Chapter 12 THE MOTION OF CHARGED PARTICLES IN ELECTRIC FIELDS

The prime objective of this chapter is given in the first paragraph which says that we will extend the study of electricity to the atomic scale. We will begin by examining evidence for the existence of electrons. Next we will be introduced to the volt and electron-volt as appropriate units when working with single electrons or ions.

We will then examine how electrical forces act on charged objects which are set into motion. During this study we will use analytical tools developed in the study of mechanics to analyze this motion. Some old favorites from mechanics will return: work, force, energy, and we will see that the application of these concepts to electrical phenomena comes rather naturally. As an example, we will use the concept of kinetic energy and work to show how the mass of the electron and proton can be measured.

PERFORMANCE OBJECTIVES

After completing this chapter, you should:

1. be able to cite evidence for the existence of electrons.

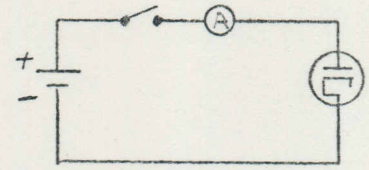
2. be able to describe the motion of electrons and other charged particles in a uniform electric force field.

3. given any three of: charge 'q', accelerating potential 'V', mass of an object 'm', and speed of the object 'v', be able to calculate the fourth.

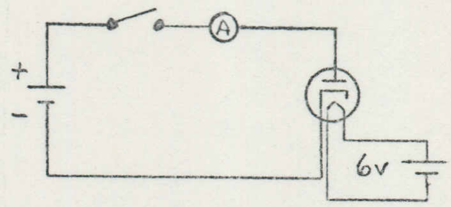
1. Read: Section 12-1 Charges in Metals: Electrons page 237

   a. As you read this paragraph, make written notes which will be helpful as you perform the following.

2. Obtain a base with tube holder with a 6AX5 tube.



(a)



   a. Hook up circuit 'a'. Close switch. Is there any current?

   b. Reverse anode and cathode connections. Close switch. Is there any current?

   c. Hook up circuit 'b'. Close switch. Is there any current?

   d. Reverse anode and cathode connections. Close switch. Is there any current?

   e. Summarize your findings and then discuss with instructor.

3. Problems: page 241: #1 #2

4. Read: Section 12-2 Conductivity of Gases: Ions page 241
   Section 12-3 The Electric Charge of Electrons and Ions p-243

5. Problems: page 242: #3 #4

6. Read Section 12-4 Volts and Electron Volts page 241

   a. In the MKS Metric system, electric potential 'V' is measured in units called the _______ which is a ________ per ___________.

   b. If one coulomb is 6.25 x E18 elementary charges, then:

   1 volt = _________________ Joules per elementary charge.

   c. This unit of energy is identified as _____ e.v.

   d. Since V = E/q, then E = _______ where E is in ______ , q is in ________ and V is in _________.

   e. Ask instructor for practical usage of the electron-volt.

7. Problems: page 245: #5 #6

9. Read: Section 12-5 Accelerating Charged Particles page 246

   a. E.M.F. stands for ________________ is represented by symbol _____ , has units ___________ which when simplified represents ______ per ______.

   b. Between the plates which accelerate the charged particle there is an ______________________ ($\vec{E}$). Since $\vec{E} = \vec{F}/q$, the force exerted by the electric field on an object with charge 'q' is calculated using: $\vec{F}$ = ________.

c. To calculate the work done, one multiplies this force 'F' by the ____________________ 'd'.

d. In Section 12-4 we found that the work done 'W' could be calculated using the relationship W = qV where 'V' is the ______________________ and 'q' is the _________ on the object being accelerated.

e. The work done (W = Fd or W = qV) causes an increase in the _____________ energy 'E_K'.

f. Knowing that E_K = 1/2 mv^2 (and that the initial velocity of the charged object is zero) the speed 'v' can be calculated by either v = _________ or v = ___________.

g. Examine Figure 12-10 page 247 and explain to your instructor how an electron is accelerated.

h. Explain to your instructor how we can check up on whether a charged object acquires a certain amount of energy.

