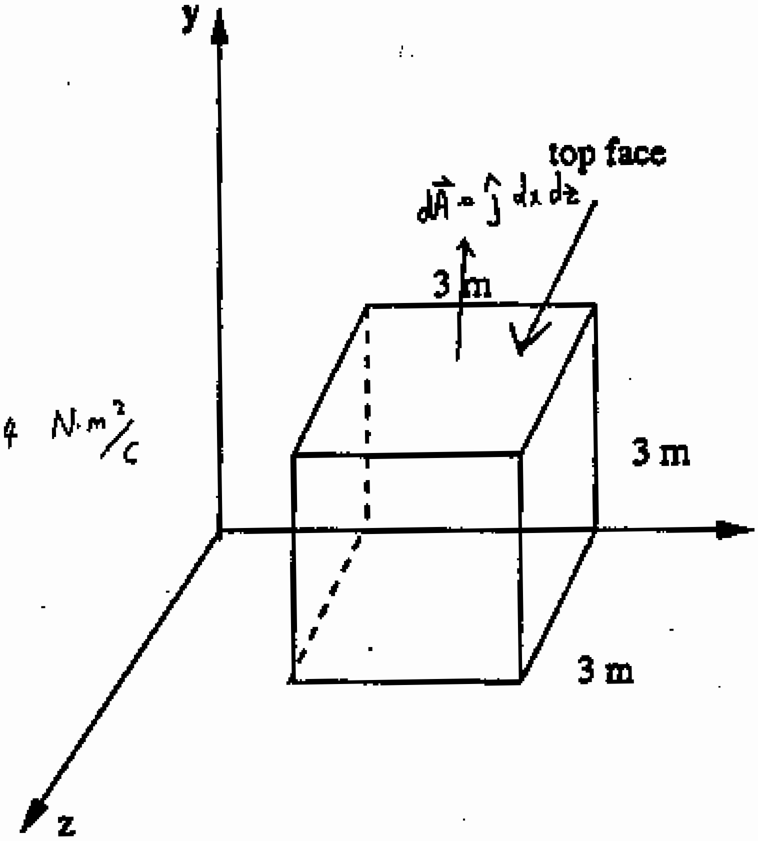
PHYS 241 Exam I Fall 1997.

1. The electric field in the region of space shown is given by $\mathbf{E} = (8\hat{i} + 2y\hat{j})$ N/C where y is in m. What is the magnitude of the electric flux through the top face of the cube shown?

(a) 90 $N{\cdot}m^2/C$
(b) 6.0 $N{\cdot}m^2/C$
(c) 54 $N{\cdot}m^2/C$
(d) 12 $N{\cdot}m^2/C$
(e) 126 $N{\cdot}m^2/C$



$\Phi = \int_{top} \vec{E} \cdot d\vec{A} = \int_{top} 2y \, dx\, dz$

$= \int_{top} 2(3)\, dx\, dz = 6 \underbrace{\int_{top} dx\, dz}_{3^2} = 54 \; N{\cdot}m^2/C$

2. In an RC circuit, how many time-constants must elapse if an initially uncharged capacitor is to reach 80% of its final potential difference?

