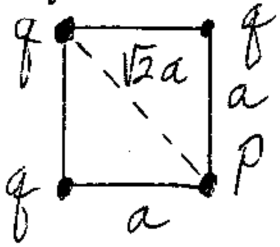
A. MULTIPLE-CHOICE QUESTIONS. CIRCLE THE BEST ANSWER (8 Pts. each):

1. Identical point charges q are placed at the 4 corners of a square of side a. The potential at the location of any one charge produced by the other 3 is

A. 1.4 kq/a
B. 2.0 kq/a
C. 2.7 kq/a
D. 3.0 kq/a
E. 3.7 kq/a



$$V(P) = \sum_i \frac{kq_i}{r_i} = \frac{kq}{a}\left(\frac{1}{1}+\frac{1}{1}+\frac{1}{\sqrt{2}}\right)$$
$$= 2.7\, kq/a$$

2. The surface charge density is 3 C/m^2 and the potential is 600V at point A on a conductor. What is the potential at point B on the same conductor if the surface charge density there is 1 C/m^2 ?**(Circle the best answer).**

a) 200V
b) 400V
c) 600V → Conductor is an equipotential!
d) 1200 V
e) 1800 V

3. The electric field in a region is given by $\mathbf{E} = (3\ V/m^3)\ y^2\ \hat{\mathbf{j}}$ where y is the y-axis coordinate value.. What is the value of the potential difference $V_{x=0,y=2m} - V_{x=0,y=1m}$? **(Circle the best answer).**

a) 7 V
b) 9 V
c) 21 V
d) -7 V
e) -9 V
f) -21 V

$$\Delta V = -\int_{y=1m}^{2m} \vec{E}\cdot d\vec{l} = -\int_{y=1m}^{2m} (3V/m^3)\, y^2 dy = -(3V/m^3)\left[\frac{y^3}{3}\right]_{1m}^{2m}$$
$$= -7V$$

4. A closed cubic box has sides of length 0.10 m. If a charge of 2.5 μC is placed at the center of the box, the flux through each side of the box is

A. $1.8 \times 10^5\ Nm^2/C$
B. $9.4 \times 10^4\ Nm^2/C$
C. $4.7 \times 10^4\ Nm^2/C$
D. $2.4 \times 10^4\ Nm^2/C$
E. $1.2 \times 10^4\ Nm^2/C$

$$\Phi_E = \frac{Q_{in}}{\varepsilon_0} = \frac{2.5\times10^{-6}C}{8.85\times10^{-12}(C^2/Nm^2)}$$
$$\Phi_{E_{Face}} = \frac{1}{6}\Phi_{E_{total}} = 4.7\times10^4\ Nm^2/C$$

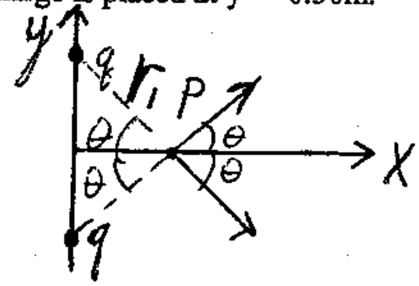
5. When an electric dipole is placed in a region containing a uniform electric field, the dipole experiences

A. a torque which tends to align the direction of the dipole moment with the direction of the electric field
B. a net force which tends to align the direction of the dipole moment opposite to the direction of the electric field
C. a net force which tends to align the direction of the dipole moment in a direction perpendicular to the electric field.
D. a torque which tends to align the direction of the dipole moment opposite to the direction of the electric field.
E. zero net force, and zero net torque

PROBLEMS. BE SURE TO SHOW YOUR METHOD CLEARLY. BE SURE THAT ANSWERS ARE WRITTEN IN TERMS OF ONLY *GIVEN* QUANTITIES AND STANDARD CONSTANTS AND UNIT VECTORS SUCH AS k, π, ε_0, $\hat{i}$, $\hat{j}$, $\hat{k}$, and $\hat{r}$. (20 points per problem)

1. A point charge of 1.0×10^{-6} C is placed at y= 0.50m and a similar point charge is placed at y = -0.50m.

a) What is the electric field at position 0.50 m $\hat{i}$?
(Give the answer in terms of unit vectors $\hat{\mathbf{i}}$, $\hat{\mathbf{j}}$, **and** $\hat{\mathbf{k}}$.)



