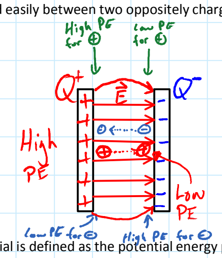
Potential: Electric

May 23, 2016 8:34 PM

An electric field can be created when two opposite charges are fixed in space. A uniform electric field can be created easily between two oppositely charged parallel plates which are large compared to their separation.



$\vec{E}$: Electric Field (N/C)

E_p : Potential Energy (J)

V : Electric Potential (V)

Electric Potential is defined as the potential energy per unit charge. Electric potential is given the symbol V and is a scalar quantity. Don't get this confused with the Potential Energy of the charge.

$$V_a = \frac{E_P}{Q} \qquad \text{Units: } \frac{J}{C} = \text{Volts (V)}$$

V_a : Electric Potential @ Point a (V)

E_p : Potential Energy (J)

Q : Charge (C)

A particle moving from one side of a set of plates to another side will experience a change in its potential energy. Using our work formula we get:

$$\Delta V = \frac{\Delta E_P}{Q} \quad \text{OR} \quad \Delta E_P = \boxed{Work = \Delta V \cdot Q}$$

ΔV: Change in Electric Potential

Since electrical potential is measured in Volts, we often refer to it as the voltage.

Example: An electron in the picture tube of an old TV set is accelerated from rest through a potential differenceΔV=5000 V.

a) What is the change in potential energy of the electron?

$$\Delta V = \frac{\Delta E_p}{Q}$$

$$5000 = \frac{\Delta E_p}{1.602\times10^{-19}\,C}$$

$$\Delta E_p = 8.01\times10^{-16}\,J$$

b) What is the speed of the electron as a result of this acceleration?

$m = 9.11\times10^{-31}\,kg$

$$\Delta E_p = -\Delta E_k$$

$$-8.01\times10^{-16} = -\Delta E_k$$

$$= -(E_{kf} - \cancel{E_{ki}})$$

from rest

$M_e = 9.11\times10^{-31}\,kg$

$$+8.01\times10^{-16} = +\tfrac{1}{2}mv_f^2$$

$$\sqrt{\frac{2(8.01\times10^{-16})}{m_e}} = v_f$$

$$4.19\times10^{7}\,m/s = v_f$$

Relationship between electric fields and electric potential.

$\vec{E}$: describes the Electric Field

$$\Delta E_P = W = Q\Delta V \text{ and } W = \vec{F}d \text{ and } \boxed{\vec{F} = Q\vec{E}}$$

$$\text{So } \Delta V = \frac{W}{Q} = \frac{\vec{F}d}{Q} = \frac{\cancel{Q}\vec{E}d}{\cancel{Q}} \text{ therefore}$$

$$\boxed{\Delta V = \vec{E}d} \text{ or } \boxed{\vec{E} = \frac{\Delta V}{d}}$$

$\vec{E}$: Electric Field Equation

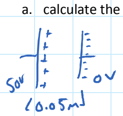
d: Seperation between two Points

*This is for a uniform electric field only.

i.e. Parallel Plates

Example: Two parallel plates are charged to a voltage of 50 V. If the separation between the plates is 0.050 m,

a. calculate the electric field between them.

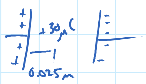


$$\vec{E} = \frac{\Delta V}{d} = \frac{50}{0.05} = 1000\ N/C \text{ right}$$

Two Charged plates

Two Charged plates

b. If I put a +30 μC charge in the middle, what force is acting on it?



$E = \frac{F}{Q} \Rightarrow F = EQ$

$= (1000)(30\times10^{-6})$

$= 30\times10^{-3}$ N

or

$= 0.03$ N

c. What is the velocity of the particle when it hits the ~~left~~ Right plate if it is made of helium nuclei?