(a) 2.2
(b) 1.9
(c) 1.6
(d) 3.0
(e) 5.0

$q_0 = C\mathcal{E}$

$q = q_0(1 - e^{-t/RC})$

$CV = C\mathcal{E}(1 - e^{-t/RC})$

$.8 = \frac{V}{\mathcal{E}} = 1 - e^{-t/RC}$

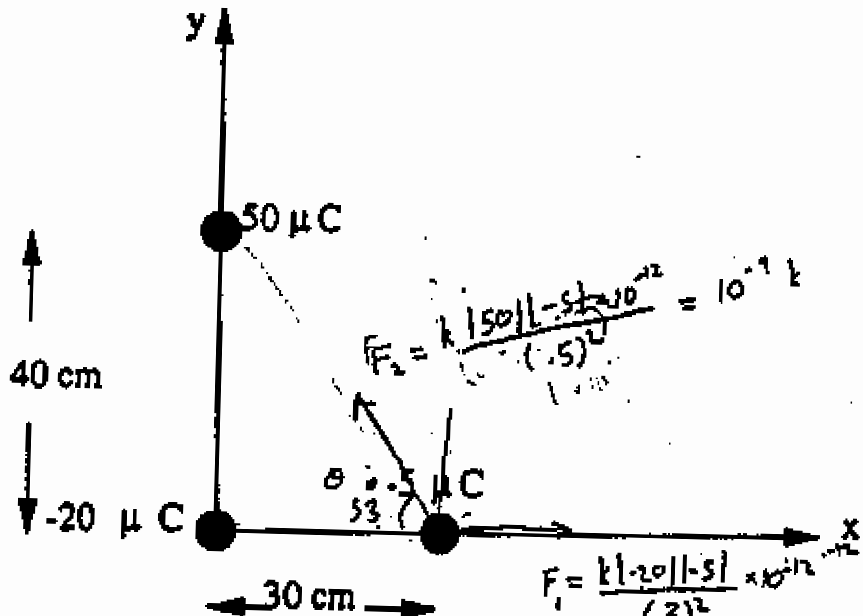
$e^{-t/RC} = .2$

$\frac{t}{RC} = \frac{t}{\tau} = -\ln .2 = 1.6$

$q =$

3. A particle (charge = +50 μC) is placed on the y axis at the point y = +40 cm, and a second particle (charge = −20 μC) is placed at the origin ($x = y = 0$). What is the direction of the total electrostatic force on a third particle with respect to the +x axis (charge = −5.0 μC) placed on the x axis at the point x = +30 cm?

(a) 33°
(b) 57°
(c) − 53°
(d) 127°
(e) 63°



$F_2 = k\frac{|50||-5|\times 10^{-12}}{(.5)^2} = 10^{-9}k$

$F_1 = \frac{k|-20||-5|\times 10^{-12}}{(.3)^2} = 1.11\times 10^{-9}k$

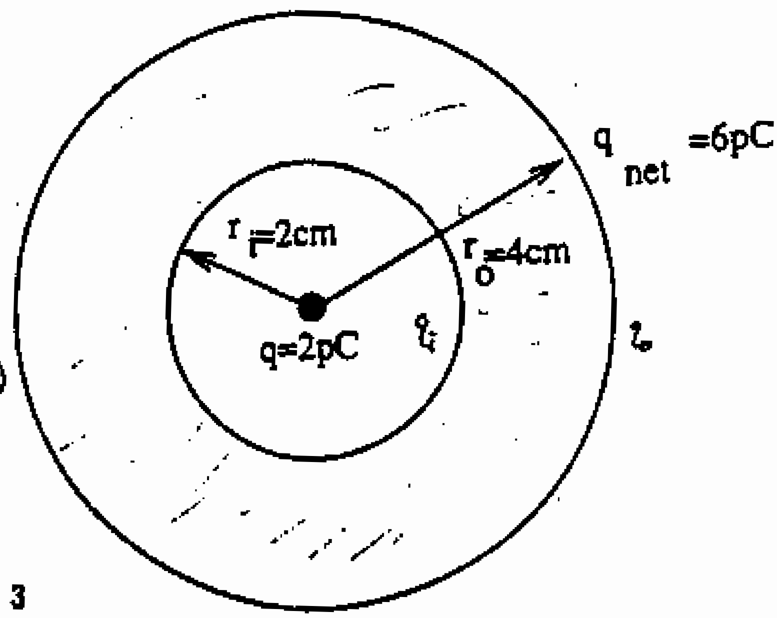
$F_x = F_1 - F_2 \cos\theta$
$= (1.111\times 10^{-9}k) - (10^{-9}k)\frac{30}{50}$
$= 5.11\times 10^{-10}k$

$F_y = F_2 \sin\theta = 10^{-9}k\ \frac{40}{50} = 8\times 10^{-10}k$

$\theta = \tan^{-1}\frac{F_y}{F_x} = \tan^{-1}\frac{8}{5.11} = 57.4°$

4. A 2.0 pC point charge is placed at the center of a hollow (inner radius = 2.0 cm, outer radius = 4.0 cm) conducting sphere. The net charge of the conductor is 6.0 pC. Determine the surfac e charge density on the outer surface of the sphere.

