A.P. Physics – B

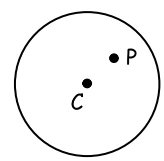
UNIT 8 TEST REVIEW

Electrostatics: Chapters 16-17

*** In studying for your test, make sure to study this review sheet <u>along with your quizzes and homework assignments.</u>**

Multiple Choice Review: **On this portion of the test, you will not be allowed to use your calculator or AP formula sheet. (You may, however, use your AP table of information.) Approximate $g=10m/s^2$ for simplicity of calculations. No partial credit will be given.**

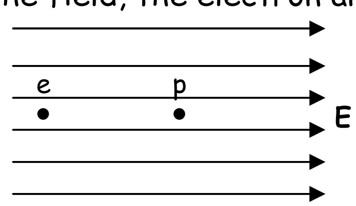
1. The hollow metal sphere shown in the diagram is positively charged. Point C is the center of the sphere, and point P is any other point within the sphere. Which one of the following is true of the electric field at these points?



a. It is zero at both points.
b. It is zero at C, but at P it is non-zero and directed inward.
c. It is zero at C, but at P it is non-zero and directed outward.
d. It is zero at P, but at C it is non-zero.

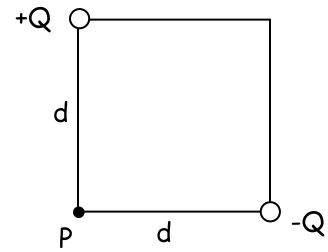
2. Two parallel conducting plates, separated by a distance D, are connected to a battery of potential difference V. Which of the following is correct if the plate separation is doubled while the battery remains connected?
a. The electric charge on the plates is doubled.
b. The electric charge on the plates is halved.
c. The potential difference between the plates is doubled.
d. The potential difference between the plates is halved.
e. The capacitance is unchanged.

3. An electron e and proton p are simultaneously released from rest in a uniform electric field E, as shown. Assume that the particles are sufficiently far apart so that the only force acting on each particle is that due to the electric field. At a later time when the particles are still in the field, the electron and proton will have the same…



a. direction of motion
b. speed
c. displacement
d. magnitude of acceleration
e. magnitude of force acting on them

4. The given figure shows two charged particles, one of charge positive Q and the other of charge -Q, that are located at the opposite corners of a square with sides of length d. What is the direction of the electric field at point P?



a. ↖

b. ↘

c. ↙

d. ↗

e. →

5. For the same diagram as in problem #4, what is the magnitude of the electric field at point P?

a. $\frac{kQ}{2d^2}$

b. $\frac{kQ}{\sqrt{2}d^2}$

c. $\frac{kQ}{d^2}$

d. $\frac{\sqrt{2}kQ}{d^2}$

e. $\frac{2kQ}{d^2}$

6. For the same diagram as in problem #4, what is the magnitude of the electric potential at point P? (Assume potential to be zero at infinity.)

a. zero

b. $\frac{kQ}{\sqrt{2}d}$

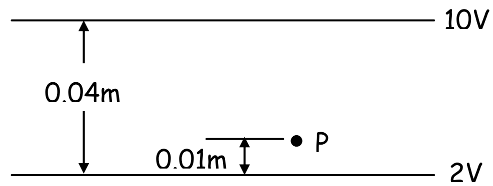
c. $\frac{kQ}{d}$

d. $\frac{\sqrt{2}kQ}{d}$

e. $\frac{2kQ}{d}$

7. Two large, flat, parallel, conducting plates are 0.04m apart, as shown in the diagram. The lower plate is at a potential of 2V with respect to ground, while the upper plate is at a potential of 10V with respect to ground. Point P is located 0.01m above the lower plate. The electric potential at point P is…

a. 10V
b. 8V
c. 6V
d. 4V
e. 2V



8. For the same two plates and point P as used in problem #7, what is the magnitude of the electric field at point P?

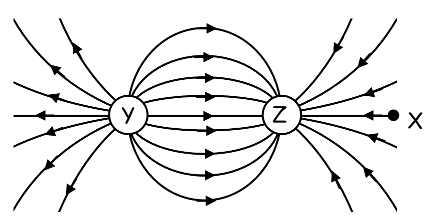
a. 800 V/m
b. 600 V/m
c. 400 V/m
d. 200 V/m
e. 100 V/m

9. For the same two plates and point P as used in problem #7, in which direction would an electron move, if released at point P?

a. To the right.
b. To the left.
c. Upward.
d. Downward.
e. Out of the plane of the page.

