$\varepsilon_0 = 8.85 \times 10^{-12} \quad C^2 / N \cdot m^2$

PHYS 102 Midterm examination #1 (Version 1B)

October 15, 2010 — Name ~~Key~~

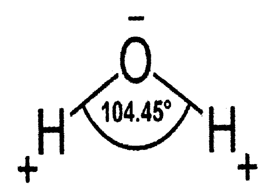
Time: 50 minutes — Student No.__________

Signature __________

Part I (Multiple choice questions. 1 mark each.)

C

1. Does a water molecule carry an electric dipole moment?
   - A) No, because the molecule is electrically neutral.
   - B) No, because the molecule is symmetrical and the net dipole moment is zero.
   - (C) Yes, because of the uneven distribution of electron density and the asymmetrical structure.
   - D) Can't tell from the structure of the molecule.
   - E) It depends on the environment such as the existence of an external field.

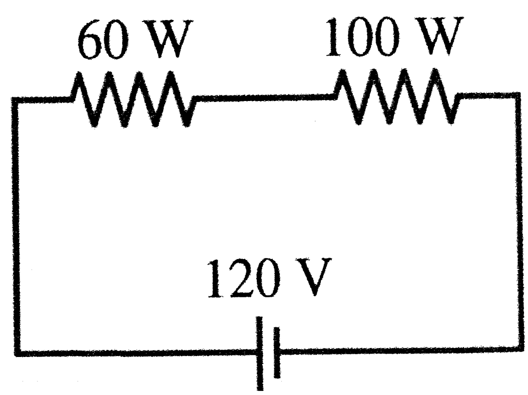


E

2. The equation of Gauss's law only includes the charges inside the Gaussian surface (GS). Any charges outside the GS do not appear in the equation because
   - A) Gauss's law fails when there are charges outside the Gaussian surface.
   - B) charges outside the Gaussian surface do not contribute to the electric field inside the GS.
   - C) we choose the GS surface such that the charges outside do not appear in the equation.
   - D) we always take the advantages of symmetry.
   - (E) charges outside the GS do not contribute to the total flux through the GS.

A

3. A 100-W, 120-V lightbulb and a 60-W, 120-V lightbulb are connected in series as shown. Which lightbulb glows more brightly?
   - ((A)) The 60-W light bulb.
   - (B) The 100-W light bulb.
   - (C) The two light bulbs glow equally brightly.
   - (D) None of the lightbulbs will glow.
   - (E) Can't be determined without additional information.



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D

4. A capacitor with capacitance C is initially charged with charge q. At time t=0, a switch is thrown to close the circuit connecting the capacitor in series with a resistor of resistance R.

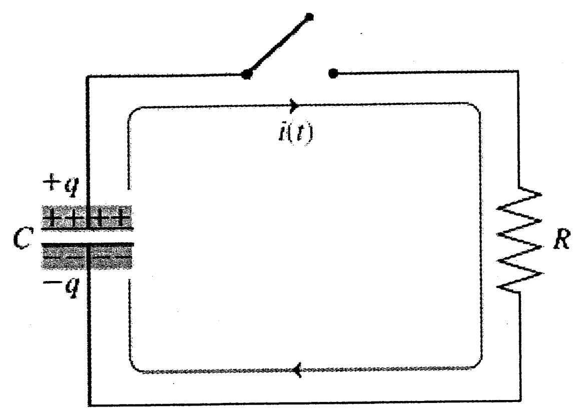
(A) The electrons on the negative plate of the capacitor are held inside the capacitor by the positive charge on the other plate.

(B) Only the surface charge is held in the capacitor; the charge inside the metal plates flows through the resistor.

(C) The electrons on the negative plate immediately pass through the resistor and neutralize the charge on the positive plate.

(D) The electrons on the negative plate eventually pass through the resistor and neutralize the charge on the positive plate.

(E) A constant current (independent of time) flows through the resistor.



D

5. Resistors R_1 and R_2 are connected in parallel. Given that R_1 is much greater than R_2, i.e., $R_1 >> R_2$, estimate the equivalent resistance.

