**Kuwait University** **Physics Department**

# Physics 102

## First Midterm Examination
## First Semester (2011-12)

**October 30, 2011**

**Time: 6.30 p.m. to 8.00 p.m.**

Name…………………………………… Student No.………………..

Instructors: Drs. Abdel-Karim, Afrousheh, Davis, Farhan, Kokaj, Lajko, Marafi, Pichler, Rakhshani, Razee, and Sharma

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**(Fundamental constants)**

| | |
|---|---|
| $k = \frac{1}{4\pi\varepsilon_o} = 9.0\times10^{9}\ \mathrm{N.m^2/C^2}$ | (Coulomb constant) |
| $\varepsilon_o = 8.85\times10^{-12}\ \mathrm{C^2/(N\cdot m^2)}$ | (Permittivity of free space) |
| $\mu_0 = 4\pi\times10^{-7}\ \mathrm{T.m/A}$ | (Premeability of free space) |
| $\lvert e \rvert = 1.60\times10^{-19}\ \mathrm{C}$ | (Elementary unit of charge) |
| $N_A = 6.02\times10^{23}$ | (Avogadro’s number) |
| $g = 9.8\ \mathrm{m/s^2}$ | (Acceleration due to gravity) |
| $m_e = 9.11\times10^{-31}\ \mathrm{kg}$ | (Electron mass) |
| $m_p = 1.67\times10^{-27}\ \mathrm{kg}$ | (Proton mass) |

**Prefixes of units**

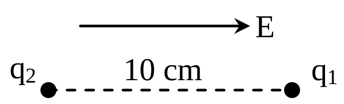
| | | | |
|---|---|---|---|
| $m = 10^{-3}$ | $\mu = 10^{-6}$ | $n = 10^{-9}$ | $p = 10^{-12}$ |
| $k = 10^{3}$ | $M = 10^{6}$ | $G = 10^{9}$ | $T = 10^{12}$ |

**For use by Instructors only**

| Prob. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Total |
|---|---|---|---|---|---|---|---|---|---|
| Marks | | | | | | | | | |

| Ques. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Total |
|---|---|---|---|---|---|---|---|---|---|
| Marks | | | | | | | | | |

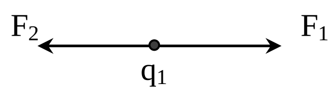
1. Two point charges $q_1 = 5$ nC and $q_2 = -6$ nC are inside a uniform electric field of magnitude $3 \times 10^3$ N/C and direction as shown. If $q_2$ is fixed and $q_1$ which has a mass of 15 g is released from rest at the position shown in the figure, what is its initial acceleration? **[4 Points]**




$F_1 = q_1 E = 1.5 \times 10^{-5}$N

$F_2 = K \frac{q_1 q_2}{r^2} = 2.7 \times 10^{-5}$ N

$a = \frac{F_2 - F_1}{m} = 8 \times 10^{-4}$ m/s$^2$.



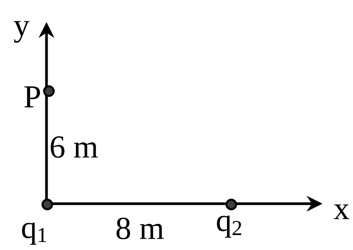

2. In the figure shown, $q_1$ is a positive and $q_2$ is a negative point charge. Find the charges $q_1$ and $q_2$ if the net electric field at point P is given by $\vec{E} = (5000\ \text{N/C})\ \hat{\imath}$. **[4 Points]**

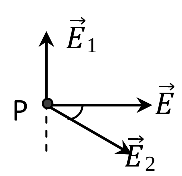
$E = E_2 \cos\theta \rightarrow 5000 = k \frac{|q_2|}{10^2} \cdot \frac{8}{10}$

$q_2 = -69.4$ μC

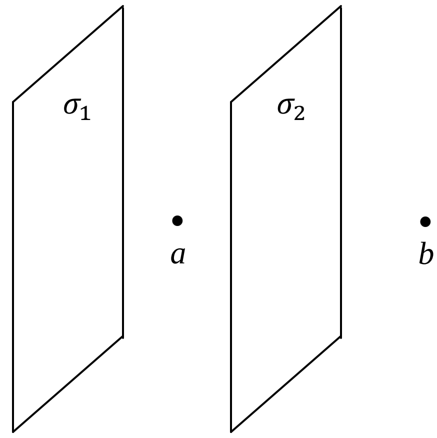
$E_1 = E_2 \sin\theta \rightarrow k \frac{|q_1|}{r_1^2} = k \frac{|q_2|}{r_2^2} \cdot \frac{6}{10}$

$q_1 = 15$ μC



3. Two infinite parallel plates have uniform surface charge densities $\sigma_1$ and $\sigma_2$. If $\sigma_1 = -17.7\ \text{nC/m}^2$, and the total electric field at point $a$ is $\vec{E} = (-500\ \text{N/C})\hat{\imath}$, find the total electric field $\vec{E}$ at point $b$. **[4 Points]**