$V_i = 0$ m/s

$V_f =$

$a = 4.76\times10^{10}$ m/s²

$d = 0.025$ m

$t =$

$F = ma$

$0.03 = 6.3\times10^{-13}\, a$

$a = 4.76\times10^{10}$ m/s²

$V_f^2 = V_i^2 + 2ad$

$V_f = 4.98\times10^{4}$ m/s

1 He

$M = 4\times 1.68\times10^{-27}$ kg $=$

$Q = 2\times 1.602\times10^{-19}$ C $= 3.204\times10^{-19}$

$\#\text{Helium nuclei} = \frac{30\times10^{-6}}{3.204\times10^{-19}} = 9.36\times10^{13}$

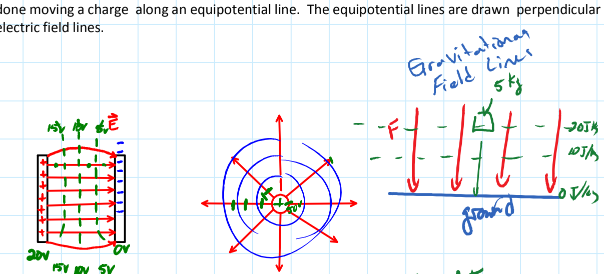
The mass of our 30 μC Charge is

$m = (9.36\times10^{13})\times(4\times1.68\times10^{-27})$

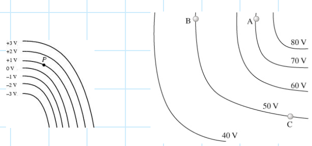
$m = 6.3\times10^{-13}$ kg

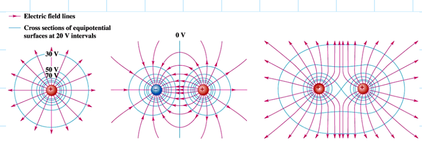
Equipotential Lines

The electric potential can be represented diagrammatically by drawing equipotential lines. No work is done moving a charge along an equipotential line. The equipotential lines are drawn perpendicular to electric field lines.



$\Delta V = \frac{\Delta E_p}{Q}$

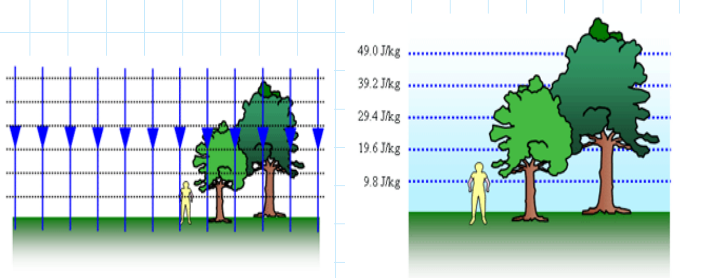




(a) A single positive charge (b) An electric dipole (c) Two equal positive charges

No work is required for a charge to move along an equipotential line.
Work is required for a charge to move to a different equipotential line.

please



The electron volt

The electron volt is a unit of energy. One electron volt is defined as the energy acquired by an electron as a result of moving through a potential difference of 1 V.

$\Delta E = |Q|\Delta V = 1.602\times10^{-19}\,\text{C}\times 1\,\text{V} = 1.602\times10^{-19}$ J

$1\,\text{eV} = 1.602\times10^{-19}$ J

$1eV = 1.602 \times 10^{-19}$ J

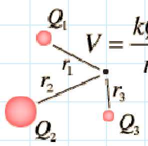
~~Pages 332 Q: all~~ Old Book
~~Pages 294 Q: all~~ New Book

$\boxed{\text{P. 522 Q: 1-23}}$

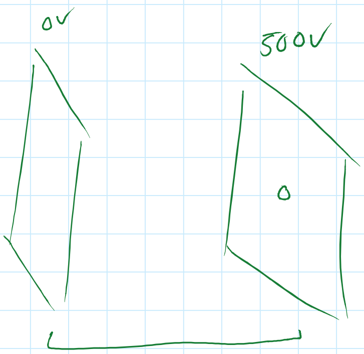
Electric potential due to single point charges.
The electric potential at a distance 'r' from a single point charge Q can be derived from the expression for its electric field using calculus. The potential in this case is usually taken to be zero at infinity (∞), where the electric field is also zero. The result is...

$$V = \frac{kQ}{r} \quad \text{unit: volt(V)}$$

Example: Calculate the electric potential at point P.



$$V = \frac{kQ_1}{r_1} + \frac{kQ_2}{r_2} + \frac{kQ_3}{r_3}$$



The electron enters the plates with a speed of 50m/s.

