University of Alberta

Department of Physics

Phys 230 EA01 Midterm Exam — CEB 326

Thursday October 11, 2007 — Prof. I. Isaac

08:00 – 09:20

No notes or textbooks allowed

Formula sheet is provided with the exam

This exam has four questions; the value of each is indicated in the table below. Budget your time accordingly.

Show all your work in a neat and logical manner in the space provided

Messy work will not be marked

Include diagrams as appropriate

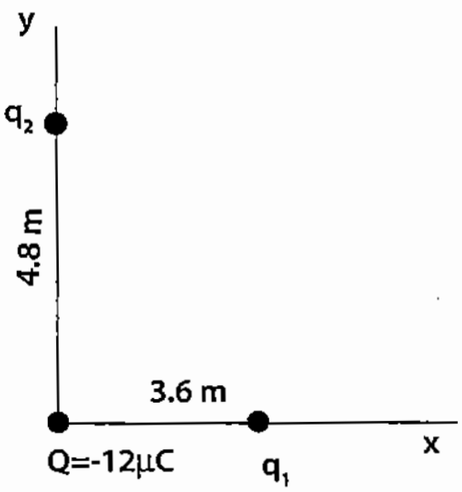
Do not separate the pages of the exam

Student Name:

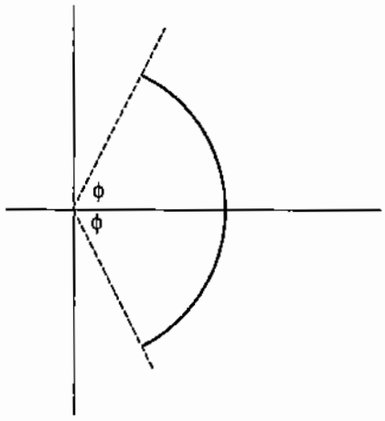
Student ID:

| Question | Value | Mark |
|---|---|---|
| 1 | 6 | |
| 2 | 8 | |
| 3 | 8 | |
| 4 | 8 | |
| Total | 30 | |

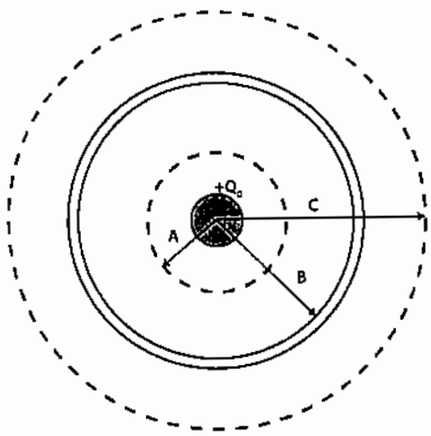
1. A point charge $Q$ = -12 μC, and two other charges $q_1$ and $q_2$ are placed as shown. The electric force components on charge $Q$ are $F_x$ = +0.005 N and $F_y$ = -0.003 N.
   a) Find the number of excess electrons in charge $Q$.
   b) Find the charge $q_1$, sign included.
   c) Find the charge $q_2$, sign included.
   d) Charge $Q$ is moved to a new position such that the resultant electric field at the origin due to charges $q_1$, $q_2$ and $Q$ is equal to zero. Find the x- and y-coordinates of the new position of charge $Q$.



2. An insulating rod is bent to form an arc of a circle of radius $a$. The arc subtends an angle of $2\phi$ at the centre, and carries a linear charge density $\lambda$, uniformly distributed over its length. Find the magnitude of the electric field due to such charge distribution at the centre of the circle Indicate the direction of that electric field.



3. A very small, charged, metal sphere is placed inside a thin conducting spherical shell of radius B without touching it. Two Gaussian spheres of radii *A* and *C* are used to find the net electric flux inside and outside the shell.
    a) If the two Gaussian surfaces have the same electric flux, what is the charge on the inner and outer surfaces of the conducting shell?
    b) Now suppose the electric flux through the outer Gaussian surface is three times that through the inner Gaussian surface. What is the charge on the inner and outer surfaces of the conducting shell?
    c) If the electric flux through the outer Gaussian surface is zero, what is the electric flux through the inner Gaussian surface?
    d) If the electric flux through the outer Gaussian surface is zero, what is the charge on the inner and outer surfaces of the conducting shell?



4. A very long non-conducting cylinder of radius 5.00 cm carries positive charges whose charge density (in $C/m^3$) varies with the radius as $\rho(r) = Ar$, where A is a constant. If the magnitude of the electrostatic field at the surface is 282 V/m,
    a) Find the numerical value of the constant $A$.
    b) What are the units of $A$?

**Formula Sheet**

Coulomb's Law $\mathbf{F} = k\frac{q_1 q_2}{r^3}\mathbf{r}$, $k = 8.99\times10^9\ \mathrm{Nm^2/C^2}$, $\varepsilon_0 = 8.85\times10^{-12}\ C^2/Nm^2$

Gauss's Law: $\Phi = \int_A \mathbf{E}\bullet d\mathbf{A} = \frac{q}{\varepsilon_0}$

E for a point charge: $\mathbf{E} = k\frac{q_1}{r^2}\hat{\mathbf{r}}$

E for a dipole at a distant point $z$ along the dipole axis: $E = \frac{1}{2\pi\varepsilon_0}\frac{p}{z^3}$, where $p=qd$.

Electric potential energy of dipole: $U = -\vec{p}.\vec{E}$

Torque on dipole : $\tau = pE\sin(\theta) = \vec{p}\times\vec{E}$

E for an infinite plane conducting surface: $E = \frac{\sigma}{\varepsilon_0}$.

E for a plane non-conducting sheet of charge: $E = \frac{\sigma}{2\varepsilon_0}$

E due to an infinite line charge: $E = \frac{\lambda}{2\pi\varepsilon_0 r}$

E outside a spherical charged conductor: $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$

Electric Potential: $\Delta V = -\frac{W}{q} = V_f - V_i = -\int_i^f \mathbf{E}\bullet\mathbf{ds}$

Electric Potential: $\Delta V = \int\frac{kdQ}{r}$

Electric potential due to a point charge: $V = k\frac{q}{r}$

Electric potential of electric dipole: $V = \frac{1}{2\pi\epsilon_0}\frac{p\cos(\theta)}{r^2}$, where $p=qd$

E calculated from $V$: $E_s = -\frac{dV}{ds}$

Capacitance $C = \frac{Q}{V}$

Parallel-plate Capacitor $C = \varepsilon_0\frac{A}{d}$

$\int\frac{dr}{r} = \ln(r)$

$\int\cos\theta d\theta = \sin\theta$

$e$ : electron charge $= 1.6\times10^{-19}\ C$