10. Problems: page 248: #7 #8 #9
page 259: #20

11. Read: Section 12-6 Deflecting Charged Particles page 248

a. Refer to Figure A, page 250. What is responsible for accelerating the charged particle?

b. How is the speed of the charged particle calculated?

c. How is the length of time it will take for an electron to pass between the deflecting plates of length 'l' calculated?

d. How is the sideways velocity that the electron will acquire when passing between the deflecting plates with electric field 'E' calculated?

e. How is the distance that the electron is pushed sideways calculated?

12. Problems: page 250: #10

13. Read: Section 12-8 Determining the Mass of the Proton and the Electron page 254

a. To what speed will a 90-volt potential gradient accelerate an electron that is initially at rest?

b. What speed would the electron attain if you replaced a 90-volt EMF with a 900,000-volt EMF?

14. A body is accelerated from rest by a constant force of 2.0 Newtons, acting for a distance of 2.5 meters.

a. If the body has a mass of 3.0 kg, what is its final speed?

b. How long does it take for the body to cover the 2.5 meters?

c. If another body, accelerated by the same force for the same distance, achieves a final speed of 120 m/sec, what is the mass of the 2nd body?

15. In the experiment in the text discussed in Figure 12-18, page 255, the distance between the plates is changed from 9.3 mm to 18.6 mm. The 90-volt battery is still connected. What is the final speed achieved by the following in crossing between the plates?

a. a proton?
b. an electron?
c. a singly-charged oxygen ion (mass = 16 amu)?
d. a doubly-charged oxygen ion?

16. Problems: page 258: #15 #16
page 259: #18 #19

17. Complete Written Exercise. Have evaluated.

ANSWERS CHAPTER 12

3. (1) 6.0×10^{17} electrons per second, (b) same
   (2) S.A.B.

5. (3) S.A.B.
   (4) The gases from the burning match contain ions.

6. (a) volt, joule, coulomb
   (b) 1.6×10^{-19} (c) one (d) Vq, joules, coulombs, volts

7. (5) 14 eV
   (6) (a) 1.2×10^{3} eV (b) 1.9×10^{-16} joules

9. (a) electromotive force, ($\mathcal{E}$), volts, joules, coulomb
   (b) electric field, Eq (c) the plate separation
   (d) potential difference, charge (e) kinetic (f) $\sqrt{2Vq/m}$, $\sqrt{2Fd/m}$

10. (7) 4.3×10^{-14} Newtons
    (8) 45 eV or 7.2×10^{-18} Joules
    (9) S.A.B.
    (20) (a) 1.6×10^{-17} joule (b) 1.6×10^{-15} N/elem chg,
    6.4×10^{-15} N/elem chg (c) S.A.B.

11. (a) the potential difference between the plate (V) which caused the unbalanced charge on the plates
    (b) $Vq = 1/2\ mv^2$: $v = \sqrt{2Vq/m}$ (c) $t = l/v$ (d) $v_s = q\vec{E}t/m$
    (e) $d = v_{avg} = (1/2\ v_s t)$

12. (10) (a) 2.0 volts (b) 3.0×10^{7} m/s (c) 2.0×10^{-9} sec
    (d) 3.5×10^{5} m/sec (e) 3.5×10^{-4} m

13. (a) 5.6×10^{6} m/s (b) 2.8×10^{8} m/sec

14. (a) 1.8 m/sec (b) 2.8 sec (c) 6.9×10^{-4} kg

15. (a) 1.31×10^{5} m/s (b) 5.6×10^{6} m/s (c) 3.3×10^{4} m/s
    (d) 4.7×10^{4} m/s

16. (15) 1.5×10^{6} m/s
    (16) 1.54×10^{-7} sec
    (18) (a) 5.8×10^{-17} joules (b) 2.9×10^{-17} joules
    (19) 1.7×10^{16} ions

Questions from "The Flying Circus of Physical Phenomena" by Jearl Walker

1. How is it that an electric eel can shock you? A healthy eel can produce something like 1 amp at 6000 volts. What could possibly cause this? Does the eel continually discharge in the sea water?

