PHYSICS 121 MIDTERM 1 Key

2019-06-07

Academic Honesty: Cheating in an examination includes the following:

1. the unauthorized sharing of material such as textbooks during an open book" examination;
2. concealing information pertaining to the examination in the examination room, or in washrooms or other places in the vicinity of the examination room;
3. using course notes or any other aids not approved by an Instructor during an examination; or,
4. the unauthorized possession or use of an examination question sheet, an examination answer book, or a completed examination or assignment.

There are 10 multiple choice questions. Select the correct answer for each one and mark it on the bubble form. Each question has only one correct answer. (2 marks each) $k = 1/4\pi\epsilon_0$

1. A positively charged pith ball is hanging from a thread. A neutral glass rod is brought close to the pith ball. What will happen?

   (a) Nothing, the rod has no effect

   (b) The pith ball will be repelled by the glass rod.

   (c) The pith ball will be attracted by the glass rod. *

2. Three charges are on a line: Q_1, q, and Q_2. The net electrical force on q is zero and Q_2 is twice as far from q as Q_1. From this we can conclude.

   (a) $Q_1 = 2Q_2$

   (b) $Q_2 = 2Q_1$

   (c) $Q_1 = 4Q_2$

   (d) $Q_2 = 4Q_1$ *

   (e) None of the above.

3. Equipotential surfaces

   (a) may intersect each other

   (b) are always spheres

   (c) are perpendicular to the conducting surfaces

   (d) are normal to electric field lines that they intersect *

4. A hollow conducting sphere has radius R and uniform surface charge density σ in coulombs/meter^2. What is the value of the electric field a distance d from the center of the sphere?

   (a) $\sigma/4\pi\epsilon_0 d^2$

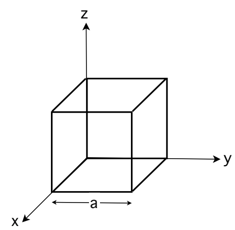
   (b) $\sigma R^2/\epsilon_0 d^2$ *

   (c) $\sigma/\epsilon_0(d-R)^2$

   (d) $\sigma R^2/4\pi\epsilon_0(d-R)^2$

   (e) None of the above

5. A cube is positioned as shown where the electric field is given by $\vec{E} = 2.0\hat{\imath}$ V/m. What is the net electric flux through the entire surface of the cube with side $a = 2$ m and its corner at the origin.



   (a) zero *

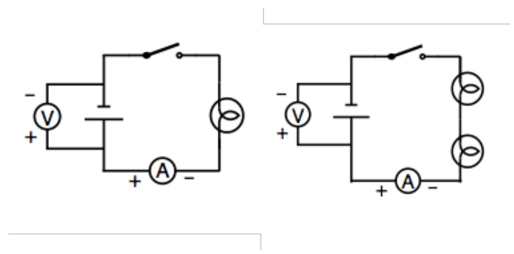
   (b) 4 V-m

   (c) 8 V-m

   (d) 24 V-m

   (e) None of the above

6. Two circuits with light bulbs have the same voltage source power supply (battery). The left-hand circuit has only one bulb and the right-hand circuit has two bulbs of the same kind as the left-hand circuit. Which circuit requires more current as measured by the ammeter when the switches are closed?



   (a) The left-hand one *

   (b) The right-hand one

   (c) They will use the same current

7. An ideal battery maintains a constant voltage across its terminals regardless of what is connected to it or how much it has been used. A real battery deviates from the ideal one and is modelled by

   (a) an ideal battery in series with an internal resistance *

(b) an ideal battery in parallel with an internal resistance

(c) an ideal battery in parallel with another battery

(d) an ideal battery in series with another battery

8. Two conducting spheres have the same potential respect to infinity. Sphere 1 has twice the radius of sphere 2. How do the surface charge densities, σ_1 and σ_2, compare?

