Physics 111, Exam #2
Fall 2004

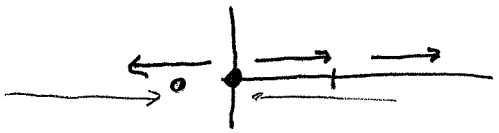
Name: KEY (1 point)

Multiple Choice: Choose the ***best*** answer for each question. (3 points each) Write your answer in the space provided.

1 B Three charged Styrofoam balls are suspended from thin silk threads. It is found that balls 1 and 2 attract each other and that ball 2 and 3 repel each other. From this we may conclude that:
a) Balls 1 and 3 carry charges of the same sign.
b) Balls 1 and 3 carry charges of opposite sign.
c) Balls 1 and 2 carry charges of the same sign.
d) None of the above

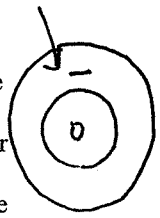
1+2 opp
2+3 same
⇒ 1+3 opp

2 A A positive point charge with charge +Q is located at the origin (x=0, y=0). Where should we place a negative point charge of charge -2Q if we wish the ***electric field*** at the point (x=1,y=0) to be zero?
a) On the x-axis where x<0.
b) On the x-axis between 0 and 1
c) On the x-axis where x>1.
d) On the y-axis where y>0.
e) On the y-axis where y<0.
f) It can't be done with these two charges.



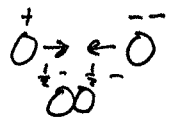
3 D A solid spherical ***conductor*** has a positive charge Q uniformly placed on it. The electric field is:
a) constant on the interior of the sphere and equal to its value on the surface
b) largest at the center of the sphere.
c) largest somewhere between the center and the surface of the sphere.
d) largest on the surface of the sphere.

4 C Consider two concentric spherical shells. The net electric flux through the smaller shell is zero while the net electric flux through the larger sphere is inward (negative). What can you conclude?
a) Gauss's law does not apply since we are comparing the flux between two different surfaces.
b) Due to the geometry, the electric field on the surface of the inner sphere is zero at all points and the electric field on the surface of the outer sphere is constant on the surface and points inward.
c) There is no net charge inside the smaller sphere and there is a net negative charge between the inner and outer spheres
d) There is a net positive charge inside the smaller sphere and a larger net negative charge between the inner and outer spheres
e) There is no net charge inside the smaller sphere and there is a net positive charge between the inner and outer spheres



5 D Which of the following statements are true regarding the electric potential?
a) The electric potential is always zero at infinity. N
b) The electric potential inside of a conductor is always zero N
c) The electric potential is always positive N
d) The electric potential may be chosen to be zero at any convenient location.
e) None of the above

6 C Two ***conducting*** spheres having charge +Q and -2Q respectively are initially at rest and separated by a distance *d*, but are free to move. Which of the following best describes the future motion of the spheres
a) Since they are initially at rest, they will remain at rest. (i.e. they will not move.)
-2 (b) They will approach each other, touch, and stick together.
c) They will approach each other, touch, and then move apart.
d) They will immediately star moving apart.



7 A

8 C

7 A A parallel plate air filled capacitor is connected to a battery of voltage V. After charging the capacitor has a charge Q and is disconnected from the battery. A Teflon plate (k=2.1) is inserted (while the battery is still disconnected) so as to just fill the space between the plates.(Hint since the battery is disconnected, the charge on the capacitor must remain constant) The energy stored in the capacitor:

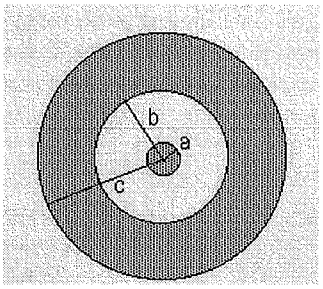
a) decreases
b) will not change
c) increases
d) none of the above

$U = \frac{1}{2}\frac{Q^2}{C}$ $C \uparrow \Rightarrow U \downarrow$

8 C The capacitance of a given capacitor depends on:

a) the potential difference across the capacitor.
b) the charge on the capacitor.
c) the geometric configuration of the capacitor and the materials that it is constructed from.
d) all of the above.

2. A conducting sphere of radius a is surrounded by a concentric, thick spherical conducting shell of inner radius b and outer radius c. It is found that the inner sphere has a net charge of +2Q and that the outer shell has a net charge of +3Q (Note that the net charge on the outer shell is Qb+Qc).



a) What are the charges located on the surface $r=a$, $r=b$, and $r=c$? (5 points)

$Q_a = 2Q$ (1)

$Q_b = -2Q$ (2) $\Rightarrow$ $Q_c = 5Q$ (2)

b) Determine the electric field in the four regions i)$r<a$, ii) $a<r<b$, iii) $b<r<c$, and iv) $r>c$. (10 points)

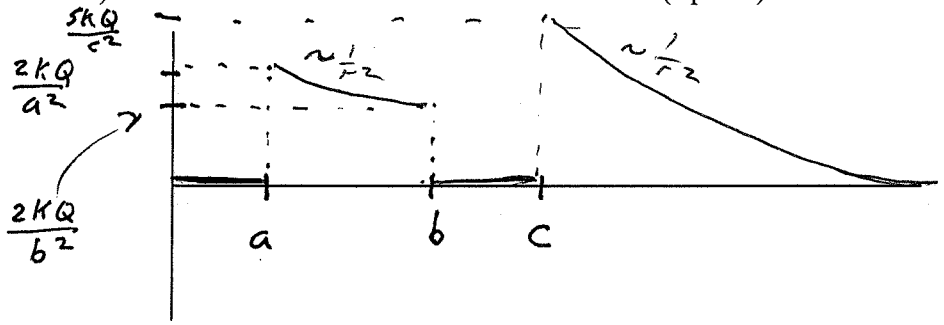
$r<a$ $E=0$ inside cond. (2)

