Physics 161-001 Spring 2014 Exam 2

Name: ______________________________ Box#__________

Multiple Choice (6 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 (non-zero) inside and perpendicular to the surface outside.
C) zero inside and perpendicular to the surface outside.
D) constant (non-zero) inside and parallel to the surface outside.
E) none of the above.

2) 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) a dipole is placed near the first charge completely inside the surface.
E) more than one of these
F) none of these

$$\underbrace{\oint \vec{E}\cdot d\vec{A}}_{\text{net electric flux}} = \frac{q_{enc}}{\epsilon_0}$$

← only total charge enclosed

3) The electric field at a distance of 25cm from an isolated point charge of 5×10^{-7} C is:

$$|\vec{E}| = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2} = 8.99 \times 10^9 \frac{N \cdot m^2}{C^2} \cdot \frac{5 \times 10^{-7} C}{(0.25 m)^2}$$

A) 2.7×10^3 N/C
B) 1.8×10^3 N/C
C) 1.2×10^5 N/C
D) 3.6×10^4 N/C
E) 7.2×10^4 N/C
F) 1.8×10^4 N/C
G) 4.5×10^3 N/C
H) 3.6×10^3 N/C
I) 4.5×10^5 N/C
J) none of the above

4) **A solid cylindrical conductor of radius 0.5m with -5C of charge on its outer surface has a potential V = 4V on its surface. What is the potential at the center of the cylinder?**

A) 0V
B) 0.1V
C) 1V
D) 2V
E) 3V
F) 4V
G) 5V
H) 10V
I) goes to infinity
J) cannot determine without more information

Since $E=0$ throughout a conductor, V is constant.

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

A) -12 V/m
B) -8 V/m
C) -3 V/m
D) -1 V/m
E) 0 V/m
F) 1 V/m
G) 2 V/m
H) 3 V/m
I) 8 V/m
J) 12 V/m

$$E_x = -\frac{\partial V}{\partial x} = -\left[8xz - 3y^2\right]_{x=2m,\, y=1m,\, z=0m}$$

$$= 3\ V/m$$

6) **A 4.0 Coulomb charge is 1m from a -3.0 Coulomb charge. The electrostatic force on the positive charge is:**

A) 1.1×10^7 N toward the negative charge
B) 1.1×10^7 N away from the negative charge
C) 1.1×10^8 N toward the negative charge
D) 1.1×10^8 N away from the negative charge
E) 1.1×10^9 N toward the negative charge
F) 1.1×10^9 N away from the negative charge
G) 1.1×10^{10} N toward the negative charge
H) 1.1×10^{10} N away from the negative charge
I) 1.1×10^{11} N toward the negative charge
J) 1.1×10^{11} N away from the negative charge

$$|\vec{F}| = k\frac{q_1 q_2}{r^2} = 8.99\times10^9 \frac{N\cdot m^2}{C^2} \cdot \frac{4C\cdot(-3C)}{(1m)^2}$$

$$= 1.1\times10^{11} N$$

Opposite charges attract

7) A 2μC charge is placed 2m from the origin on the x-axis, and a -2μC charge is placed 2m from the origin on the y-axis. The potential at the origin is:

A) 0V
B) 1.3 x 10^4 V
C) 4.5 x 10^3 V
D) (9.0 x 10^3 V)i - (9.0 x 10^3 V)j
E) (4.5 x 10^3 V)i - (4.5 x 10^3 V)j
F) -1.3 x 10^4 V
G) -4.5 x 10^3 V
H) -(9.0 x 10^3 V)i + (9.0 x 10^3 V)j
I) -(4.5 x 10^3 V)i + (4.5 x 10^3 V)j
J) 1.8 x 10^4 V

$$V_{Net} = V_1 + V_2$$
$$= k\frac{q_1}{d_1} + k\frac{q_2}{d_2}$$

but $d_1 = d_2$

and $q_1 = -q_2 \Rightarrow V_{Net} = 0V$

8) A 2μF 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 8μF 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) 0V
B) 0.6V
C) 1.2V
D) 1.8V
E) 2.4V
F) 3.0V
G) 4.0V
H) 5.0V
I) 6.0V
J) need more information