2. Exactly what kills you when someone gets electrocuted? What SIZE of electricity does it take to be lethal?

3. When you turn on a light switch, how long does it take for the light to come on?

Chapter 12 WRITTEN EXERCISE

1. A positive test charge of 2×10^{-8} coulomb is placed at a certain point P. The electrostatic force on it is found by measurement to be 4×10^{-3} newton in an eastward direction. Find the electric field at P.

____

2. It is found by actual trial that 6.0×10^{-5} joules of work must be done on a positive test charge of 3.0×10^{-6} coulomb to push it from point Y to point X. Find the potential difference between Y and X.

____

3. How much work must be done on a charge of 0.60 coulomb to move it from point B to point A if the potential difference between the two points is 110 volts?

____

4. Suppose that two parallel plates are spaced 0.02 m apart and are connected to a 90-volt battery. Compute the electric field for any point in the central part of the air gap.

____

5. Two parallel metal plates are mounted horizontally in a vacuum at a distance of 0.02 m apart. They are connected to a source that maintains between them a potential difference of 12 kilovolts. The upper plate is positive and the lower plate is negative. A negatively charged droplet of oil, which is known from other measurements to have a mass of 1×10^{-9} kg, is in the space between the plates. Evidently the droplet tends to rise because of the electrostatic force on it, and to fall because of its weight.
   a. Compute the weight of the droplet.
   b. If the drop is observed to remain motionless, neither rising nor falling, what must be the magnitude of the upward electrostatic force on the droplet?
   c. Compute the charge on the droplet.

   a. _______________

   b. _______________

   c. _______________

$$E_K = E_T - E_{AT\ REST}$$

$$E_K = mc^2 - m_0 c^2$$

$$E_K = (m - m_0)\, c^2 \qquad m = \frac{m_0}{\sqrt{1 - v^2/c^2}} = \frac{m_0 c}{(c^2 - v^2)}$$

$$E_K = \left[\left(\frac{m_0 c}{\sqrt{c^2 - v^2}}\right) - m_0\right] c^2$$

$$\frac{E_K}{c^2} + m_0 = \frac{m_0 c}{\sqrt{c^2 - v^2}}$$

$$E_K + m_0 c^2 = \frac{m_0 c^3}{\sqrt{c^2 - v^2}}$$

7.29×10^{50}

$$E_K^2 + 2E_K m_0 c^2 + m_0^2 c^4 = \frac{m_0^2 c^6}{c^2 - v^2}$$

$$(c^2 - v^2)(E_K^2 + 2E_K m_0 c^2 + m_0^2 c^4) = m_0^2 c^6$$

$$c^2 - v^2 = \frac{m_0^2 c^6}{E_K^2 + 2E_K m_0 c^2 + m_0^2 c^4}$$

↓↓ ↑↑↑↑↑ ↓↓

$$v^2 = c^2 - m_0^2 c^6 / E_K^2 + 2E_K m_0 c^2 + m_0^2 c^4$$

$$v^2 = \left(3.0 \times 10^8 \tfrac{M}{sec}\right)^2 - \frac{(9.1 \times 10^{-31} Kg)^2 \left(3 \times 10^8 \tfrac{M}{sec}\right)^6}{(1.44 \times 10^{-13} Joule)^2 + 2(1.44 \times 10^{-13} Joule)(9.1 \times 10^{-31} Kg)(3 \times 10^8 M/sec)^2 + (9.1 \times 10^{-31} Kg)^2 (3 \times 10^8 M/s)^4}$$

$$9.0 \times 10^{16} - \frac{6.04 \times 10^{-10}}{2.07 \times 10^{-26} + 2.36 \times 10^{-26} + .67 \times 10^{-26}}$$

$$9.0 \times 10^{16} - \frac{6.04 \times 10^{-10}}{5.10 \times 10^{-26}} \qquad \frac{\frac{Kg^2\, M^6}{sec^6}\left(\frac{M^2}{sec^2}\right)}{\frac{Kg^2\, M^4}{sec^4} + \frac{Kg^2 M^2}{sec^4} + \frac{Kg^2\, M^4}{sec^4}}$$