$a<r<b$ $\oint E\cdot dA = \frac{Q_a}{\epsilon_0} \Rightarrow 4\pi r^2 E = \frac{2Q}{\epsilon_0} \Rightarrow (3)\ E = \frac{1}{4\pi\epsilon_0}\frac{2Q}{r^2} = \boxed{\frac{2kQ}{r^2}}$

$b<r<c$ $E=0$ inside cond. (2)

$r>c$ $\oint E\cdot dA = \frac{Q_c}{\epsilon_0} \Rightarrow 4\pi r^2 E = \frac{5Q}{\epsilon_0} \Rightarrow (3)\ E = \frac{1}{4\pi\epsilon_0}\frac{5Q}{\epsilon_0} = \boxed{\frac{5kQ}{r^2}}$

c) Sketch the electric field as a function of the radius. (5 points)



d) If the potential at $r=c$ is taken to be zero, find the potential at $r=\infty$. (5 points)

$\Delta V = V(r) - V(c) = -\int_c^r \frac{5kQ}{r^2}\,dr$ ($V(c)=0$)

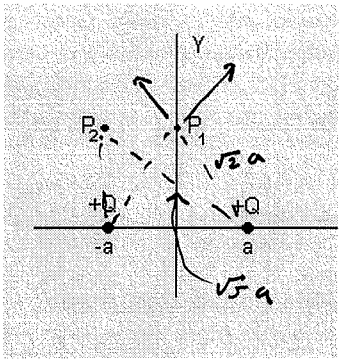
$V(r) = +\frac{5kQ}{r}\Big|_c^r = \frac{5kQ}{r} - \frac{5kQ}{c}$

at ∞

$V(\infty) = \boxed{-\frac{5kQ}{c}}$

2. Two identical point charges of charge $+Q$ are located at $x=\pm a$ as shown.

a) What is the magnitude and direction of the force on the charge at $x=-a$? (4 points)



$$F = -\frac{kQ^2}{4a^2}\hat{i}$$

b) Calculate the electric field at the point P_1 located at $x=0$, $y=a$. *(8 points)*

By symm, only a y- comp.

$$\underline{E} = 2\,\frac{kQ}{2a^2}\left(\frac{1}{\sqrt{2}}\right)\hat{j} = \boxed{\frac{kQ}{\sqrt{2}\,a^2}\hat{j}}$$

2 charges; Mag of E from Each; only y-comp

c) What is the electric potential at the point P_2 located at $x=-a$, $y=a$ (Assume that the potential is zero at infinity) *(8 points)*

$$V = \frac{kQ}{a} + \frac{kQ}{\sqrt{5}a}$$

$$= \frac{kQ}{a}\left(1+\frac{1}{\sqrt{5}}\right)$$

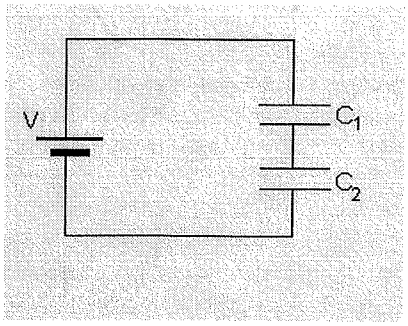
d) How much work must be done in order to bring a third point charge of charge $+3Q$ from infinity to the point P_2? (5 points)

$$W = q\Delta V$$

$$= (3Q)V$$

$$\boxed{W = \frac{3kQ^2}{a}\left(1+\frac{1}{\sqrt{5}}\right)}$$

3. Two air filled capacitors C_1=25μF and C_2 = 5μF are hooked in series across a battery V=100V as shown.



a) What is the equivalent capacitance of the two capacitors in series. (4 points)

$$\frac{1}{C_{eff}} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{25} + \frac{1}{5} = \frac{6}{25}$$

$$C_{eff} = \frac{25}{6}\mu F = 4.17\mu F$$

b) What is the charge on each of the capacitors? (5 points)

$$Q_1 = Q_2 = Q = C_{eff} V$$

$$= (4.17\mu F)(100V)$$

$$Q = 417\mu C$$

c) What is the potential difference across each capacitor? (6 points)

$$V_1 = \frac{Q}{C_1} = \frac{417\mu C}{25} = 16.7\,V$$

$$V_2 = \frac{Q}{C_2} = \frac{417\mu C}{5} = 83.4\,V$$

d) How much energy is stored in the pair of capacitors? (5 points)

$$U = \frac{1}{2} C_{eff} V^2 = \frac{1}{2}(4.17\mu F)(100V)^2$$

$$= 20850\mu J$$

$$= 20.85\ mJ$$

e) We now insert a dielectric slab into C_2 that just fills the volume between the plates. What is the value of the dielectric constant if the equivalent capacitance of the series combination of C_1 and the new C_2 is exactly twice that of the series combination without the dielectric? (5 points)

$$C_2' = 5k$$

$$C_1 = 25$$

$$\frac{1}{C_{eff}} = \frac{1}{25} + \frac{1}{5k} = \frac{1}{2C_{eff}} = \frac{3}{25}$$

$$\frac{1}{5k} = \frac{3}{25} - \frac{1}{25} = \frac{2}{25}$$

$$10k = 25$$

$$k = 2.5$$