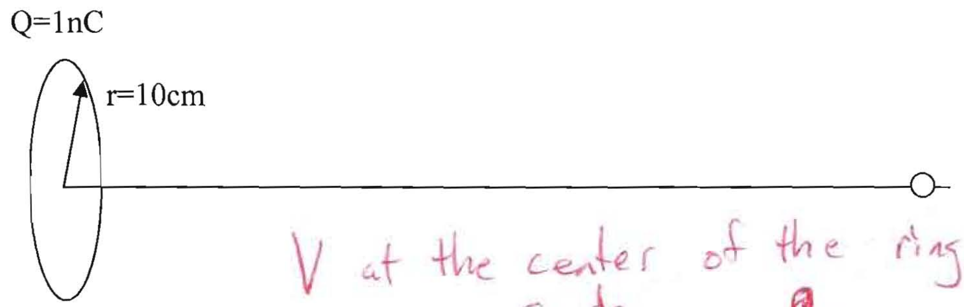
The initial charge on C_1 is

$$Q = CV = 2\mu F \cdot 6V = 12\mu C$$

This charge is then shared by the two capacitors in parallel with equiv. capacitance $= C_1 + C_2 = 10\mu F$

$$\therefore V_{final} = \frac{Q}{C_{eq}} = \frac{12\mu C}{10\mu F} = 1.2V$$

9) An electron is placed a long way from, but on the axis of ring of charge with total charge Q = +1nC and radius 10cm. With what kinetic energy does the electron pass through the ring?



A) 0eV
B) 10eV
C) 20eV
D) 30eV
E) 40eV
F) 50eV
G) 60eV
H) 70eV
I) 80eV
J) 90eV

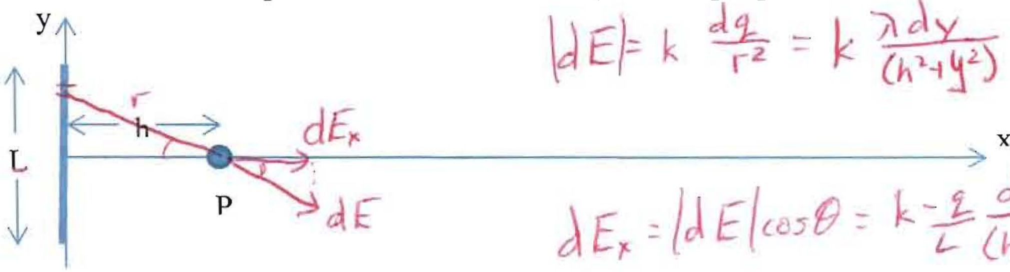
V at the center of the ring is just $V = k\int_{\text{around ring}} \frac{dq}{r} = k\frac{Q}{r} = 8.99\times10^{9}\frac{N\cdot m^2}{C^2}\cdot\frac{1nC}{0.1m}$

$= 90\,V$

$\Delta KE = q\Delta V = e\Delta V = 90eV$

10) A thin non-conducting rod of length L has charge -q uniformly distributed along its length. What is the most appropriate integral to use to find the magnitude of the electric field at point P a distance h away on the perpendicular bisector of the rod?

$|dE| = k\frac{dq}{r^2} = k\frac{\lambda\,dy}{(h^2+y^2)}$ with $\lambda = \frac{-q}{L}$



$dE_x = |dE|\cos\theta = k\frac{-q}{L}\frac{dy}{(h^2+y^2)}\frac{h}{(h^2+y^2)^{1/2}}$

A) $\vec{E} = \frac{-q}{4\pi\varepsilon_0}\int_0^h \frac{dx}{\sqrt{y^2+x^2}}$

B) $\int_0^L \vec{E}\cdot d\vec{A} = \frac{-q}{\varepsilon_0}$

C) $E_x = \frac{-q}{4\pi\varepsilon_0}\int_{-L/2}^{L/2}\frac{h\,dy}{\sqrt{y^2+h^2}}$

D) $E_x = \frac{-q}{4\pi\varepsilon_0}\int_0^L \frac{h\,dy}{y^2+h^2}$

E) $E_x = \frac{-2q}{4\pi\varepsilon_0 L}\int_0^L \frac{dy}{\sqrt{y^2+h^2}}$

F) $\oint_{cyl} \vec{E}\cdot d\vec{A} = \frac{-q}{\varepsilon_0}$

G) $E_x = \frac{-q}{4\pi\varepsilon_0 L}\int_{-L/2}^{L/2}\frac{h\,dy}{\left(y^2+h^2\right)^{3/2}}$

