Physics 161-001 Spring 2012 Exam 2

Name: _________________________________ Box#____________

Multiple Choice (5 points each):

1) In a static situation, the electric field associated with a conductor is

A) zero inside and parallel to the surface outside.
B) constant inside and perpendicular to the surface outside.
C) zero inside and perpendicular to the surface outside.
D) constant inside and parallel to the surface outside.
E) none of the above.

2) Charge is uniformly distributed on a very large flat non-conducting sheet. The magnitude of the electric field 4m from the sheet is 4V/m. What is the magnitude of the electric field 8m from the sheet?

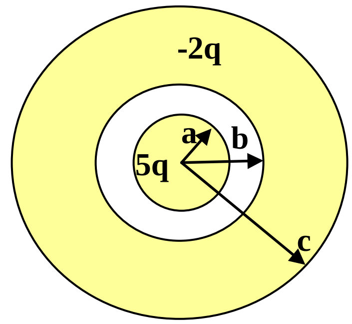
A) 0.5V/m
B) 1V/m
C) 2V/m
D) 3V/m
E) 4V/m

It's still 4V/m since the electric field is constant outside of a large (infinite) sheet of charge.

3) A point charge is placed at the center of a spherical Gaussian surface. The net electric flux through the surface is *changed* if

A) the sphere is replaced by a larger sphere with the point charge still centered
B) the point charge is moved off center (but still inside the original sphere)
C) a second point charge is moved to just outside the sphere (the original charge is still centered)
D) more than one of these
E) none of these

4) A solid conducting sphere carrying a charge of 5q has a radius *a*. It is inside a concentric hollow conducting shell of inner radius *b* and outer radius *c* carrying a net charge of –2q. What is the *charge density* on the outer surface of the shell?



A) 3q
B) $-2q/4\pi c^2$
C) $2q/4\pi b^2$
D) $3q/4\pi c^2$
E) 7q

-5q of the charge is distributed on the inner surface of the shell which means there must be 3q on the outer surface so that the net charge is 3q-5q=-2q. The density then must be 3q/area = $3q/4\pi c^2$.

5) The equipotential surfaces associated with an isolated point charge are

A) radially outward from the charge
B) vertical planes
C) horizontal planes
D) concentric spheres centered on the charge
E) concentric cylinders with the charge on the axis

6) The electric field at a distance of 10cm from an isolated point charge of 2×10^{-9} C is:

A) 1.8 N/C
B) 180 N/C
C) 18 N/C
D) 1800 N/C
E) none of the above

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} = 9x10^9 \frac{Nm^2}{C^2}\frac{(2x10^{-9}C)}{(.1m)^2}$$

$E = 1800 N/C$ pointing away from the charge

7) A solid spherical conductor of radius 5m with -5C of charge on its outer surface has a potential V = 0 at its center. What is the potential at the surface?

A) 5V
B) 1V
C) 0V
D) –1V
E) –5V

The potential anywhere on a conductor is constant.

8) An air filled parallel-plate capacitor has a capacitance of 10 pF. The plate area is then halved and a wax dielectric is inserted, completely filling the space between the plates. As a result, the capacitance remains unchanged. The dielectric constant of the wax is:

A) 2.0
B) 3.0
C) 4.0
D) 6.0
E) 8.0

9) A 3μF capacitor, C_1 is charged to a potential difference V_o = 6V. It is then disconnected from the source of the potential and connected in parallel to an uncharged 9μF capacitor C_2. Charge flows to C_2 until the potential difference across both capacitors is the same. What is this common potential difference?

A) 4.0V
B) 2.5V
C) 3.0V
D) 1.5V
E) 5.0V

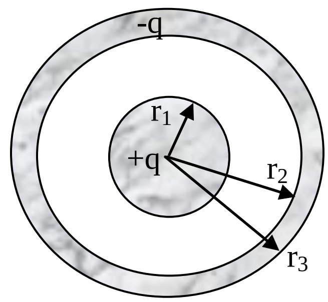
10) If the potential in a region is given by $V(x,y,z) = 4xy-3x^2$ (with appropriate units), then the x-component of the electric field at the point (x=2m, y=1m, z=0m) is:

A) -8 V/m
B) -4 V/m
C) 0 V/m
D) +4 V/m
E) +8 V/m

Written Problems (25 points each) SHOW ALL WORK!

