Physics 202 MWF10:20 Spring 2009 (Ford) Name (printed) Version 1 Key

Name (signature as on ID)_____ Lab Section_____

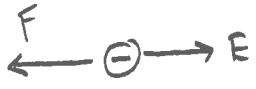
Exam I Chapts. 17–18 in Young&Geller 8e

Multiple choice questions. Circle the correct answer. No work need be shown and no partial credit will be given.

(5 pts) 1. A negative point charge with $q = -5.0 \times 10^{-9}$ C is placed at a point where the electric field is in the $+x$ direction. What is the direction of the force that the electric field exerts on the point charge?

(a) $+x$
(b) $-x$
(c) $+y$
(d) $-y$

b



(5 pts) 2. A parallel plate capacitor has charge Q on its plates. The capacitor is not connected to a battery, so the charge on the plates can't change. If the plates are pulled apart, so the separation between the plates increases, the potential difference between the plates

a

(a) increases
(b) decreases
(c) stays the same

$V = \frac{Q}{C}$ and $C = \frac{\epsilon_0 A}{d}$

d larger, C smaller, V larger

or $V = Ed$. $E = \frac{Q}{\epsilon_0 A}$ same,

so V increases

(5 pts) 3. A hollow spherical shell with radius $R = 0.6$ m has charge $q = 2 \times 10^{-9}$ C distributed uniformly over its surface. What is the magnitude of the electric field due to the shell at $r = 0.30$ m, that is, at a point 0.30 m from the center of the shell?

(a) 200 N/C
(b) 60 N/C
(c) 50 N/C
(d) 30 N/C
(e) zero
(f) none of the above

e

inside the shell, $E = 0$

(6 pts) 4. In a region of space there is a uniform electric field with magnitude $E = 400$ N/C and that is in the $-x$-direction. If the potential at the origin is 500 V, what is the potential at $x = +0.30$ m?

(a) 100 V
(b) 120 V
d (c) 380 V
(d) 620 V
(e) 900 V
(f) zero
(g) none of the above

The difference in potential is $Ed = (400\ N/C)(0.3\ m)$
$= 120\ V$
$\vec{E}$ points toward lower potential, so $V = 500V + 120V = 620V$

or $\frac{W_{a\to b}}{q'} = V_a - V_b$. Let a be at origin and b be at $x = 0.3$ m.

For $q' > 0$, $\frac{W_{a\to b}}{q'} = -Ed = V_a - V_b$. $V_b = V_a + Ed = 500V + 120V = 620\ V$

(6 pts) 5. A particle with charge $q = -2 \times 10^{-3}$ C is released from rest at point a. When the particle reached point b, its kinetic energy is 3.0 J. If the potential of point a is 800 V, what is the potential of point b? (Gravity can be neglected.)

(a) zero
(b) -700 V
f (c) -1500 V
(d) 803 V
(e) 1500 V
(f) 2300 V
(g) none of the above

$W_{a\to b} = 3.0\ J$

$\frac{W_{a\to b}}{q} = V_a - V_b$

$V_b = V_a - \frac{W_{a\to b}}{q} = 800V - \frac{3.0\ J}{-2\times10^{-3}\ C} = 800V + 1500\ V$

$V_b = 2300\ V$ (negative charge gains kinetic energy when it moves to higher potential)

On the following problems show all your work. Partial credit will be given if earned. Write your answers in the blanks provided.

(12 pts) 6. An air-filled capacitor with $C = 5.0 \times 10^{-6}$ F is connected to a battery that has $V = 20$ V. While the battery remains connected, a dielectric with dielectric constant $K = 3.0$ is inserted between the plates of the capacitor, completely filling the space between the plates. After the dielectric has been inserted, what is the charge on the capacitor?

Ans. $3.0\times10^{-4}\ C$

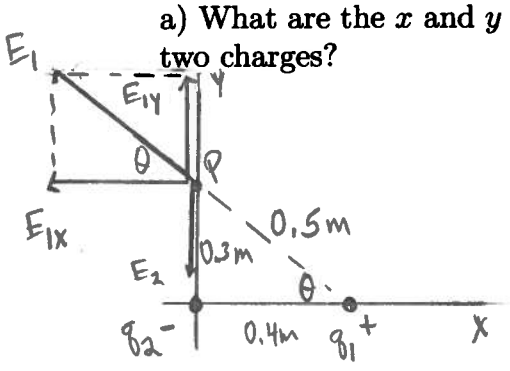
$C_0 = 5\times10^{-6}\ F$

$C = KC_0 = 15\times10^{-6}\ F$

$Q = CV = (15\times10^{-6}\ F)(20\ V) = 3.0\times10^{-4}\ C$

(22 pts) 7. A positive point charge $q_1 = +9.0 \times 10^{-9}$ C is on the x-axis at $x = +0.40$ m. A negative point charge $q_2 = -3.0 \times 10^{-9}$ C is at the origin. Point P is on the y-axis at $y = +0.30$ m.

a) What are the x and y components of the total electric field produced at point P by the two charges?



$\sin\theta = \frac{0.3}{0.5}$, $\theta = 37°$

Ans. x -259 N/C

y -105 N/C

$E_1 = k\frac{|q_1|}{r_1^2} = (9\times10^9)\frac{9\times10^{-9}}{(0.5)^2} = 324$ N/C

$E_{1x} = -E_1\cos\theta = -259$ N/C

$E_{1y} = +E_1\sin\theta = +195$ N/C

$E_2 = k\frac{|q_2|}{r_2^2} = 9\times10^9\,\frac{3\times10^{-9}}{(0.3)^2} = 300$ N/C

$E_{2x} = 0$, $E_{2y} = -300$ N/C

$E_x = E_{1x} + E_{2x} = -259$ N/C $+ 0 = -259$ N/C

$E_y = E_{1y} + E_{2y} = +195$ N/C $+ (-300$ N/C$) = -105$ N/C

b) What is the total electric potential produced at point P by these two charges?