$$9.0 \times 10^{16} - 1.18 \times 10^{16}$$

$$v^2 = 7.82 \times 10^{16}$$

$$v = 2.80 \times 10^8 \ M/s$$

CHAPTER 20

$$E_K = \frac{1}{2} m v^2 \quad : \quad m = \frac{m_0}{\sqrt{1 - v^2/c^2}} = \frac{m_0 c}{\sqrt{c^2 - v^2}}$$

$$\frac{2E_K}{v^2} = \frac{m_0 c}{\sqrt{c^2 - v^2}}$$

$$\frac{4E_K^2}{v^4} = \frac{m_0^2 c^2}{c^2 - v^2} \quad : \quad 4E_K^2 c^2 - 4E_K^2 v^2 = m_0^2 c^2 v^4$$

$$\left|m_0^2 c^2\right| v^4 + \left|4E_K^2\right| v^2 - \left|4E_K^2 c^2\right| = 0 \qquad X = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$v^2 = \frac{-4E_K^2 \pm \sqrt{[4E_K^2]^2 + 4 \cdot m_0^2 c^2 \cdot 4 \cdot E_K^2 c^2}}{2 m_0^2 c^2}$$

$E_K = 1.44 \times 10^{-13}$ J
$m_0 = 9.1 \times 10^{-31}$ Kg
$c = 3.0 \times 10^8$ M/s

$$v^2 = \frac{-4E_K^2 \pm \sqrt{16 E_K^4 + 16 m_0^2 c^4 E_K^2}}{2 m_0^2 c^2}$$

$$v^2 = \frac{-4\left[1.44\times10^{-13} J\right]^2 \pm 4\left[1.44\times10^{-13} J\right]\sqrt{\left[1.44\times10^{-13} J\right]^2 + \left[9.1\times10^{-31} Kg\right]^2\left[3\times10^8 \frac{M}{S}\right]^4}}{2\left[3\times10^8 M/s\right]^2\left[9.1\times10^{-31} Kg\right]^2}$$

$$v^2 = \frac{[\text{Joule}]^2 \pm \text{Joule}\sqrt{[\text{Joule}]^2 + [Kg]^2 \frac{M^4}{sec^4}}}{\frac{M^2}{sec^2}\ Kg^2} = \frac{J^2 \pm J\sqrt{J^2 + J^2}}{J \cdot Kg}$$

$$Kg\frac{M^2}{S^2} \pm Kg\frac{M^2}{sec^2} \Big/ Kg = \frac{M^2}{S^2}$$

$$v^2 = \frac{-8.29\times10^{-26} \pm 5.76\times10^{-13}\sqrt{2.07\times10^{-26} + 8.26\times10^{-61} \cdot 8.1\times10^{33}}}{1.49\times10^{-43}}$$

$$v^2 = \frac{-8.29\times10^{-26} \pm 9.53\times10^{-26}}{1.49\times10^{-43}}$$

1.66×10^{-13}

$$v^2 = \frac{1.24\times10^{-26}}{1.49\times10^{-43}}$$

$$v^2 = 8.32\times10^{16}$$

$$v = 2.88\times10^8 \text{ M/s}$$

USING EINSTEIN'S MASS CORRECTION FORMULA WHEN LARGE POTENTIAL GRADIENT IS USED.

$$E_K = Vq = 1.4418 \times 10^{-13}\ J$$
$$m_o = 9.109 \times 10^{-31}\ Kg$$
$$c = 2.9979 \times 10^{8}\ \frac{M}{sec}$$

$$E_K = \frac{1}{2} m v^2 \qquad m = \frac{m_o}{\sqrt{1 - v^2/c^2}} = \frac{m_o c}{\sqrt{c^2 - v^2}}$$

$$\frac{2E_K}{v^2} = \frac{m_o c}{\sqrt{c^2 - v^2}}$$

$$\frac{4E_K^2}{v^4} = \frac{m_o^2 c^2}{c^2 - v^2} \Rightarrow 4E_K^2 c^2 - 4E_K^2 v^2 = m_o^2 c^2 v^4$$