Y-Components of Field cancel
X-Components add

$$E = 2E_{x_1} = \frac{2kq}{r_1^2}\cos\theta$$

$$= \frac{2kq}{r_1^2}\left(\frac{x}{r_1}\right) = \frac{2(k)(1\times10^{-6}C)(.5m)}{[(0.5m)^2+(0.5m)^2]^{3/2}} = 2.8\times10^{-6}\left(\frac{C}{m^2}\right)k$$

$$\vec{E} = 2.8\times10^{-6}\left(\frac{C}{m^2}\right)k\,\hat{i} = 2.5\times10^{4}\left(\frac{N}{C}\right)\hat{i}$$

b. What would be the electric force on a charge -2.0×10^{-6} C placed at position 0.50 m $\hat{i}$?

$$\vec{F} = q\vec{E} = (-2.0\times10^{-6}C)(2.5\times10^{4}\tfrac{N}{C}\,\hat{i})$$

$$= -5.0\times10^{-2}\,N\,\hat{i}$$

c. With only the charge at y= 0.50 m and the charge at y = - 0.50 m present initially, how much work would needed to bring a 1.0 x 10^{-6}C charge from infinitely far away to the origin?

Q

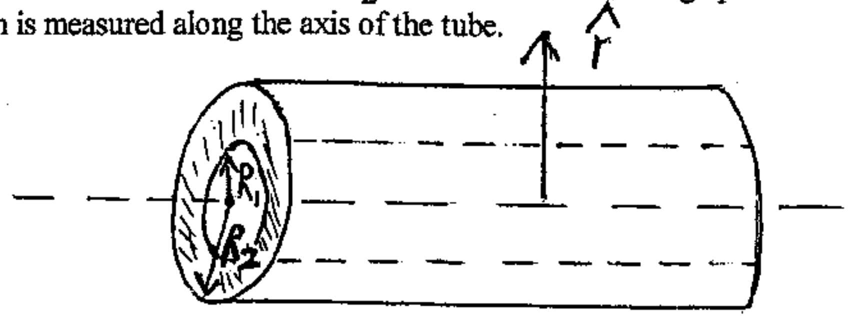
$$U = \sum\frac{kqQ}{d} = kqQ\left(\frac{1}{0.5m}+\frac{1}{0.5m}\right)$$

$$= (9\times10^{9}Nm^2/C^2)(1.0\times10^{-6}C)(1.0\times10^{-6}C)\left(\frac{2}{0.5m}\right)$$

$$= 3.6\times10^{-2}\,J$$

2. An infinitely long tube with inside radius $R_1 = 0.1$m and outside radius $R_2 = 0.15$ m carries a charge per unit length of 1.0×10^{-6} C/m. where the length is measured along the axis of the tube.

(5) a) Describe the Gaussian surface you would use to find the magnitude of the electric field at radial distance r=0.2 m (Give the shape - sphere, cube, etc.- and dimensions of your Gaussian surface).



Cylinder of radius r and length l, centered on tube axis

(5) b) What is the value of the total electric flux out of your Gaussian surface?

$$\Phi_E = \frac{Q_{in}}{\varepsilon_0} = \frac{\lambda l}{\varepsilon_0} = \frac{(1.0 \times 10^{-6} \frac{C}{m}) l}{8.85 \times 10^{-12} (C^2/Nm^2)}$$

$$= (1.13 \times 10^{5} Nm/C) l$$

(10) c) What is the electric field at radial distance r=0.2 m

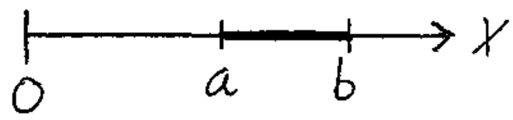
$$\Phi_E = 2\pi r l E = \frac{\lambda l}{\varepsilon_0}$$

$$E = \frac{\lambda}{2\pi r \varepsilon_0} = \frac{(1.0 \times 10^{-6} C/m)}{2\pi (0.2m)(8.85 \times 10^{-12} C^2/Nm^2)}$$

$$= 9.0 \times 10^{4} N/C$$

$$\vec{E} = 9.0 \times 10^{4} \left(\frac{N}{C}\right) \hat{r}$$

3. A thin string extends along the x-axis from position x=a to position x=b. The string carries charge Q uniformly distributed over it.



a. Write down an expression for the element dV of potential produced at the origin by an element dQ of charge at position x if a<x<b. (Take the reference position to be at infinity, as usual.)

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$$dV = \frac{k\,dQ}{X}$$

b. Write dq in terms of dx and the given quantities Q, a, b.

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$$dQ = \frac{Q}{b-a}$$

c. Integrate to find the total potential produced at the origin by the string.

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$$V = \int_{X=a}^{b} \frac{k\,dQ}{X} = \frac{kQ}{(b-a)}\int_{X=a}^{b}\frac{dX}{X} = \frac{kQ}{(b-a)}\left[\ln X\right]_a^b$$

$$= \frac{kQ}{(b-a)}\ln\left(\frac{b}{a}\right)$$