   (a) $\sigma_1 < \sigma_2$ *

   (b) $\sigma_1 = \sigma_2$

   (c) $\sigma_1 > \sigma_2$

   (d) cannot be computed with this information

9. A conductor with total charge Q on it has a cavity inside it with an arbitrary shape. What is the electric potential inside the cavity?

   (a) kQ/r where r is the distance from origin.

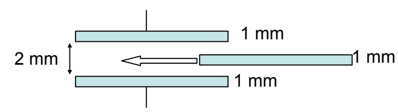
   (b) zero

   (c) kQ/r where r is the distance from the surface of the conductor.

   (d) constant and equals the potential on the surface of the conductor. *

   (e) none of the above.

10. A capacitor is formed of two 1 mm thick parallel plates that are separated by 2 mm. An identical metal plate is now carefully inserted between the two plates so that a space of 0.5 mm is left on either side of the new plate, as shown below.



When the metal plate is inserted the capacitance

   (a) increases. *

   (b) decreases.

   (c) remains the same.

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To get full credit for the *written problems* you must clearly show all your steps and explain well.

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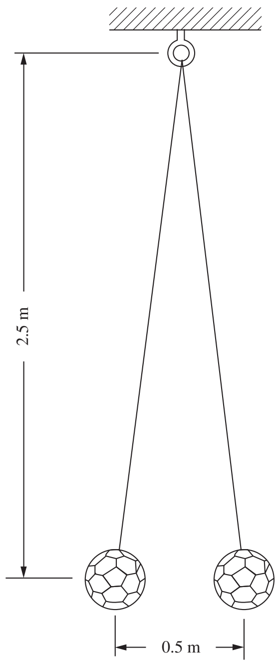
11. Two volley balls, mass 0.3 kg each, tethered by nylon strings and charged with an electrostatic generator, hang as shown. (a) What is the electrical force in newtons on each of the balls? (b) What is the charge on each, assuming the charges are equal?



They should draw a free body diagram or at least show the forces on the diagram. Balance the horizontal electrical force with the vertical gravitational force and string tension.

$$\ell = 2.5m$$

$$F_e/mg = \frac{(kq^2/r_s^2)}{mg} = r_s/2\ell$$

$$q^2 = \frac{mgr_s^3}{(2\ell k)} = 8.167 \times 10^{-12}\ C$$

$$q = 2.858 \times 10^{-6}\ C$$

Note that the length of the stringis slightly longer than 2.5 m. No need to calculate that.

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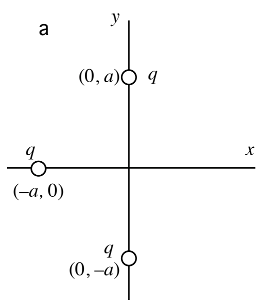
12. A symbolic answer is required for this problem. Three charges each with charge q are at $(0, a), (0, -a)$ and $(-a, 0)$ as shown in figure a.

(a) Calculate the magnitude and direction of the electric field at the origin. Express the final answer symbolically and in rectangular coordinates.[3]



The electric fields at the origin of the top and bottom (0,a) and (0,-a) cancel to zero. This leaves only the electric field of the charge at (-a,0).

$$E_x = \frac{q}{2\pi\epsilon_0 a^2}, \quad E_y = 0$$
$$\vec{E} = \frac{q}{2\pi\epsilon_0 a^2}\hat{\imath}$$

(b) What is the electric potential at the origin? (Set the potential at infinity to be zero.) [3]

Each charge is a distance a from the origin. In this case potential is a scalar and there is no cancellation.

$$V(origin) = \frac{3q}{4\pi\epsilon_0 a}$$

(c) What is the total potential energy of the system of 3 charges? [4]

First charge at (0.-a) can be placed in position without any energy. Second charge placed at (-a,-0) a distance $\sqrt{2}a$ from first charge

$$\Delta PE_2 = \frac{q^2}{4\pi\epsilon_o \sqrt{2}a}$$

Third charge is a distance of $\sqrt{2}a$ and $2a$ from the other two

$$\Delta PE_3 = \frac{q^2}{4\pi\epsilon_0 a}\left(\frac{1}{\sqrt{2}} + \frac{1}{2}\right)$$

The total PE is

$$\Delta PE_{tot} = \frac{q^2}{4\pi\epsilon_0 a}\left(\frac{2}{\sqrt{2}} + \frac{1}{2}\right)$$

It doesn't matter what order the charges are put in place.

