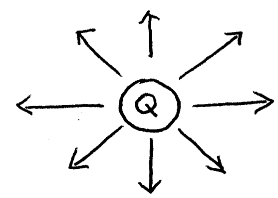
PHY 212 General Physics II - Electricity, Magnetism and Light
Summer 2007

Exam 1 Monday, July 16

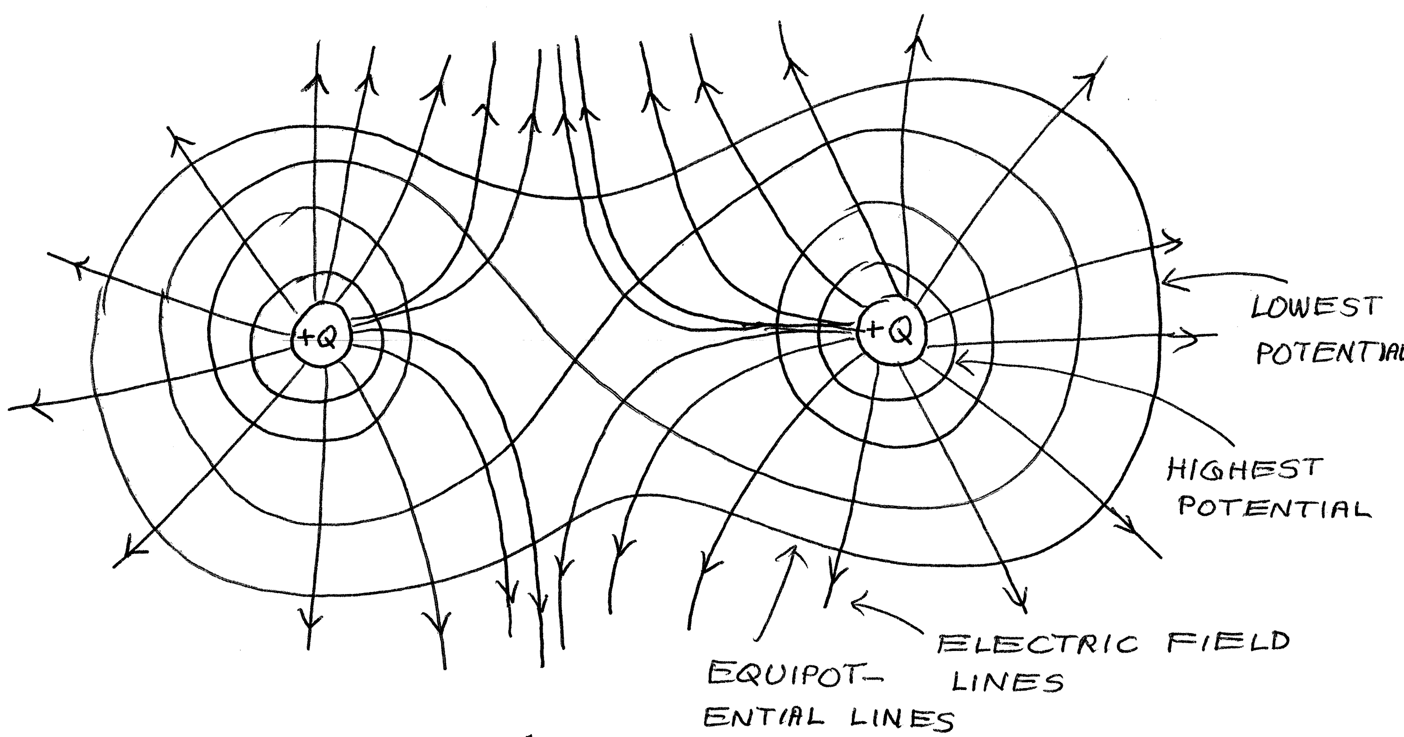
Name:

1. (2 points) If the electric field around a charge Q is oriented as shown by the arrows in the sketch below, Q could be
(a) a proton ✓
(b) an electron
(c) any point charge
(d) an electric dipole