$$m_o^2 c^2 v^4 + 4E_K^2 v^2 - 4E_K^2 c^2 = 0 \qquad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$v^2 = \frac{-4E_K^2 \pm \sqrt{(4E_K^2)^2 - 4 \cdot m_o^2 c^2 \cdot (-4E_K^2 c^2)}}{2 m_o^2 c^2}$$

$$v^2 = \frac{-4E_K^2 \pm \sqrt{16E_K^4 + 16E_K^2 m_o^2 c^4}}{2 m_o^2 c^2}$$

$$v^2 = \frac{-4E_K^2 \pm 4E_K \sqrt{E_K^2 + m_o^2 c^4}}{2 m_o^2 c^2}$$

$$v^2 = \frac{-4(1.4418 \times 10^{-13} J)^2 \pm 4(1.4418 \times 10^{-13} J)\sqrt{(1.4418 \times 10^{-13} J)^2 + (9.109 \times 10^{-31} Kg)^2 (2.9979 \times 10^{8} \frac{M}{S})^4}}{2(9.109 \times 10^{-31} Kg)^2 (2.9979 \times 10^{8} \frac{M}{sec})^2}$$

$$\frac{J^2 \pm J\sqrt{J^2 + \frac{Kg^2 M^4}{sec^4}}}{Kg^2 \frac{M^2}{sec^2}} = \frac{J^2 \pm J\sqrt{J^2 + J^2}}{J \cdot Kg} = \frac{J^2 + J^2}{J \cdot Kg} = \frac{J}{Kg} = \frac{Kg}{Kg}\frac{M^2}{S^2}$$

$$v^2 = \frac{-8.3151 \times 10^{-26} \pm 5.7672 \times 10^{-13}\sqrt{2.0788 \times 10^{-26} + (8.2974 \times 10^{-61})(8.0733 \times 10^{33})}}{1.4914 \times 10^{-43}}$$

$$v^2 = \frac{-8.3151 \times 10^{-26} \pm 9.5621 \times 10^{-26}}{1.4914 \times 10^{-43}}$$

$$v^2 = \frac{1.2469 \times 10^{-26}}{1.4914 \times 10^{-43}}$$

$$v^2 = 8.3605 \times 10^{16}$$

$$v = 2.8915 \times 10^{8}\ \frac{M}{sec}$$

$$E_K = 1.4418 \times 10^{-13}\,J$$
$$m_0 = 9.109 \times 10^{-31}\,Kg$$
$$c = 2.9979 \times 10^{8}\,\frac{M}{sec}$$

$$E_K = E_{TOTAL} - E_{AT\ REST}$$
$$E_K = mc^2 - m_0c^2 \qquad m = \frac{m_0}{\sqrt{1 - v^2/c^2}} = \frac{m_0 c}{\sqrt{c^2 - v^2}}$$
$$E_K = (m - m_0)\,c^2$$
$$\frac{E_K}{c^2} + m_0 = m$$
$$\frac{E_K}{c^2} + m_0 = \frac{m_0 c}{\sqrt{c^2 - v^2}}$$
$$E_K + m_0c^2 = \frac{m_0 c^3}{\sqrt{c^2 - v^2}}$$
$$E_K^2 + 2E_K m_0 c^2 + m_0^2 c^4 = \frac{m_0^2 c^6}{c^2 - v^2}$$
$$(c^2 - v^2) = \frac{m_0^2 c^6}{E_K^2 + 2E_K m_0 c^2 + m_0^2 c^4}$$
$$v^2 = c^2 - \frac{m_0^2 c^6}{E_K^2 + 2E_K m_0 c^2 + m_0^2 c^4}$$

$$v^2 = \left(2.9979\times10^{8}\,\tfrac{M}{sec}\right)^2 - \frac{(9.109\times10^{-31}\,Kg)^2\left(2.9979\times10^{8}\,\tfrac{M}{sec}\right)^6}{(1.4418\times10^{-13}\,J)^2 + 2(1.4418\times10^{-13}\,J)(9.109\times10^{-31}\,Kg)\left(2.9979\times10^{8}\,\tfrac{M}{sec}\right)^2 + (9.109\times10^{-31}\,Kg)^2\left(2.9979\times10^{8}\,\tfrac{M}{sec}\right)^4}$$