$V = V_1 + V_2 = \frac{kq_1}{r_1} + \frac{kq_2}{r_2}$

Ans. 72 V

$V = \frac{(9\times10^9)(9\times10^{-9})}{0.5} + \frac{(9\times10^9)(-3\times10^{-9})}{0.3} = +162\text{V} + (-90.0\text{V})$

$V = 72$ V

(18 pts) 8. Two identical objects each have mass $m = 0.50$ kg and charge $q = -3.0 \times 10^{-4}$ C. If they are placed 0.20 m apart and released from rest, what is the speed of one of the objects when the distance between them is 0.50 m? (Air resistance and gravity can be neglected.)

Ans. 69.7 m/s

$r_a = 0.2\text{m}, \; r_b = 0.5\text{m}$

$K_a + U_a = K_b + U_b$

$K_a = 0$

$U_a = \frac{kqq'}{r_a} = 9\times10^9 \frac{(-3\times10^{-4})^2}{0.2} = 4050\text{ J}$

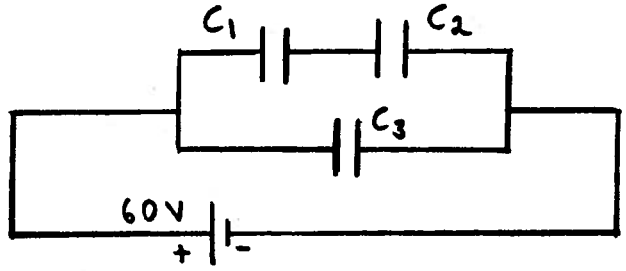
$U_b = \frac{kqq'}{r_b} = 9\times10^9 \frac{(-3\times10^{-4})^2}{0.5} = 1620\text{ J}$

$K_b = K_a + U_a - U_b = 4050\text{J} - 1620\text{J} = 2430\text{J}$

$K_b = 2\left(\frac{1}{2}mv^2\right)$

$v = \frac{K_b}{m} = \sqrt{\frac{2430\text{ J}}{0.5\text{ kg}}} = 69.7\text{ m/s}$

(21 pts) 9. Three capacitors are connected to a 60 V battery as shown in the sketch. $C_1 = 6.0 \times 10^{-6}$ F, $C_2 = 3.0 \times 10^{-6}$ F, and $C_3 = 3.0 \times 10^{-6}$ F.

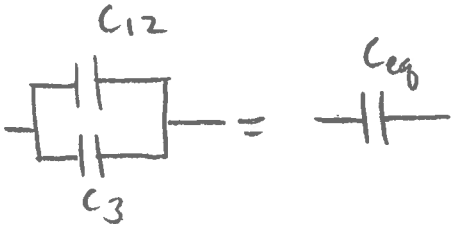


a) What is the equivalent capacitance of the capacitor network?

$\frac{1}{C_{12}} = \frac{1}{C_1} + \frac{1}{C_2}$

$C_{12} = \frac{C_1 C_2}{C_1 + C_2} = 2 \times 10^{-6}\,F$

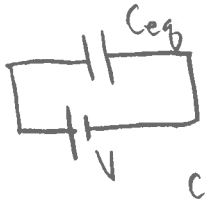
Ans. $5.0 \times 10^{-6}\,F$



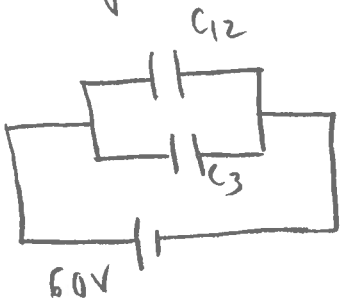
$C_{12} + C_3 = C_{eq}$

$C_{eq} = 2 \times 10^{-6}\,F + 3 \times 10^{-6}\,F = 5 \times 10^{-6}\,F$

b) Calculate the charge on each capacitor.



$Q = C_{eq} V = (5 \times 10^{-6})(60) = 3 \times 10^{-4}\,C$

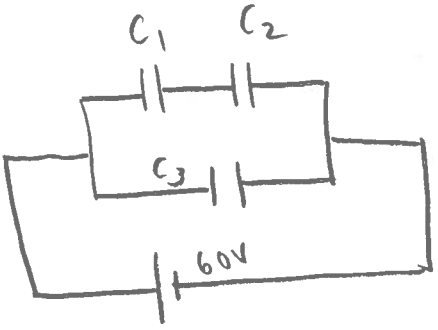


$V_{12} = V_3 = 60\,V$

$Q_3 = C_3 V_3 = (3 \times 10^{-6})(60) = 1.8 \times 10^{-4}\,C$

$Q_{12} = C_{12} V_{12} = (2 \times 10^{-6})(60) = 1.2 \times 10^{-4}\,C$

Note: $Q_{12} + Q_3 = Q$



$Q_1 = Q_2 = Q_{12} = 1.2 \times 10^{-4}\,C$

$V_1 = \frac{Q_1}{C_1} = \frac{1.2 \times 10^{-4}\,C}{6 \times 10^{-6}\,F} = 20\,V$

$V_2 = \frac{Q_2}{C_2} = \frac{1.2 \times 10^{-4}\,C}{3 \times 10^{-6}\,F} = 40\,V$

Note: $V_1 + V_2 = V$

Ans. Q_1 $1.2 \times 10^{-4}\,C$

Q_2 $1.2 \times 10^{-4}\,C$

Q_3 $1.8 \times 10^{-4}\,C$