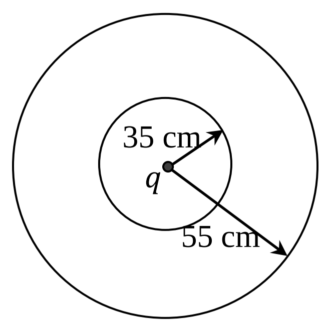

$\vec{E}_1 = (-1000\ \text{N/C})\hat{\imath}$

$\vec{E}_2 = \left(-500 - (-1000\ )\right)\hat{\imath} = (500\ \text{N/C}\ )\hat{\imath}$

$\sigma_2 = -8.85\ \text{nC/m}^2$

$\vec{E}_b = (-1500\ \text{N/C})\hat{\imath}$

4. A spherical conducting shell of inner radius 35 cm and outer radius 55 cm is given a total charge of $-12\ \mu\text{C}$. Find the surface charge density on the outer surface of the shell if a point charge $q = 3\ \mu\text{C}$ is placed at its center. **[3 Points]**



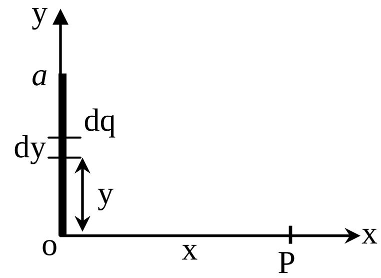

$q_{outer} = Q + q = -9\ \mu\text{C}$

$\sigma_{outer} = \frac{q_{outer}}{4\pi R^2} = -2.4\ {}^{\mu\text{C}}\!/_{\text{m}^2}$

5. A line of length $a$ and of uniform positive charge density $\lambda$ is along the y axis as shown.

a) For the charge element $dq$ shown in the figure, write the magnitude of the electric field $dE$ at point P in terms of given parameters. **[6 Points]**

$$dE = k\frac{dq}{r^2} = k\,\frac{dq}{(x^2+y^2)}$$




b) Express $dq$ in terms of $dy$, and write down $E_x$ and $E_y$ in terms of integrals.

$$E_x = \int k\frac{\lambda dy}{(x^2+y^2)} \cdot \frac{x}{(x^2+y^2)^{1/2}} = k\lambda x \int_o^a \frac{dy}{(x^2+y^2)^{3/2}}$$

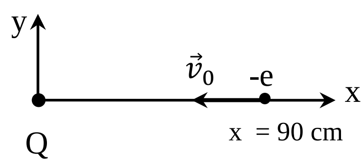
$$E_y = -k\lambda \int_o^a \frac{y\,dy}{(x^2+y^2)^{3/2}}$$

c) Calculate $E_y$.

$$E_y = k\lambda\left(\frac{1}{\sqrt{x^2+a^2}} - \frac{1}{x}\right)$$

6. A point charge Q = $-25$ nC is fixed at the origin. An electron, initially at $x = 90$ cm, is launched along the x-axis with an initial speed of $\vec{v}_0 = (-3\times 10^5\ \mathrm{m/s})\hat{\imath}$ as shown. How close does the electron get to charge Q? **[4 Points]**

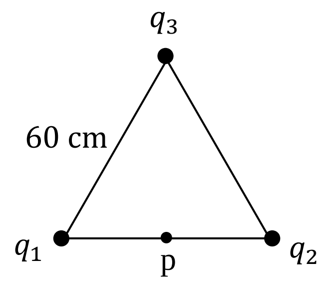
$$K_i + U_i = K_f + U_f$$




$$\frac{1}{2}\,m\,v_o^2 + k\,\frac{Q(-e)}{r_1} = 0 + k\,\frac{Q(-e)}{r_2}$$

$$r_2 = 89.9\ \mathrm{cm}$$

7. Three point charge $q_1 = +12$ nC, $q_2 = +12$ nC, and $q_3 = -15$ nC are at three corners of an equilateral triangle of side 60.0 cm as shown below. Find the total electric potential at point P that is at the middle of one side of the triangle. **[4 Points]**




$V_1 = V_2 = k\frac{q_1}{r_1} = 360$ V

$r_3 = 52$ cm

$V_3 = k\frac{q_3}{r_3} = -260\ V$

$V = V_1 + V_2 + V_3 = 460\ V$

8. A 4.0 pC charge is uniformly distributed over the surface of a solid spherical conductor of radius 8.0 mm. If point A is 4.0 mm from the center of the conductor and point B is 20.0 mm from the center, determine the electric potential difference $V_A - V_B$. **[3 Points]**

