Date: 05 April 2021

Duration: 90 minutes

**SUBJECT: PHYSICS 3**

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| Signature: | Signature: |
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**INSTRUCTIONS: This is a closed book examination. Use of cell phones, laptops, dictionaries is not allowed.**

**1/ (20 pts)** Three charged particles ($q_1 = q_3 = +5$ μC, and $q_2 = -15$ μC) form a straight line. Particles 1 and 2 are placed at separation of 50 cm. Determine the distance between particles 1 and 3 so that the net electrostatic force on particle 3 from particles 1 and 2 is zero.
($k = 8.99\times10^9$ N.m$^2$/C$^2$)

**2/ (20 pts)** **Fig. 1** shows a thin rod with a non-uniform linear charge density of $\lambda = 0.2x$ μC/m. Evaluate the electric potential at point P if $D = L/4 = 25$ cm. Assume that the potential is zero at infinity.

Hint: $\int_a^b \frac{x\,dx}{d+x} = (x - d\ln(x+d))\Big|_a^b$

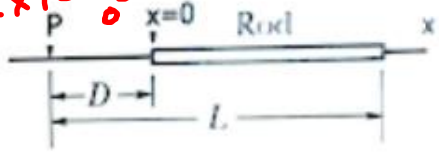
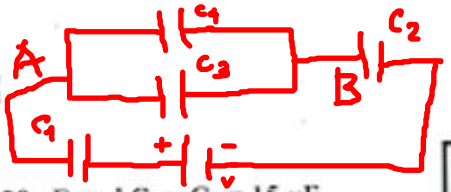



Fig. 1




**3/ (20 pts)** In **Fig. 2**, $V = 9.0$ V, $C_1 = C_2 = 30$ μF, and $C_3 = C_4 = 15$ μF. What is the charge on capacitor 4?

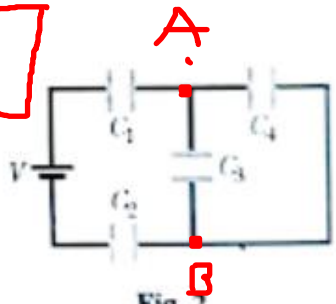



Fig. 2

**4/ (20 pts)** Determine the current through each resistor in the circuit in **Fig. 3**: $\varepsilon_1 = 12$ V, $\varepsilon_2 = 6$ V, $R_1 = 6\ \Omega$, $R_2 = 4\ \Omega$, and $R_3 = 12\ \Omega$.

**5/ (20 pts)** Two charged concentric spherical shells have radii 10.0 cm and 15.0 cm. The charge on the inner shell is $4\times10^{-8}$ C, and that on the outer shell is $2\times10^{-8}$ C. Find the electric field at:

(a) r = 12.0 cm

(b) r = 20.0 cm

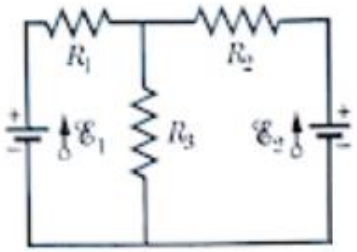



Fig. 3

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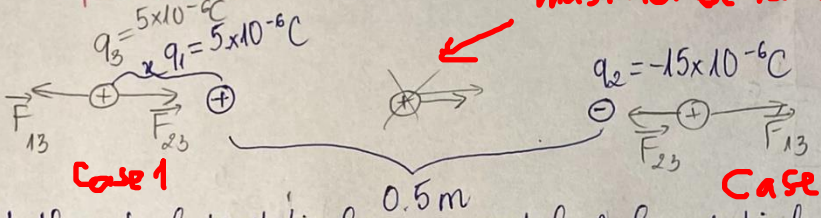
Q1.




Let $x$ be the distance between particles 1 and 3

To let the net electrostatic force on particle 3 from partical 1 and 2 be zero, partical 3 must not stay between particles 1 and 2.

$\vec{F}_3 = \vec{F}_{13} + \vec{F}_{23} = \vec{0}$ Case 1: Particle 3 is on the left-hand side

$\Rightarrow F_{13} = F_{23}$

$\Leftrightarrow k\frac{|q_1||q_3|}{r_{13}^2} = k\frac{|q_2||q_3|}{r_{23}^2} \Leftrightarrow \frac{|q_1|}{r_{13}^2} = \frac{|q_2|}{r_{23}^2} \Leftrightarrow \frac{|5\times10^{-6}|}{x^2} = \frac{|-15\times10^{-6}|}{(x+0.5)^2}$

$\Rightarrow x = 0.683$ m

Case 2: Particle 3 is on the right-hand side.