10. The diagram shows electric field lines in an isolated region of space containing two small charged spheres, Y and Z. Which one of the following statements is true?

a. The charge on Y is negative and the charge on Z is positive.
b. The strength of the electric field is the same everywhere.
c. The electric field is strongest midway between Y and Z.
d. A small negatively charged object placed at point X would tend to move toward the right.
e. Both charged spheres Y and Z carry charge of the same sign.



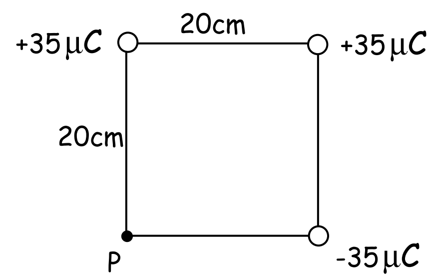
11. A 4μF capacitor is charged to a potential difference of 100V. The electrical energy stored in the capacitor is…

a. $2E^{-10}$ J
b. $2E^{-8}$ J
c. $2E^{-6}$ J
d. $2E^{-4}$ J
e. $2E^{-2}$ J

Problem Review: On this portion of the test, you may use your calculator, AP formula sheet, and AP table of information. Partial credit will be given on these problems.

12. Three charges, all of magnitude 35μC, are placed at three corners of a square of side-length 20cm, as shown in the diagram.

a. Calculate the net electric field at point P in the diagram.



b. If a fourth charge of -20nC were to be placed at point P, calculate the electric force that it would experience.

c. Calculate the potential at point P. (Assume potential to be zero at infinity.)

d. If a fourth charge of –20nC were to be placed at point P, calculate the amount of work that would be required to move the charge to infinity.

13. A +40nC and a +27nC charge are located 10cm apart from each other. How far from the 27nC charge should a third charge be placed, so that the net electric force on the third charge is zero?

14. What is the speed of a proton whose kinetic energy is 740keV?

15. A –8.6μC charge in an electric field moves from point A which has a potential of +130V, to point B which has a different potential. If the work done by the electric field in moving the charge from point A to point B is 5.92E^{-4}J, find the potential at point B. (Hint: Start by deciding whether point B is at a higher or lower potential than point A.)

16. An electron starts from rest 41cm from a fixed point charge with Q= -2.3μC. How fast will the electron be moving when it is very far away?

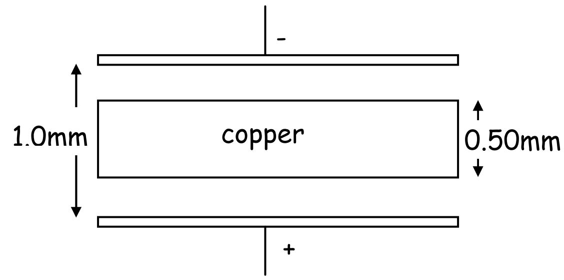
17. An electric field of 30,000V/m is desired between two parallel plates, each of area $12cm^2$ and separated by 3.14mm of air. What charge must be on each plate?

18. A 124pF capacitor is fully charged by a 9V battery, and then disconnected from the battery. When this capacitor is then connected to a second capacitor, which is initially uncharged, the final potential difference across each capacitor is 3V. Find the capacitance of the second capacitor.

19. How much energy is stored by the electric field created between two square plates, 4.2cm on a side, separated by a 1.2mm air gap, when $7.8E^{25}$ free electrons are moved from one plate to the other?

20. Actual A.P. Physics B Free-Response Question, sort of (2000):

A capacitor of $1.0E^{-9}$ F is connected to a battery. After the capacitor is fully charged to $3E^{-8}$C per plate, a conducting copper block is inserted midway between the plates, as shown below. The plates of the capacitor are separated by a distance of 1.0mm, and the copper block has a thickness of 0.5mm.



