$\varepsilon = \varepsilon_0 \cdot K$

$\therefore \quad E = -\frac{1}{4\pi\varepsilon_0 K} \cdot \frac{Q}{r^2} = \frac{E_0}{K}$

$\therefore \quad \Delta V_{ab}^{new} = \frac{\Delta V_{ab}}{K} = \frac{k_e Q}{3} \left[\frac{1}{a} - \frac{1}{b} \right]$

Question III. (30 points)

The circuit shown consists of a 110 V battery with negligible internal resistance, three bulbs B1, B2, and B3 and four switches S1, S2, S3 and S4. Bulbs B1 and B2 are rated 110 V and 40 W, while bulb B3 is rated 110 V and 100 W. Switches S1, S2 and S3 are closed while S4 is open.



(06) 1. Calculate the resistance of each bulb.

$P = \frac{\Delta V^2}{R} \Rightarrow R = \frac{\Delta V^2}{P}$

$R_1 = R_2 = \frac{(110)^2}{40} = 302.5\ \Omega$

$R_3 = \frac{(110)^2}{110} = 121\ \Omega$ //

(06) 2. Calculate the power dissipated in each bulb.

R_2 and R_3 parallel

$R_{23} = \frac{1}{1/121 + \frac{1}{302}} = 86.4\ \Omega \Rightarrow R_{eq} = R_{123} = 86.4 + 302.5 = 389\ \Omega$

$\Rightarrow I_1 = 140/389 = 0.28\ A \Rightarrow$ (continued ...)

(06) 3. Calculate the currents through bulbs B2 and B3.

$\Delta V_2 = \Delta V_3 = \Delta V_{23} = 25\ V$

$I_2 R_2 = \Delta V_2 \Rightarrow I_2 = \frac{\Delta V_2}{R_2} = \frac{25}{302.5} = 0.083\ A$

$I_3 R_3 = \Delta V_3 \Rightarrow I_3 = \frac{25}{121} = 0.2\ A$

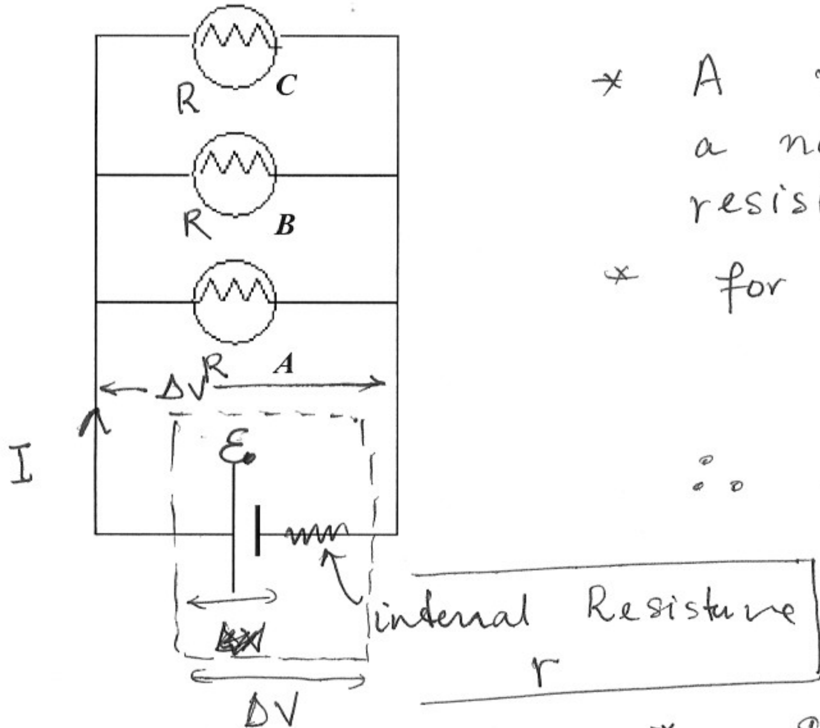
(06) 4. Describe what happens to the brightness of each bulb if switch S4 is also closed.

when switch S_4 is closed, $\Delta V_{23} = 0$

$\therefore I_2 = I_3 = 0$. So B_2 and B_3 turn off.

But $R_{eq} = R_1 = 302\,\Omega$ now; so more current through B_1 $\Rightarrow$ it glows brighter.

(06) 5. A **PHYS232** student connects a single light bulb (**A**) across a regular 9V battery she bought at the store. Then she adds two more bulbs (**B** and **C**), with the same resistance as **A**, in parallel with **A**. Since the new bulbs are added in parallel she expects the brightness of **A** to remain unchanged. However, the intensity of **A** goes down when **B** and **C** are added. Explain this observation



* A regular battery has a non zero internal resistance.

* for a parallel cct.

$$R_{eq} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} \cdots}$$

$\therefore$ in this case

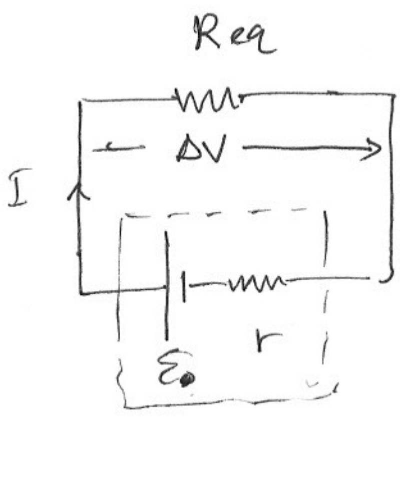
$$R_{eq} = \frac{R}{3}$$

* But $I = \dfrac{\mathcal{E}_0}{R_{eq} + r}$

$\Downarrow$

with only Bulb A

$$I_A = \frac{\mathcal{E}_0}{R + r}$$



with A, B and C

$$I_{ABC} = \frac{\mathcal{E}_0}{R/3 + r}$$

$\therefore I_{ABC} > I_A$

(continued...)

Question II.2 continued.

∴ $\Delta V_1 = I_1 R_1 = 85\ V$

• and $\Delta V_{23} = \Delta V - \Delta V_1 = 110 - 85$
$= 25\ V$

∴ $P_1 = \frac{\Delta V_1^2}{R_1} = 24\ W$

$P_2 = \frac{\Delta V_{23}^2}{R_2} = 2\ W$

$P_3 = \frac{\Delta V_{23}^2}{R_3} = 5.2\ W$

Question III.5 continued.

But the potential diffrence ΔV accross each bulb.

$\Delta V = \mathcal{E} - Ir = \mathcal{E}$

and with only A $\Delta V_A = \mathcal{E} - \frac{\mathcal{E}.r}{R+r}$

and with A, B + C $\Delta V_{ABC} = \mathcal{E} - \frac{\mathcal{E}r}{R/3 + r}$

⇒ $\Delta V_A > \Delta V_{ABC}$

⇒ Sine P for each bulb ⇒ $P = \frac{\Delta V^2}{R}$
brightness for A goes down with more bubs added.

Alternate answer for III.5

⇒ for parallel cct. Req. goes down with more resistors added

⇒ There is more current out of the battery with more bulbs

⇒ Battery has internal resistance, power dissipated in the battery, $I^2 r$ and the potential drop accross the battery $\Delta V_{Battery} = Ir$, are now more

⇒ ΔV accross Bulb A goes down with new bulbs added

$P = \frac{\Delta V^2}{R}$, ⇒ power goes down.