$v = 50$ m/s

$\leftarrow \circ e^-$

Does the electron hit the 0V plate?

$E = \frac{F}{Q}$ $\quad E = \frac{\Delta V}{d}$

The force is changing which makes it difficult to use these equations.

$m_e = 9.11 \times 10^{-31}$ kg, 10 m

$Q = -1.602 \times 10^{-19}$ C

$kE = \frac{1}{2}mv^2$

For the electron coming to rest

$\Delta kE = -\frac{1}{2}(m_e)(50)^2$

$= -\frac{1}{2}(9.11 \times 10^{-31})(50)^2$

$= -1.139 \times 10^{-27}$ J

$\Delta PE = -\Delta kE$

$\Delta PE = 1.139 \times 10^{-27}$ J

*Note $PE = E_p$

$\frac{\Delta E_p}{Q} = \Delta V$

$\Delta V = \frac{1.139 \times 10^{-27}}{-1.602 \times 10^{-19}}$

$\Delta V = 7.11 \times 10^{-9}$ V

We know the Voltage change will be linear (i.e. evenly spaced out)

$\frac{7.11 \times 10^{-9}\,V}{500\,V} = \frac{x}{10\,m}$

$(10)(7.11 \times 10^{-9})$

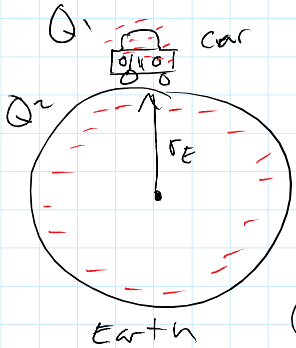
$$\frac{(10)(7.11\times10^{-9})}{500} = x$$

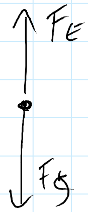
$$\underline{\underline{1.42\times10^{-10}\,m = x}}$$

No the electron does not reach the other plate

$\boxed{7/9 \quad pg\ 497}$

$m_c = 1050kg$

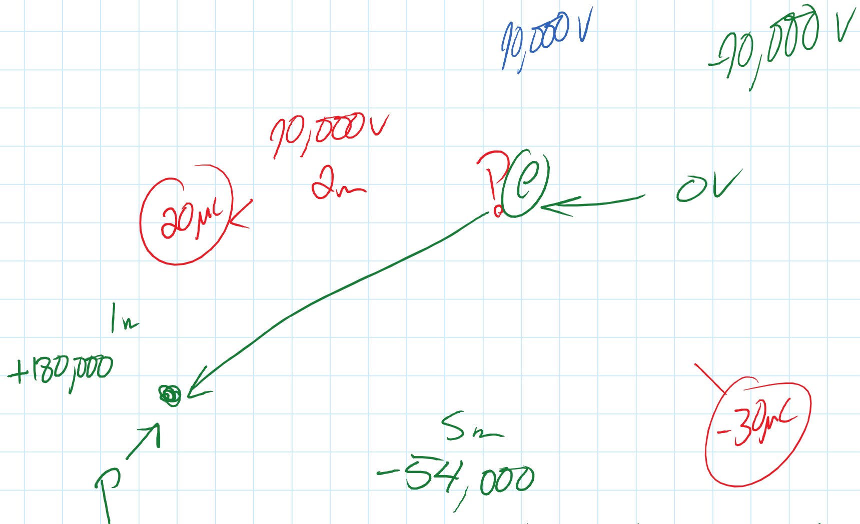




$Q_1 = Q_2$

$$F_{Net} = F_E - F_g$$
$$0 = F_E - F_g$$
$$F_g = F_E$$
$$m_c g = \frac{k\,Q_1 Q_2}{r_E^2}$$
$$m_c g = \frac{k\,Q^2}{r_E^2}$$
$$\sqrt{\frac{m_c g r_E^2}{k}} = Q$$
$$r_E\sqrt{\frac{m_c g}{k}} = Q$$
$$6.38\times10^{6}\,m\sqrt{\frac{(1050)(9.8)}{9\times10^{9}}} = Q$$
$$\boxed{-6.82\times10^{12}\,C = Q}$$

$$\#\ electrons = \frac{-6.82\times10^{12}}{-1.602\times10^{-19}} = \underline{\underline{4.26\times10^{31}\ electrons}}$$