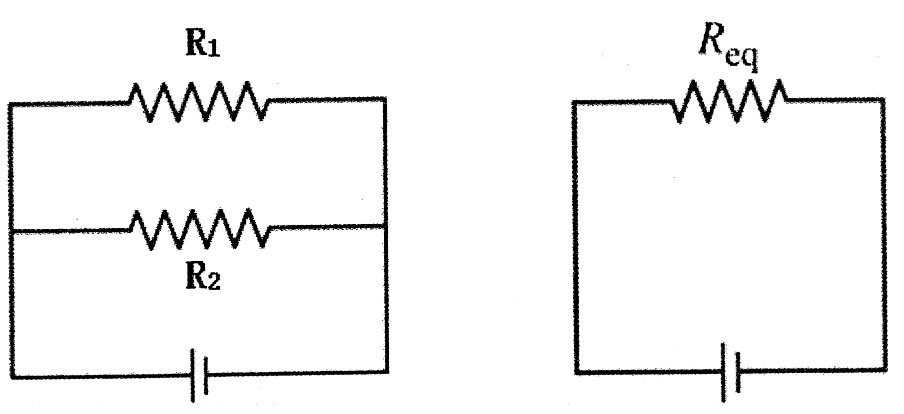
(A) $R_{eq} \approx R_1 + R_2$.

(B) $R_{eq} \approx (R_1 + R_2)/2$.

(C) $R_{eq} \approx R_1$.

(D) $R_{eq} \approx R_2$.

(E) $R_{eq} \approx R_1 R_2$.



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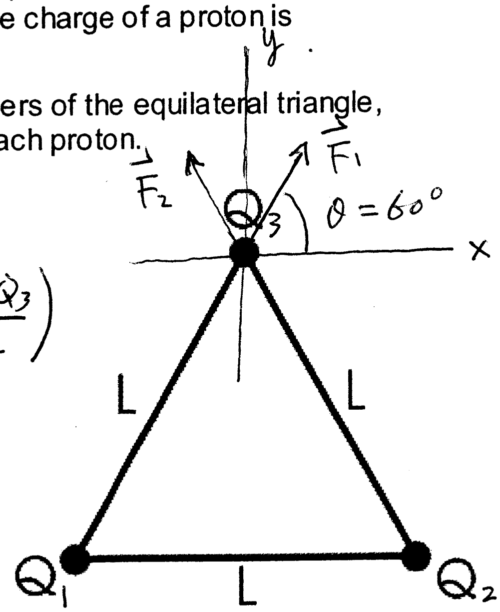
Part II (Full solution questions, 5 marks each. **SHOW ALL WORK FOR FULL MARKS!**)

6. (a) How much work must be done to bring three protons from a great distance apart to within 4.00×10^{-10}m from one another (at the corners of an equilateral triangle) as shown in the diagram below? The charge of a proton is $e = 1.60\times10^{-19} \quad C$.

(b) Now that the three protons are at the corners of the equilateral triangle, calculate the magnitude of the net force on each proton.



(2/5) a). $W = U_{12} + U_{13} + U_{23}$

$$= \frac{1}{4\pi\varepsilon_0}\left(\frac{Q_1Q_2}{L} + \frac{Q_1Q_3}{L} + \frac{Q_2Q_3}{L}\right)$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{3Q^2}{L}$$

$$= \frac{3\times(1.6\times10^{-19})^2}{(4\pi)(8.85\times10^{-12})(4\times10^{-10})}$$

$$= 1.73\times10^{-18} \text{ J}$$

(3/5) b). Net force on the charge on top (Q_3):

$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2$, by symmetry: $F_{net\,x} = 0$

$F_{net} = F_y$.

$$F_{net} = F_1\sin60° + F_2\sin60°.$$

$$= 2F_1\sin60°.$$

$$= 2\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{L^2}\sin60°$$

$$= \frac{2\times(1.6\times10^{-19})^2\sin60°}{(4\pi)(8.85\times10^{-12})(4\times10^{-10})^2}$$

$$= 2.49\times10^{-9} \text{ N}$$

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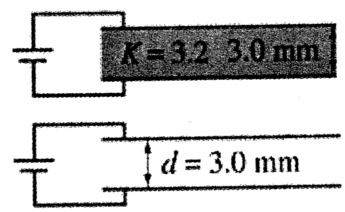
7. A slab of plastic with dielectric ~~strength~~ constant K=3.2 is placed between the plates of a parallel-plate capacitor with plate area $A = 2.0\,\mathrm{m}^2$ and plate separation $d = 3.0\,\mathrm{mm}$ (The space between the plates is completely filled with the dielectric). The capacitor is connected to a 12-V battery.

(*a*) Determine the capacitance, the charge on the capacitor, the electric field, and the energy stored in the capacitor.

(*b*) With the capacitor still connected to the battery, the plastic slab is removed from the capacitor. What are the new values of capacitance, charge, electric field, and the energy stored in the capacitor?



(2.5/5) (a) $C = K\varepsilon_0 \frac{A}{d}$

$= 3.2 \times 8.85 \times 10^{-12} \frac{2.0}{3 \times 10^{-3}}$

$= 1.89 \times 10^{-8}\ F$

$Q = CV = 1.89 \times 10^{-8} F \times 12\ V = 2.27 \times 10^{-7}\ C$.