(a) 0.50 nC/m²
(b) 0.45 nC/m²
(c) 0.40 nC/m²
(d) 0.55 nC/m²
(e) 1.60 nC/m²



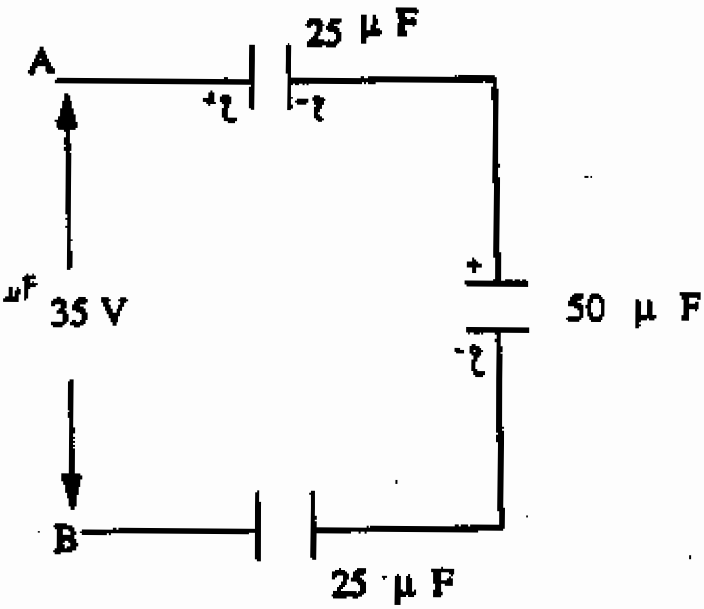
$q_i = -2\ pC$

$q_i + q_o = 6\ pC \Rightarrow q_o = 6\ pC - (-2\ pC) = 8\ pC$

$\sigma = \frac{8\times 10^{-12}\ C}{4\pi (.04)^2} = .397\ \frac{nC}{m^2}$

5. **What is the potential difference across the 50 μF capacitor shown?**

(a) 5.0 V
(b) 9.0 V
(c) 7.0 V
(d) 8.0 V
(e) 12 V



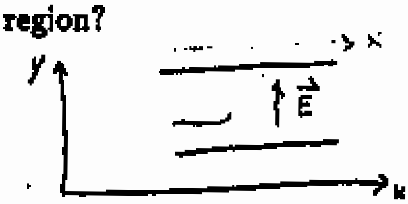
$\frac{1}{C_{eq}} = \frac{1}{25} + \frac{1}{50} + \frac{1}{25} = \frac{5}{50} \Rightarrow C_{eq} = 10\,\mu F$

$q = C_{eq} V = (10\times10^{-6}\ F)(35\ V)$
$= 3.5\times10^{-4}\ C$

$V_{50} = \frac{q}{C_{50}} = \frac{3.5\times10^{-4}\ C}{50\times10^{-6}\ V} = 7\ V$

6. **A proton enters a region of uniform electric field ($E = 80$ N/C) with an initial velocity of 20 km/s directed perpendicularly to the electric field. What is the speed of the proton 2.0 μs after entering this region?**

(a) 15 km/s
(b) 35 km/s
(c) 4.7 km/s
(d) 25 km/s
(e) 42 km/s



$V_x = 20\times10^3\ m/s$

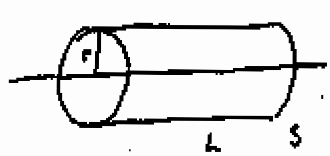
$V_y = a_y \Delta t = \frac{F_y}{m}\Delta t = \frac{eE}{m}\Delta t$
$= \frac{(1.6\times10^{-19}\ C)(80\ N/C)(2.0\times10^{-6}\ s)}{1.67\times10^{-27}\ kg}$
$= 1.533\times10^{4}\ m/s$

$v = \sqrt{v_x^2 + v_y^2} = 2.519\times10^{4}\ m/s$

7. **Charge is uniformly distributed along the entire x axis. If each 20 cm length of the x axis carries 2.0 nC of charge, what is the magnitude of the electric field at the point, $y = 2.0$ m, on the y axis?**

$\lambda = \frac{2.0\times10^{-9}\ C}{.2} = 10^{-8}\ C/m$

(a) 45 N/C
(b) 90 N/C
(c) 18 N/C
(d) 36 N/C
(e) 180 N/C



$\oint \vec{E}\cdot d\vec{A} = \frac{\lambda L}{\epsilon_0}$

$E \cdot 2\pi r L$

$E = \frac{\lambda}{2\pi\epsilon_0 r}$

$= \frac{2\lambda k}{r} = \frac{2(10^{-8}\ C/m)(9\times10^{9}\ \frac{m^2}{C})}{2\ m}$

$= 90.$

8. A charge of 10 nC is distributed uniformly along the x axis from $x = -2$ m to $x = +3$ m. Which of the following integrals is correct for the electric potential (relative to zero at infinity) at the point $x = +5$ m on the x axis?