H) $E_x = \frac{-2q}{4\pi\varepsilon_0 L}\int_0^L \frac{dy}{\sqrt{y^2+h^2}}$

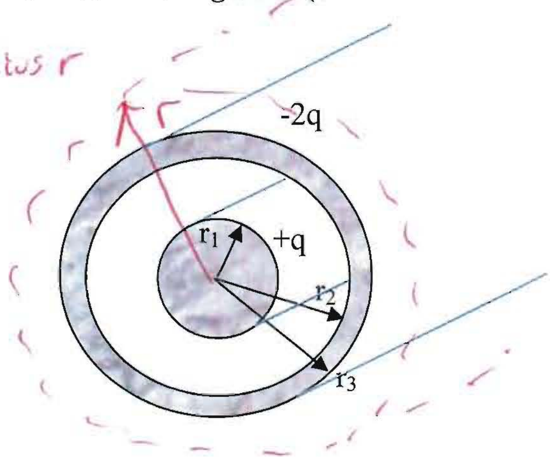
I) $E_x = \frac{-q}{4\pi\varepsilon_0}\int_{-L/2}^{L/2}\frac{dy}{\left(L^2+h^2\right)^{3/2}}$

J) $E_x = \frac{-q}{4\pi\varepsilon_0}\int_0^L \frac{dy}{\sqrt{y^2+h^2}}$

Written Problems. SHOW ALL WORK! No credit for answers without work!

1) (25 points) 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 –2q. The length L is much larger than the radial dimensions.

(a) Use Gauss's law to find the electric field at points outside the conducting shell ($r > r_3$).



Use a cylindrical Gaussian surface of radius r and Length L:

$$\oint \vec{E}\cdot d\vec{A} = \overset{\emptyset}{\int_{cap1} \vec{E}\cdot d\vec{A}} + \overset{\emptyset}{\int_{cap2} \vec{E}\cdot d\vec{A}} + \int_{cyl.} \vec{E}\cdot d\vec{A}$$

$$= E\,2\pi r L = \frac{q_{enc}}{\epsilon_0} = \frac{+q-2q}{\epsilon_0}$$

$$\Rightarrow E = \frac{-q}{2\pi r L \epsilon_0}$$

(b) Use Gauss's law to find the electric field in all of the regions between the rod and the shell ($r_1 > r > r_2$).

Same as above, except now the Gaussian surface only encloses $+q$ $\Rightarrow$

$$E = \frac{+q}{2\pi r L \epsilon_0}$$

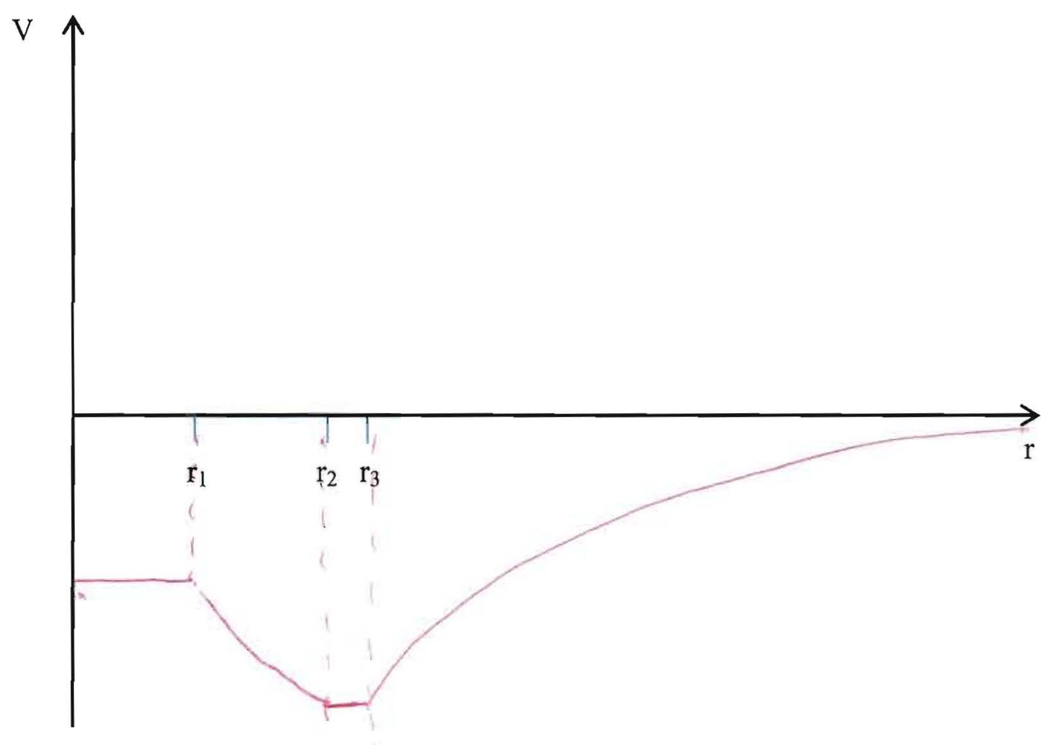
(c) What is the potential difference between the rod and the shell?

$$\Delta V = -\int_{r_1}^{r_2} \vec{E}\cdot d\vec{r} = \frac{-q}{2\pi L\epsilon_0}\int_{r_1}^{r_2}\frac{1}{r}\,dr = \frac{-q}{2\pi\epsilon_0 L}\ln\left(\frac{r_2}{r_1}\right)$$

(d) What is the capacitance of this object?