$E = \frac{V}{d} = \frac{12V}{3 \times 10^{-3}} = 4 \times 10^{3}\ V/m$.

$U = \frac{1}{2} QV = \frac{1}{2} \times 2.27 \times 10^{-7} \times 12 = 1.36 \times 10^{-6}\ J$.

(2.5/5) (b) $C_0 = \varepsilon_0 \frac{A}{d} = \frac{C}{K} = 5.9 \times 10^{-9}\ F$.

$Q_0 = C_0 V = 5.9 \times 10^{-9} \times 12\ V = 7.08 \times 10^{-8}\ C$

$\approx 7.1 \times 10^{-8}\ C$

$E = \frac{V}{d} = 4 \times 10^{3}\ V/m$.

$U = \frac{1}{2} QV = \frac{1}{2} \times 7.1 \times 10^{-8} \times 12 = 4.2 \times 10^{-7}\ J$

$= \frac{1}{2} CV^2$

$\varepsilon_0 = 8.85 \times 10^{-12} \quad C^2 / N \cdot m^2$

8. A very long solid cylinder with a radius R is uniformly charged. The charge density (charge per unit volume) is ρ. Figure A below depicts its cross section.
(a) Determine the electric field **E** at point P(2R/3, 0). i.e, the distance from the center of the rod to point P is 2R/3.
(b) If the rod has a cylindrical hole along the rod, with a radius R/2, as shown in figure B below, determine the electric field at point P(2R/3, 0). Note that the centre of the hole is at (R/2, 0).

$\frac{2R}{3} - \frac{R}{2} = \frac{4R}{6} - \frac{3R}{6} = \frac{R}{6}$

(2.5/5) a). Use a cylindrical Gaussian surface

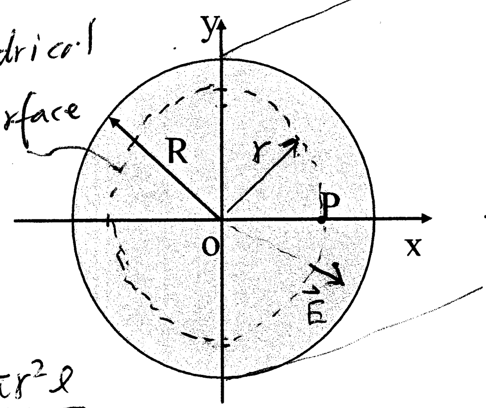


Figure A

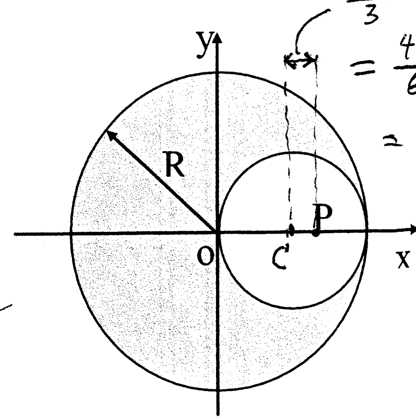


Figure B

$\Phi = \frac{Q_{encl.}}{\varepsilon_0}$

$\vec{E} \parallel \vec{r}$.

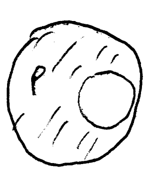
$E \cdot 2\pi r \cdot l = \frac{\rho \pi r^2 l}{\varepsilon_0}$

l — length of G.S.

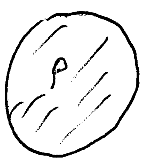
$\therefore E = \frac{\rho r}{2\varepsilon_0}$, Now $r = \frac{2R}{3}$, $E = \frac{\rho 2R}{2\varepsilon_0 \cdot 3} = \frac{\rho R}{3\varepsilon_0}$

$\vec{E} = \frac{\rho \vec{r}}{2\varepsilon_0}$, or. $\vec{E} = \hat{x} \frac{\rho R}{3\varepsilon_0}$.

(2.5/5) b).



is equivalent to



+

$\vec{E} = \vec{E}^+ + \vec{E}^-$

$\vec{E}^+ = \frac{\rho}{2\varepsilon_0} \frac{2R}{3} \hat{x}$, $\quad \vec{E}^- = \frac{-\rho}{2\varepsilon_0} \frac{R}{6} \hat{x}$

$\therefore \vec{E} = \hat{x} \frac{\rho}{2\varepsilon_0} \left(\frac{2R}{3} - \frac{R}{6} \right) = \hat{x} \frac{\rho}{2\varepsilon_0} \left(\frac{4R}{6} - \frac{R}{6} \right) = \hat{x} \frac{\rho}{2\varepsilon_0} \frac{3R}{6}$.

$\vec{E} = \hat{x} \frac{\rho R}{4\varepsilon_0}$