1) A very long conducting cylindrical rod of length L and radius r_1 with a total charge +q is surrounded by a conducting cylindrical shell (also of length L, inner radius r_2, outer radius r_3) with a total charge –q.

(a) Use Gauss's law to find the electric field at points outside the conducting shell.



For our Guassian surface, choose a co-axial cylinder of length *l*,

$$\oint \vec{E}\bullet d\vec{A} = \int_{left} \vec{E}\bullet d\vec{A} + \int_{right} \vec{E}\bullet d\vec{A} + \int_{side} \vec{E}\bullet d\vec{A}$$

then: $$= 0 + 0 + E\int_{side} dA = E2\pi rl = +q - q = 0$$

$$E = 0$$

(b) Use Gauss's law to find the electric field in all of the regions between the rod and the shell.

For our Guassian surface, choose a co-axial cylinder of length *l*, between the rod and shell, then:

$$\oint \vec{E}\bullet d\vec{A} = \int_{left} \vec{E}\bullet d\vec{A} + \int_{right} \vec{E}\bullet d\vec{A} + \int_{side} \vec{E}\bullet d\vec{A}$$

$$= 0 + 0 + E\int_{side} dA = E2\pi rl = \frac{q_{enc}}{\varepsilon_0} = \frac{\lambda l}{\varepsilon_0} \Rightarrow$$

$$\vec{E} = \frac{\lambda}{2\pi\varepsilon_0 r}\hat{r}$$

where λ is the linear charge density on the rod, given by $\frac{q}{L}$.

(c) What is the potential difference between the rod and the shell?

$$V(r_2) - V(r_1) = -\int_{r_1}^{r_2} \vec{E} \bullet d\vec{l} \Rightarrow$$

$$V(r_2) = \int_{r_1}^{r_2} \frac{\lambda}{2\pi\varepsilon_0 r} dr = \frac{\lambda}{2\pi\varepsilon_0} \int_{r_1}^{r_2} \frac{1}{r} dr \Rightarrow$$

$$V(r_2) = \frac{\lambda}{2\pi\varepsilon_0} \ln\left(\frac{r_2}{r_1}\right)$$

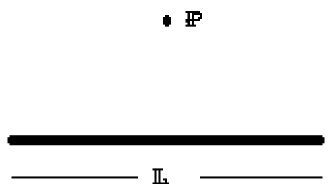
(d) What is the capacitance of this object?

$$C = \frac{q}{V} = \frac{\lambda L}{V} = \frac{\lambda L}{\frac{\lambda}{2\pi\varepsilon_0} \ln\left(\frac{r_2}{r_1}\right)} \Rightarrow$$

Q=CV, so the capacitance is just:

$$C = \frac{L 2\pi\varepsilon_0}{\ln\left(\frac{r_2}{r_1}\right)}$$

2) **A thin non-conducting rod of length L has charge -q uniformly distributed along its length. Find the magnitude and direction of the electric field at point P a distance h above and on the perpendicular bisector of the rod.**



$$\lambda = -q / L, dq = \lambda\, dx$$

$$dE = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r^2} = \frac{1}{4\pi\varepsilon_0}\frac{\lambda\ dx}{\left(h^2 + x^2\right)}$$

now, the x – components cancel so,

$$dE_y = dE\cos\theta = dE\frac{h}{r} = \frac{1}{4\pi\varepsilon_0}\frac{h\lambda\, dx}{\left(h^2 + x^2\right)^{3/2}}$$

$$E_y = \int_{-L/2}^{L/2}\frac{1}{4\pi\varepsilon_0}\frac{h\lambda\ dx}{\left(h^2 + x^2\right)^{3/2}}$$

$$E_y = \frac{\lambda}{4\pi\varepsilon_0 h}\left[\frac{x}{\sqrt{h^2 + x^2}}\right]_{-L/2}^{L/2}$$

$$E_y = \frac{-\lambda}{4\pi\varepsilon_0 h}\left(\frac{2L}{\sqrt{4h^2 + L^2}}\right) = \frac{-q}{4\pi\varepsilon_0 h}\left(\frac{2}{\sqrt{\left(\frac{2h}{L}\right)^2 + 1}}\right)$$

Notice that if you let L get very large, this goes to what you would expect for an infinite wire.