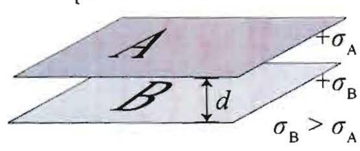
$$C = \frac{Q}{V} = 2\pi\epsilon_0 L\left[\ln\left(\frac{r_1}{r_2}\right)\right]^{-1}$$

(e) Draw a graph of the potential vs. distance from the axis of the rod, assuming V = 0 at infinity. Shape and scale are important.



2) **(15 points) The figure at right shows a small portion of two parallel, infinite sheets of positive surface charge densities $+\sigma_A$ and $+\sigma_B$. The sheets are a distance *d* apart. The surface charge density of sheet B is greater than that of sheet A (*i.e.*, $\sigma_B > \sigma_A$).**

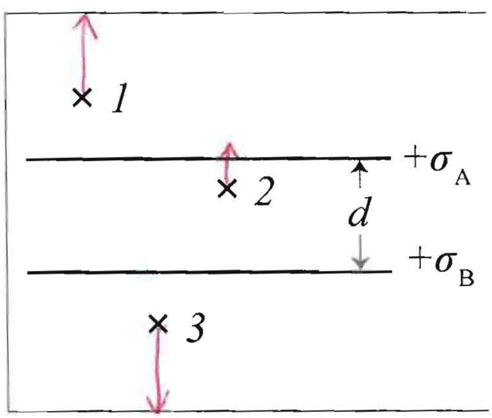
Perspective view



a) **On the side-view diagram at right, draw *vectors* with their tails at each "x" to represent the net electric field at points *1, 2,* and *3.* Your drawing should be qualitatively correct in both magnitude and direction.**

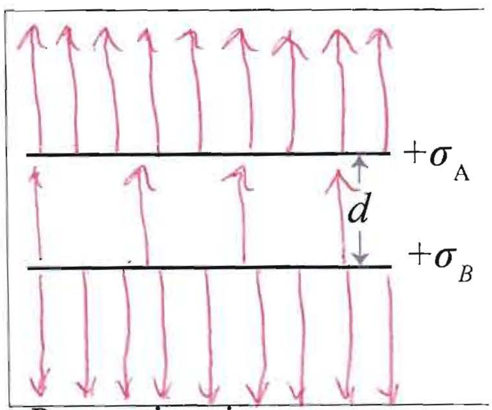
The E-field from each sheet points away from the sheet. They add above sheet A and below sheet B and partially cancel between since $\sigma_B > \sigma_A$

Side view



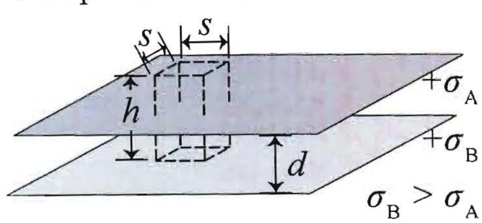
b) **On the side-view diagram at right, draw *electric field lines* to represent the net electric field above, between, and below the sheets. Your drawing should be qualitatively correct in both magnitude and direction. Explain.**

Side view

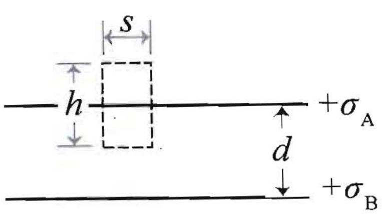


An imaginary closed surface with sides *h, s,* and *s* is shown at right.

Perspective view



Side view



c) **Evaluate the quantity $\oint \vec{E}\bullet d\vec{A}$ over the surface in terms of the magnitude of the electric field at points 1-3 from part a) ($|\vec{E}_1|$, $|\vec{E}_2|$, and $|\vec{E}_3|$) and/or other relevant quantities. (Your expression should not contain any charge densities.) Explain and show your work.**

$$\oint \vec{E}\cdot d\vec{A} = \int_{top} \vec{E}\cdot d\vec{A} + \int_{bottom} \vec{E}\cdot d\vec{A} + \int_{sides} \vec{E}\cdot d\vec{A}$$

$$= E_1 s^2 - E_2 s^2$$