$J = NT \cdot M$
$\frac{Kg\,M^2}{sec^2}$

$$\frac{M^2}{sec^2} - \frac{Kg^2\ M^6/sec^6}{J^2 + J\cdot\frac{Kg\,M^2}{sec^2} + \frac{Kg^2M^4}{sec^4}} \quad ; \quad \frac{M^2}{sec^2} - \frac{J^2\ \frac{M^2}{sec^2}}{J^2}$$

$$v^2 = (2.9979\times10^{8})^2 - \frac{(9.109\times10^{-31})^2(2.9979\times10^{8})^6}{(1.4418\times10^{-13})^2 + 2(1.4418\times10^{-13})(9.109\times10^{-31})(2.9979\times10^{8})^2 + (9.109\times10^{-31})^2(2.9979\times10^{8})^4}$$

$$v^2 = 8.9874\times10^{16} - \frac{6.0234\times10^{-10}}{2.0788\times10^{-26} + 2.3607\times10^{-26} + 6.7021\times10^{-27}}$$

$$v^2 = 8.9874\times10^{16} - \frac{6.0234\times10^{-10}}{5.1097\times10^{-26}}$$

$$v^2 = 8.9874\times10^{16} - 1.1788\times10^{16}$$

$$v^2 = 7.8086\times10^{16}$$

$$v = \underline{2.7944\times10^{8}\ M/sec}$$

Chapter 12 ~~TEST~~ Written Exercise - Corrected

1. A positive test charge of 2 x E-8 coulomb is placed at a certain point P. The electrostatic force on it is found by measurement to be 4 x E-3 newton in an eastward direction. Find the electric field at P.

$2 \times 10^{+5}$ N/C EASTWARD

3.2×10^{-14} N/e

$q = 2 \times 10^{8}$ coul
$F = 4 \times 10^{-3}$ N
$\vec{E} = ?$

$\vec{E} = \frac{\vec{F}}{q} = \frac{4 \times 10^{-3} NT}{2 \times 10^{-8} coul}$

2. It is found by actual trial that 6.0 x E-5 joules of work must be done on a positive test charge of 3.0 x E-6 coulomb to push it from point Y to point X. Find the potential difference between Y and X.

20 VOLTS

$V = \frac{E}{q} = \frac{6.0 \times 10^{-5} J}{3.0 \times 10^{-6} coul}$

$W = 6.0 \times 10^{-5}$ J
$q = 3.0 \times 10^{-6}$ coul
$V =$

3. How much work must be done on a charge of 0.60 coulomb to move it from point B to point A if the potential difference between the two points is 110 volts?

66 JOULES

$W = Vq$
$= 110 \frac{Joul}{C} \times 0.60 C$

$W = ?$
$q = 0.60$ C
$V = 110$ volts

4. Suppose that two parallel plates are spaced 0.02 m apart and are connected to a 90-volt battery. Compute the electric field for any point in the central part of the air gap.

4.5×10^{3} N/Coul (TOWARD - PLATE)

or

7.2×10^{-16} N/e

$E = \frac{V}{d} = \frac{90 \text{ Joule}}{C \; 0.02 M}$

$V = 90$ volts
$d = 0.02$ M
$\vec{E} = ?$

$\vec{E} = \frac{\vec{F}}{q} \quad q = \frac{F}{E}$

5. Two parallel metal plates are mounted horizontally in a vacuum at a distance of 0.02 m apart. They are connected to a source that maintains between them a potential difference of 12 kilovolts. The upper plate is positive and the lower plate is negative. A negatively charged droplet of oil, which is known from other measurements to have a mass of 1 x E-9 kg, is in the space between the plates. Evidently the droplet tends to rise because of the electrostatic force on it, and to fall because of its weight.

a. Compute the weight of the droplet.
b. If the drop is observed to remain motionless, neither rising nor falling, what must be the magnitude of the upward electrostatic force on the droplet?
c. Compute the charge on the droplet.