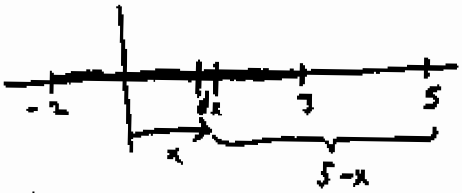
(a) $\int_{-2}^{3} \frac{90\,dx}{x}$

(b) $\int_{-2}^{3} \frac{90\,dx}{5-x}$

(c) $\int_{-2}^{3} \frac{18\,dx}{x}$

[(d)] $\int_{-2}^{3} \frac{18\,dx}{5-x}$

(e) $\int_{-2}^{3} \frac{90\,dx}{5+x}$



$\lambda = \frac{10\times10^{-9}\,C}{5\,m} = 2\times10^{-9}\,\frac{C}{m}$

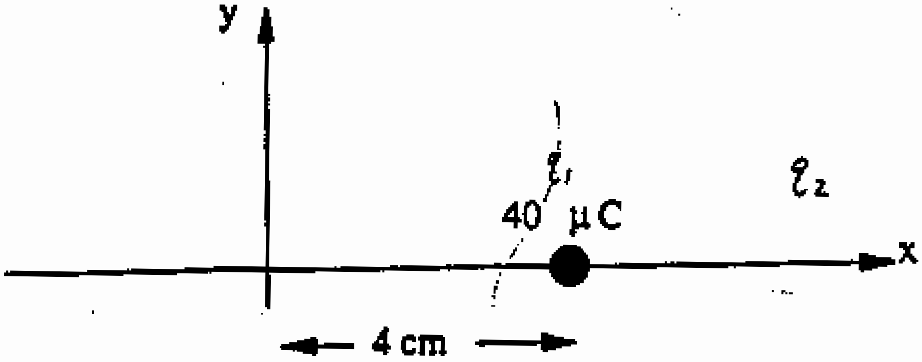
$\lambda = \frac{dq}{dx} \Rightarrow dq = \lambda\,dx$

$dV = \frac{k\,dq}{r}$

$V = \int_{-2}^{3} \frac{k\lambda\,dx}{5-x} = \int_{-2}^{3} \frac{(9\times10^{9})(2\times10^{-9})\,dx}{5-x} = \int_{-2}^{3} \frac{18\,dx}{5-x}$

9. A 40 μC charge is positioned on the x axis at $x = 4.0$ cm. To produce a net electric field of zero at the origin where should a -60 μC charge be placed on the x axis?

(a) $-$ 5.3 cm
(b) 5.7 cm
[(c)] 4.9 cm
(d) $-$ 6.0 cm
(e) + 6.0 cm



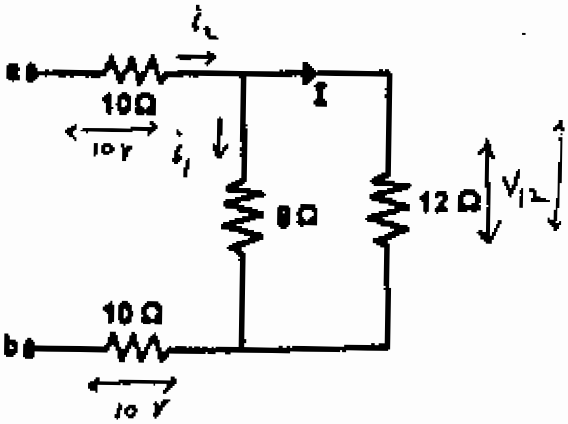
$E(0) = \frac{kq_1}{(.04)^2} + \frac{kq_2}{x^2} = 0$

$\Rightarrow q_1 x^2 = -q_2 (.04)^2$

$\Rightarrow x = \left(-\frac{q_2}{q_1}\right)^{1/2}(.04) = \left(-\frac{-60}{40}\right)^{1/2}(.04) = 4.9$ cm.