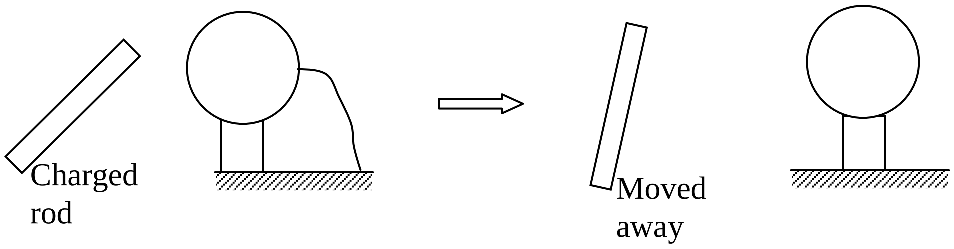
$V_A = V_{r=R} = k\frac{Q}{R} = 4.5\ V$

$V_B = k\ \frac{Q}{r} = 1.8\ V$

$V_A - V_B = 2.7\ V$

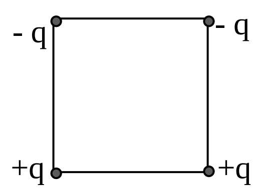
**Conceptual Questions**

1. A negatively charged rod is moved close to an uncharged spherical conductor which is on an insulating stand and is connected to the ground by a wire as shown in the figure. When the wire is disconnected from the sphere and the charged rod is moved away,




✗ a) the sphere will have a uniform positive surface charge density.
b) the sphere will have a uniform positive volume charge density.
c) the sphere will have a uniform negative surface charge density.
d) the sphere will have a uniform negative volume charge density.

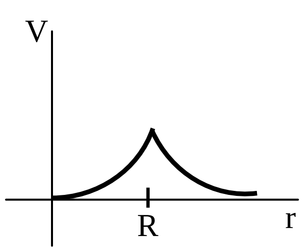
2. Four point charges are placed at four corners of a square. At which point in the space is the electric field zero?

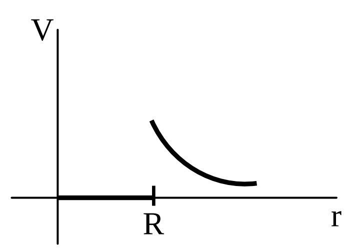



a) At the middle of each side of the square.
b) At the center of the square.
✗ c) At a point infinitely far away from the square.
d) At the center of the square and at infinity.

3. If an electron is released from rest near an infinite plane of uniform charge density, it will
a) remain stationary.
✗ b) move at constant acceleration.
c) move at constant velocity.
d) move at changing acceleration.

4. A conducting sphere of radius *R* carries an excess positive charge and is very far from any other charges. Which one of the following graphs best illustrates the potential (relative to infinity) produced by this sphere as a function of the distance *r* from the center of the sphere?

(a)



(b)



V

(c)

R r

V

✗ (d)

R r

5. Two charged conductors are joined by a long copper wire. Thus

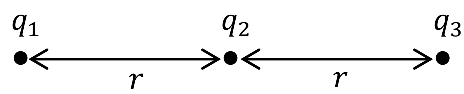
   a) each conductor carries the same free charge.

   b) no free charge can be present on either conductor.

   ×c) the two conductors have the same potential.

   d) the electric field at the surface of each conductor is the same.

6. In the figure below $q_1 = q_2 = -q_3$. If $U_1$, $U_2$ and $U_3$ are the electric potential energies of $q_1$, $q_2$, and $q_3$, which one of the following is correct?



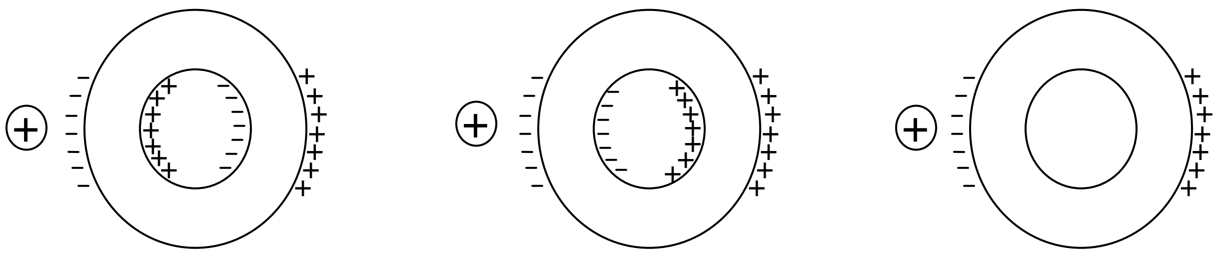

   a) $U_3 > U_2 > U_1$

   ×b) $U_1 > U_2 > U_3$

   c) $U_2 > U_1 > U_3$

   d) $U_1 > U_3 > U_2$

7. A positive charge is brought close to a fixed neutral conductor that has a cavity. The cavity is neutral; that is, there is no *net* charge inside the cavity.



1 2 3

   Which one of the figures best represents the charge distribution on the inner and outer walls of the conductor?

   a) Figure 1 only

   b) Figure 2 only.

   ×c) Figure 3 only.

   d) Figures 1 and 3.

8. Which of the following statements about Gauss's law is correct?

   a) If there is no charge inside a Gaussian surface, the electric field must be zero at all points on that surface.

   b) Only charge enclosed within a Gaussian surface can produce an electric field at points on that surface.

   c) Gauss's law is valid only for symmetric charge distributions, such as spheres and cylinders.

   ×d) The electric flux passing through a Gaussian surface depends only on the amount of charge inside that surface, not on its size or shape.