a. 9.8×10^{-9} N

b. 9.8×10^{-9} N

c. 1.6×10^{-14} C

or

1.02×10^{-5} elem chgd

(a) $W = mg = 10^{-9} Kg \times 9.8 M/s^2$

(c) $V = \frac{E}{q} = q = \frac{E}{V} = \frac{F \cdot d}{V}$

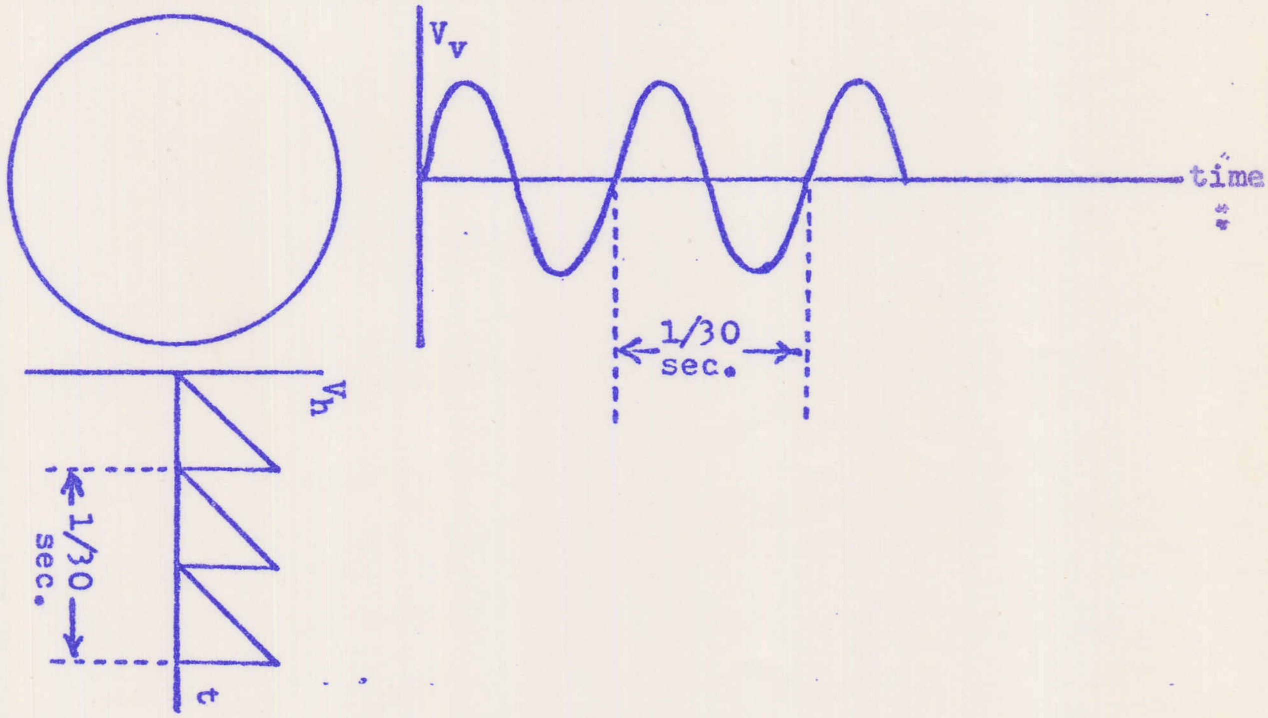
$= \frac{9.8 \times 10^{-9} N \cdot 0.02 M \text{ coul}}{1.2 \times 10^{4} J}$