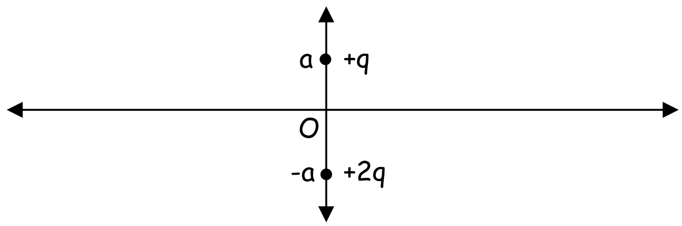
a. What is the potential difference between the plates?

b. What is the electric field inside the copper block?

c. On the diagram above, draw arrows to clearly indicate the direction of the electric field between the plates.

d. Determine the magnitude of the electric field in each of the spaces between the plates and the copper block.

21. Actual A.P. Physics B Free-Response Question (2005):

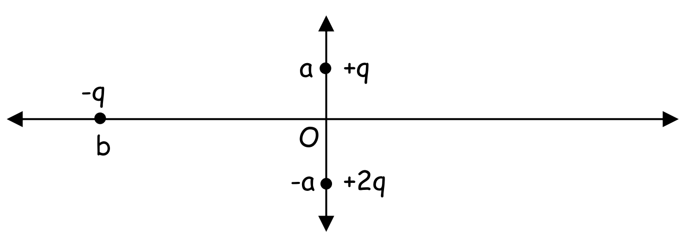


Two point charges are fixed on the y-axis at the locations shown in the figure above. A charge of +q is located at y = +a, and a charge of +2q is located at y = -a.

a. Determine the magnitude and direction of the electric field at the origin.

b. Determine the electric potential at the origin.

c. A third charge of -q is placed at an arbitrary point x = -b on the x-axis as shown in the figure below. Find the magnitudes of the two forces acting on the -q charge caused by the +q charge and the +2q charge. (Do not find the net force.)

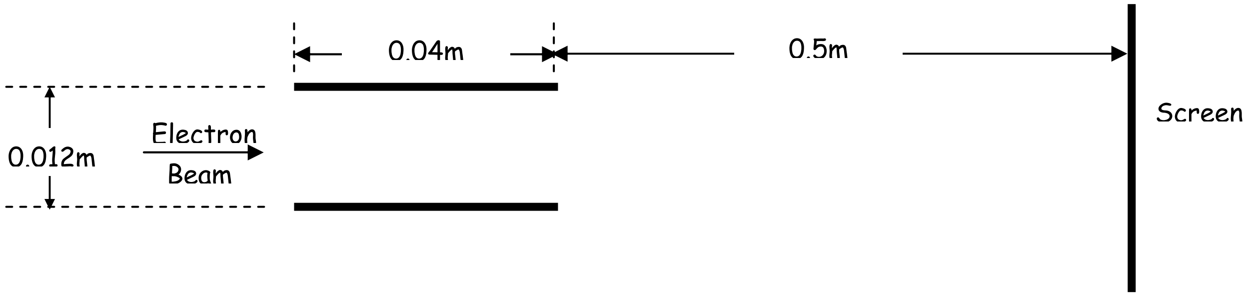


22. **Actual A.P. Physics B Free-Response Question (2005):**

In a television set, electrons are first accelerated from rest through a potential difference in an electron gun. They then pass through deflecting plates before striking the screen.

a. Determine the potential difference through which the electrons must be accelerated in the electron gun in order to have a speed of $6.0E^7$ m/s when they enter the deflecting plates.

The pair of horizontal plates shown below is used to deflect electrons up or down in the television set by placing a potential difference across them. The plates have length 0.04m and separation 0.012m, and the right edge of the plates is 0.50m from the screen. A potential difference of 200V is applied across the plates, and the electrons are deflected toward the top of the screen. Assume that the electrons enter horizontally midway between the plates with a speed of $6.0E^7$ m/s, and that fringing effects at the edges of the plates and gravity are negligible.



b. Which plate in the pair must be at the higher potential for the electrons to be deflected upward? Justify your answer.

c. Considering only an electron's motion as it moves through the space between the plates, compute the following:

i. The time required for the electron to move through the plates.

ii. The vertical displacement of the electron while it is between the plates.

d. Still neglecting gravity, describe the path of the electrons from the time they leave the plates until they strike the screen

UNIT 8 TEST REVIEW ANSWERS:

12.a. $E_1 = \frac{kq}{r^2} = 7.87E^6$ ↓ $E_2 = 3.93E^6$ 45° ↙ $E_3 = 7.87E^6$ ⟶

so $E = 1.18E^7$ N/C @ 64.5°

b. You could use Coulomb's law and 4-step vector addition, but since you already found E-field in part a, $F = qE = (20E^{-9})(1.18E^7) =$ .236N @ 64.5°

c. The potential caused by the positive and negative charges that are each 20cm from P cancel each other, so $V = \frac{kq}{r} = 1.11E^6$ V

d. $W = -\Delta U = -qV = -(-20E^{-9})(1.11E^6) = 0.022$J

13. $\frac{k(27E^{-6})}{x^2} = \frac{k(40E^{-6})}{(10-x)^2}$ so x = 4.51cm from 27nC charge

14. KE = 740,000eV = $1.184E^{-13}$ J then KE = $\frac{1}{2}mv^2$ for v = $1.19E^7$m/s

15. Since the E-field does work on the electron, the electron must be moving from low potential to high potential, as electrons naturally tend to do when acted upon by a field. W = -qV so $5.92E^{-4} = -(-8.6E^{-6})(V)$ and V = 68.84V. Recognize that this V is potential difference, so if V_A = 130V and then increases by 68.84V, V_B = 198.84V.

16. Start by calculating $V_o = \frac{kq}{r} = -50{,}432$V then $W = -qV = \Delta KE$ so $-(-1.6E^{-19})(+50{,}432) = \frac{1}{2}(9.11E^{-31})(v^2)$ and v = $1.33E^8$m/s

17. $C = \frac{\varepsilon_o A}{d} = \frac{\varepsilon_o(.0012)}{(.00314)} = 3.38\text{pF}$ and V = Ed = (30,000)(.00314) = 94.2V

so $Q = CV = (3.38E^{-12})(94.2) = 319$pC

18. $Q_1 = C_1V_1 = (124E^{-12})(9) = 1.116$nC and $Q_1' = (124E^{-12})(3) = 0.372$nC

and since $Q_1' + Q_2' = 1.116$nC, $Q_2' = 0.788$nC

then $C_2 = \frac{Q_2'}{V_2'} = \frac{0.788\text{nC}}{3} = 0.263\text{nF}$

19. $Q = (7.8E^{25})(1.6E^{-19}) = 1.248E^{7}C$ and $C = \frac{\varepsilon_o(.042^2)}{(.0012)} = 1.301E^{-11}F$

so $U_c = \frac{1}{2}QV = \frac{1}{2}Q(Q/C) = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\frac{(1.248E^7)^2}{(1.301E^{-11})} = 5.99E^{24}J$

Note: This problem is a little bit ridiculous, mostly because of the enormous number of electrons that were moved from one plate to the other.

20.a. $V = \frac{Q}{C} = \frac{3E^{-8}}{1E^{-9}} = 30V$

b. Zero, because E-field is always zero inside a conductor in electrostatic equilibrium.

c. Arrows should point upward from bottom positive plate to the bottom side of the copper block, and then other arrows should point upward from the top side of the copper block to the upper negative plate. There should be no arrows inside the block, because of part b.

d. $E = \frac{V}{d} = \frac{15}{0.00025} = 60{,}000V/m$

21.a. $E = \frac{2kq}{a^2} - \frac{kq}{a^2} = \frac{kq}{a^2}$ in positive y-direction.

b. $V = \frac{kq}{a} + \frac{2kq}{a} = \frac{3kq}{a}$

c. $F_q = \frac{kq^2}{a^2 + b^2}$ and $F_{2q} = \frac{2kq^2}{a^2 + b^2}$

22.a. $qV = \frac{1}{2}mv^2$ so $(1.6E^{-19})V = \frac{1}{2}(9.11E^{-31})(6E^7)^2$ so $V = 10{,}249V$

b. The electrons need to move upward, and electrons naturally tend to move toward higher potentials, so the top plate must be at higher V.

c.i. $t = \frac{d}{v} = \frac{.04}{6E^7} = 66.7ns$

ii. The strength of the E-field is $E = \frac{V}{d} = \frac{200}{.012} = 16{,}667N/C$ so the acceleration that the electrons will undergo is $a = \frac{F}{m} = \frac{qE}{m} = 2.927E^{15}m/s^2$

Then vertical displacement is found with the kinematic equation $x = v_o t + \frac{1}{2}at^2 = 6.5E^{-4}m$

d. Since no more forces are acting on the electron, it would continue in a straight line in whatever direction it's moving as it leaves the plates.