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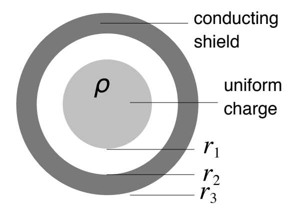
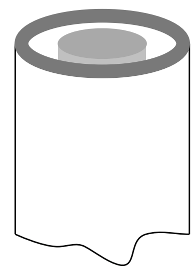
13. An insulating rod of radius r_1 and infinite length has charge distributed uniformly within it at a volume density ρ. This rod is surrounded with a conducting cylindrical shield having inside radius r_2 and outside radius r_3. The shield is concentric with the rod. This shield has zero net charge on it.

(a) Calculate the electric field for positions outside the shield, $r > r_3$. [2]





The linear charge density on the rod is the cross sectional area times the charge density/volume

$$\lambda = \pi r_1^2 \rho$$

Using Gauss' law.

$$E = \frac{\lambda}{2\pi\epsilon_0 r} = \frac{\pi r_1^2 \rho}{2\pi\epsilon_0 r} = \frac{r_1^2 \rho}{2\epsilon_0 r}$$

pointing outwards.

Note: If students use a formula with λ without establishing the relationship between λ and ρ they should lose marks.

(b) Calculate the electric field between the shield and the rod, $r_1 < r < r_2$. [2]

It's the same as in the previous part.

(c) Calculate the electric field inside the rod, $r < r_1$.[2]

Make a little can-shaped Gaussian surface inside the rod symmetric to the axis length L. Use Gauss' Law

$$E(2\pi r L) = \rho \pi r^2 L/\epsilon_0$$

$$E = \frac{\rho r}{2\epsilon_0}$$

pointing radially outward

(d) What is the potential difference between between the surfaces at r_2 and r_1? [2]

integrate E from r2 to r1:

$$\Delta V = -\int_{r_1}^{r_2} E(r)dr = -\frac{\lambda}{2\pi\epsilon_0}\ln\frac{r_2}{r_1}$$

Note: I didn't clearly specify the sign here so be lenient.

(e) Is there any surface charge on the outside of the shield? If so what is it? [2]

Yes. There is a surface charge on the inner and outer surfaces so that the E is zero inside the conductor. So the opposite charge forms on the outside.

$$\sigma(2\pi r_3) = \lambda = \pi r_1^2 \rho$$

$$\sigma = \rho r_1^2/(2r_3)$$

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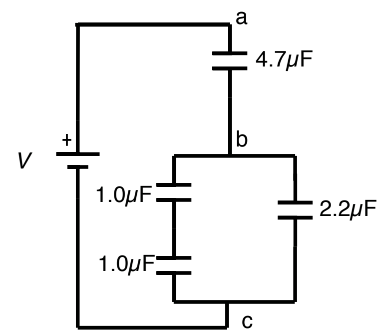
14. Analyse the circuit below.

(a) If the 4.7 μF capacitor has a charge of 9.4 μC on it what is the voltage between points a and b in the circuit? [3]

$$q = CV$$

$$V_{ab} = q/C = 2V$$



(b) What is the equivalent capacitance between points b and c. [4]

The two 1 μF caps in series reduce to 0.5 μ F. That adds to the 2.2 μF to give 2.7 μF.

(c) What is the value of the voltage source V? [3]

The charge on the lower equiv cap is the same as the top so V_{bc} = 9.8/2.7 = 3.63 V. The voltage source is 2 + 3.63 = 5.63 V.

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