10. If $I = 0.40$ A in the circuit segment shown, what is the potential difference $V_a - V_b$?

(a) 31 V
(b) 28 V
[(c)] 25 V
(d) 34 V
(e) 10 V



$V_{12} = (.40\,A)(12\,\Omega) = 4.8$ V

$i_1 = \frac{V_{12}}{8} = \frac{4.8}{8} = .6$

$i_2 = I + i_1 = .4 + .6 = 1$ A

$V_{10} = (1\,A)(10\,\Omega) = 10$ V

$V_a - V_b = V_{10} + V_{12} + V_{10}$
$= 10 + 4.8 + 10$
$= \boxed{24.8\ V}$

11. **The total electric flux through a closed cylindrical (length = 1.2 m, diameter = 0.20 m) surface is equal to − 5.0 N·m²/C. Determine the net charge within the cylinder.**

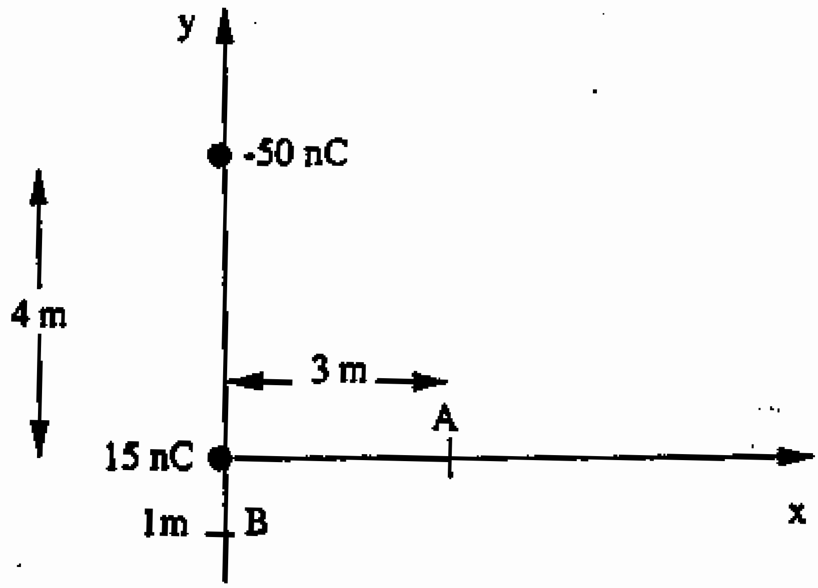
(a) − 62 pC
(b) − 53 pC
(c) − 44 pC
(d) − 71 pC
(e) − 16 pC

$\Phi = \frac{q_{encl}}{\epsilon_0}$

$\Rightarrow q_{encl} = \epsilon_0 \Phi = (8.85\times10^{-12})(-5) = -44.25\ pC$

12. **A 15 nC point charge is placed at the origin, and a charge of − 50 nC is placed on the y axis at $y = 4.0$ m. Point A is on the x axis at $x = 3.0$ m, and point B is on the y axis at $y = -1.0$ m. Determine the potential difference $V_A - V_B$.**

(a) − 66 V
(b) − 78 V
(c) − 90 V
(d) − 84 V
(e) 0 V



$V_A = \frac{k(-50\ nC)}{5} + \frac{k(15\ nC)}{3}$

$V_B = \frac{k(-50\ nC)}{5} + \frac{k(15\ nC)}{1}$

$V_A - V_B = k(15\ nC)\left(\frac{1}{3} - 1\right) = k(15\ nC)\left(-\frac{2}{3}\right) = (-k\ 10\times10^{-9})\ V$

$= -90\ V$

13. An electric device, which heats water by immersing a resistance wire in the water, generates 50 cal of heat per second when an electric potential difference of 12 V is placed across its leads. What is the resistance of the heater wire?
(Note: 1 cal = 4.186 J)

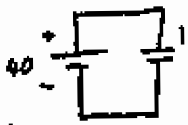
(a) 0.94 Ω
(b) 0.81 Ω
(c) 0.58 Ω
(d) 0.69 Ω
(e) 1.5 Ω

$P = \frac{50\ \text{cal}}{\text{sec}} \times \frac{4.186\ \text{J}}{1\ \text{cal}} = 209.3\ \text{W}$

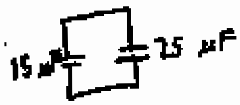
$P = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P} = \frac{(12\ \text{V})^2}{209.3\ \text{W}} = .688\ \Omega$

14. A 15 μF capacitor is charged to 40 V and then connected across an initially uncharged 25 μF capacitor. What is the final potential difference across the 25 μF capacitor?

(a) 12 V
(b) 18 V
(c) 15 V
(d) 21 V
(e) 24 V



$q_0 = C\mathcal{E} = (15 \times 10^{-6}\ \text{F})(40\ \text{V}) = 600 \times 10^{-6}\ \text{C}$




40 μF

$V = \frac{q_0}{C} = \frac{600 \times 10^{-6}\ \text{C}}{40 \times 10^{-6}\ \text{F}} = 15\ \text{V}$