$\vec{F}_3 = \vec{F}_{13} + \vec{F}_{23} = \vec{0}$

$\Rightarrow F_{13} = F_{23}$

$\Leftrightarrow k\frac{|q_1|.|q_3|}{r_{13}^2} = k\frac{|q_2||q_3|}{r_{23}^2} \Leftrightarrow \frac{|q_1|}{r_{13}^2} = \frac{|q_2|}{r_{23}^2} \Leftrightarrow \frac{|5\times10^{-6}|}{x^2} = \frac{|-15\times10^{-6}|}{(x-0.5)^2}$

$\Rightarrow x = 0.183$ m

Q2:

$dV = kd\frac{q}{R} = kd\frac{0.2x\times10^{-6}}{D+x}$

$\Rightarrow V = k\int_0^{0.75}\frac{0.2x\times10^{-6}}{D+x} = 9\times10^9\times0.2\times10^{-6}\int_{0.25}^{0.75}\frac{x}{D+x}$

$= 1800\,(x - 0.25\ln(x+0.25))\Big|_0^{0.75}$

$= 1800\{0.75 - 0.25\ln(0.75+0.25) - [0 - 0.25\ln(0+0.25)]\}$

$= 726.168$ (V)

Q3 $C_1$ series $(C_3 // C_4)$ series $C_2$

$C_{34} = C_3 + C_4 = 30\times10^{-6}$ F

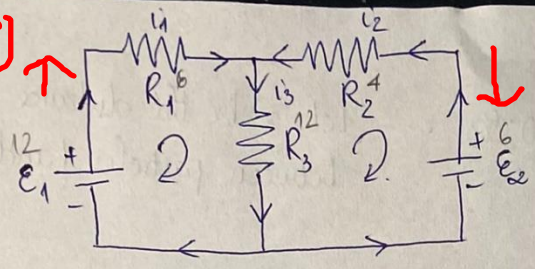
$\frac{1}{C_{1234}} = \frac{1}{C_1} + \frac{1}{C_{34}} + \frac{1}{C_2} \Rightarrow C_{1234} = 10^{-5}$ F

$q_{1234} = C_{1234}\times V = 9\times10^{-5}$ C $= q_1 = q_{34} = q_2$

$q_{34} = C_{34}\times V_{34} \Leftrightarrow 9\times10^{-5} = 30\times10^{-6}\times V_{34} \Rightarrow V_{34} = 3 = V_3 = V_4$

$q_4 = C_4\times V_4 = 4.5\times10^{-5}$ C

Q4



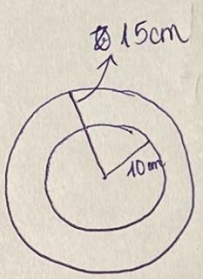

counterclock

$$\begin{cases} i_1 + i_2 = i_3 \\ \mathcal{E}_1 - i_1 R_1 - i_3 R_3 = 0 \\ i_2 R_2 - \mathcal{E}_2 + i_3 R_3 = 0 \end{cases} \quad (u_1, u_2, u_3)$$

$$\Leftrightarrow \begin{cases} i_1 + i_2 = i_3 \\ 12 - i_1 \cdot 6 - i_3 12 = 0 \\ i_2 4 - 6 + i_3 12 = 0 \end{cases}$$

$$\Leftrightarrow \begin{cases} i_1 = \frac{5}{6} \\ i_2 = -\frac{1}{4} \\ i_3 = \frac{7}{12} \end{cases}$$

Q5:




$q_{inner} = 4 \times 10^{-8} C$

$q_{outer} = 2 \times 10^{-8} C$

a) $r_1 = 12\,cm$

$q_{en_1} = q_{inner} = 4 \times 10^{-8}$

$$E_1 = k \cdot \frac{q_{en_1}}{r_1^2} = 9 \times 10^9 \cdot \frac{4 \times 10^{-8}}{0.12^2} = 25000\ N/C$$

$E = \frac{F}{q}$

b) $r_2 = 20\,cm$

$q_{en_2} = q_{inner} + q_{outer} = 6 \times 10^{-8} C$

$$E_2 = k \frac{q_{en_2}}{r_2^2} = 9 \times 10^9 \times \frac{6 \times 10^{-8}}{0.2^2} = 13500\ N/C$$

$E = \frac{F}{q}$