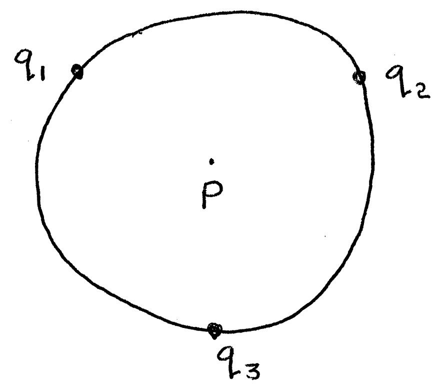


2. (2 points) As an electron is moved away from an atomic nucleus, the electrical potential energy of the electron
(a) increases ✓
(b) decreases
(c) remains constant
(d) could be any of the above depending on the charge of the nucleus

3. (9 points) For the two equal positive charges shown below (i) sketch the electric field lines, (ii) sketch a few equipotential lines and (iii) identify the equipotential line you drew which has the highest value of potential and also the one with lowest value of potential. $Q > 0$



4. (6 points) Three point charges $q_1 = (4/9)\mu C$, $q_2 = -(2/9)\mu C$ and $q_3 = -(1/9)\mu C$ are equally spaced on a circle of radius 1m whose center is at point P. What is the electric potential at point P? (You may use the approximation $k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9$ Nm^2/C^2.)



$$V_{at\ P} = \frac{1}{4\pi\epsilon_0}\left(\frac{q_1}{1} + \frac{q_2}{1} + \frac{q_3}{1}\right)$$

$$= (9\times10^9)\left(\frac{4}{9}\mu C + -\frac{2}{9}\mu C - \frac{1}{9}\mu C\right)$$

$$= 9\times10^9 \times \frac{(4-2-1)}{9} \times 10^{-6}$$

$$= 1000 \text{ Volt}$$

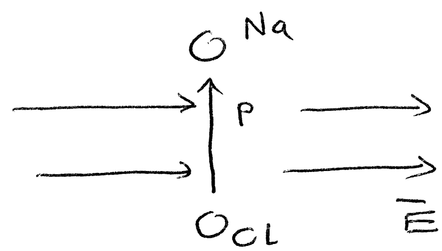
5. (10 points) The potassium chloride molecule (KCl) has a dipole moment of 8.9 $\times 10^{-30}$ Cm. (i) Assuming that this dipole moment arises from two charges $\pm 1.6 \times 10^{-19}$ C separated by distance d. Calculate d. (ii) What is the maximum magnitude of the torque that a uniform electric field with magnitude 6.0×10^5 N/C can exert on a KCl molecule? (iii) Sketch the relative orientations of the electric dipole moment $\vec{p}$ and the electric field $\vec{E}$ when the torque is a maximum.

(Problem 21.60 in the textbook)

(i) $d = p/q = (8.9 \times 10^{-30}\, C.m) / (1.6 \times 10^{-19} C) = 5.56 \times 10^{-11}$ m

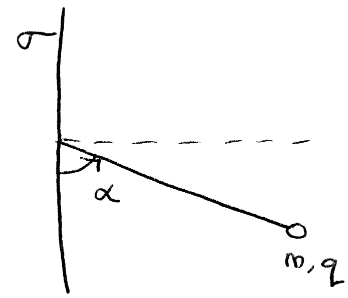
(ii) $\tau_{max} = pE = (8.9 \times 10^{-30}\, C.m)(6 \times 10^{5}\, N/C)$
$= 5.34 \times 10^{-24}$ N.m

(iii) Maximum torque:



6. (10 points) A small sphere with mass m carries a positive charge q and is attached to one end of a silk fibre of length L. The other end of the fibre is attached to a large vertical insulating sheet that has a positive surface charge density σ. Show that when the sphere is in equilibrium, the fibre makes an angle equal to arctan $(q\sigma/2mg\epsilon_0)$ with the vertical sheet.