$d = 0.02$ M
$V = 1.2 \times 10^{4}$ v
$m = 10^{-9}$ Kg

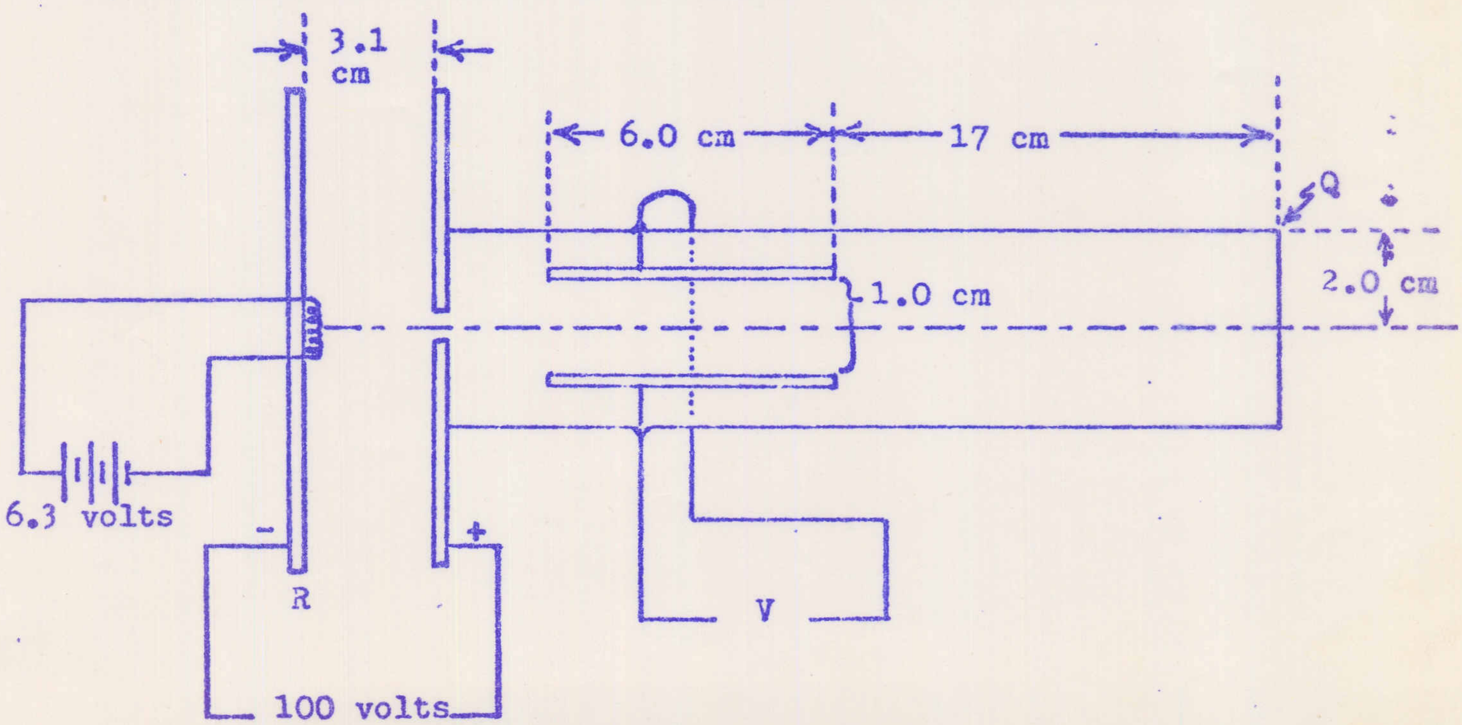
PSSC PHYSICS QUIZ #________
CHAPTER 20

NAME ____________________
DATE ____________________

(1) Signals A and B are sent respectively into the horizontal and vertical deflection plates of an oscilloscope. Draw the resulting pattern that would appear on the oscilloscope face. (1 pt.)



(2) Electrons are accelerated by the apparatus shown below:



A) What is the value of the electric field between the plates P and R? (1 pt.)

B) What is the Kinetic Energy of the electrons as they crash into plate P? (1 pt.)

C) What is the velocity of the electrons as they crash into plate P? (1 pt.)

D) What must be the voltage applied to the deflector plates so that the electrons will be deflected to the corner Q? (1 pt.)

E) By what factor do the answers to A, B, C, & D above change if the voltage of the accelerating battery is made three times larger? (1 pt.)

F) By what factor do the answers to A, B, C, & D above change if you double the distance RP between the plates? (1 pt.)

G) By what factor do the answer to A, B, C, & D above change if you double the charge on the electron? (as far as we know this is impossible but if) (1 pt.)

H) By what factor do the answers to A, B, C, & D above change if you increase the mass of the electron by a factor of four? (2 pts.)