(Problem 21.96 in the textbook)



$$\sum F_x = 0 \Rightarrow T\cos\alpha = mg$$

$$\Rightarrow T = \frac{mg}{\cos\alpha}$$

$$\sum F_y = 0 \Rightarrow T\sin\alpha = \frac{q\sigma}{2\epsilon_0}$$

$$\Rightarrow T = \frac{q\sigma}{2\epsilon_0 \sin\alpha}$$

$$\Rightarrow \frac{mg}{\cos\alpha} = \frac{q\sigma}{2\epsilon_0 \sin\alpha}$$

$$\Rightarrow \tan\alpha = \frac{q\sigma}{2\epsilon_0 mg}$$

$$\Rightarrow \alpha = \arctan\left(\frac{q\sigma}{2\epsilon_0 mg}\right)$$

7. (10 points) A flat sheet of paper of area 0.250 m^2 is oriented so that the normal to the sheet is at an angle of 60^0 to a uniform electric field of magnitude 14 N/C. (i) Find the magnitude of the electric flux through the sheet. (ii) For what angle ϕ between the normal to the sheet and the electric field is the magnitude of the flux through the sheet largest?

(Exercise 22.1 in the textbook)

(i) $\Phi = \bar{E} \cdot \bar{A} = (14\ N/C)\ (0.250 m^2) \cos 60^\circ$

$= 1.75\ Nm^2/C$

(ii) The flux is maximum when the angle between the normal and field is zero. ie $\phi = 0^\circ$

8. (6 points) A solid metal sphere with radius 0.450 m carries a net charge of 0.250 nC. Find the magnitude of electric field (i) 0.100m outside the surface of the sphere, (ii) at a point inside the sphere, 0.100m below the surface.

(Exercise 22.14 in the textbook)

(i) $E(\text{at } r = 0.45m + 0.1m) = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}$

$$= \frac{1}{4\pi\epsilon_0}\frac{2.5\times10^{-10}C}{(0.55\,m)^2}$$

$$= 7.44\ N/C$$

(ii) $\bar{E} = 0$ inside of a conductor.

9. (10 points) Two charges $-Q$ and $+2Q$ are separated by a distance d. (Note that $Q > 0$.) Find all the points along the line passing through both charges for which the electric potential V is zero (take $V = 0$ infinitely far from the charges) and for which electric field E is zero.

(Exercise 23.30 in the textbook)

V can be zero in 2 places, A and B.

at A: $\dfrac{k(-Q)}{x} + \dfrac{k(2Q)}{d-x} = 0 \rightarrow x = d/3$

at B: $\dfrac{k(-Q)}{y} + \dfrac{k(2Q)}{d+y} = 0 \rightarrow y = d$

$E_Q = E_{2Q}$ to the left of $-Q$

$$\frac{kQ}{x^2} = \frac{k(2Q)}{(d+x)^2} \rightarrow x = \frac{d}{(\sqrt{2}-1)}$$

10. (10 points) Two metal spheres of different sizes are charged such that the electric potential is the same at the surface of each. Sphere A has a radius three times that of sphere B. Let Q_A and Q_B be the charges on each sphere and E_A and E_B be the electric field magnitudes at the surface of each sphere. (i) What is the ratio Q_B/Q_A. (ii) What is the ratio E_B/E_A.

(Problem 23.81 in the textbook)

(i) $V = \frac{kQ_B}{R_B} = \frac{kQ_A}{R_A} = \frac{kQ_B}{R_A/3} \Rightarrow Q_A = 3Q_B$

$\Rightarrow \frac{Q_B}{Q_A} = \frac{1}{3}$

(ii) $E_B = -\frac{\partial V}{\partial r}\Big|_{r=R_B} = \frac{kQ_B}{R_B^2} = \frac{k(Q_A/3)}{(R_A/3)^2} = \frac{3kQ_A}{R_A^2} = 3E_A$

$\Rightarrow \frac{E_B}{E_A} = 3.$