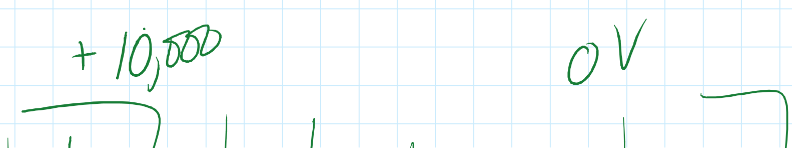


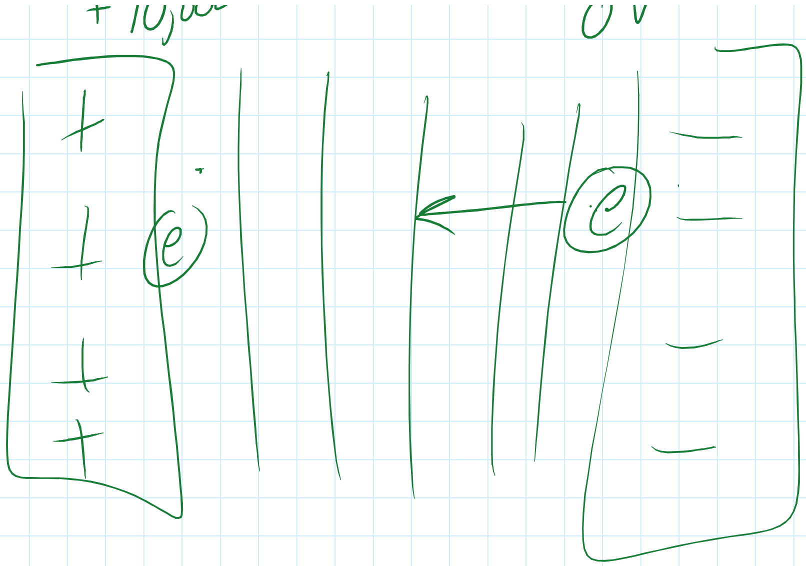
$\Delta V = \dfrac{\text{Work}}{Q}$

work $= 126{,}000\,\text{V} \cdot 1.602 \times 10^{-19}$

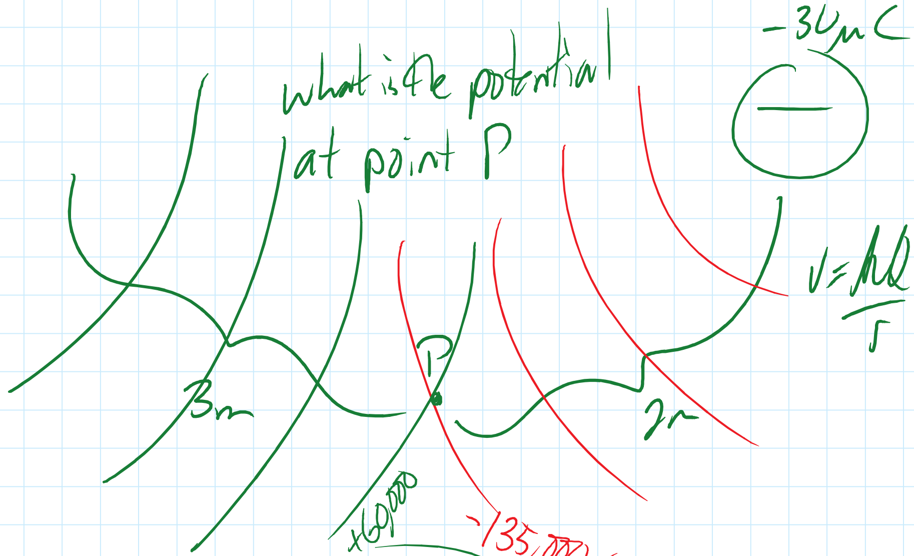
work $= \underline{2.02 \times 10^{-14}\,\text{J}}$

At point P, the electric potential is $\underline{+126{,}000\,\text{V}}$



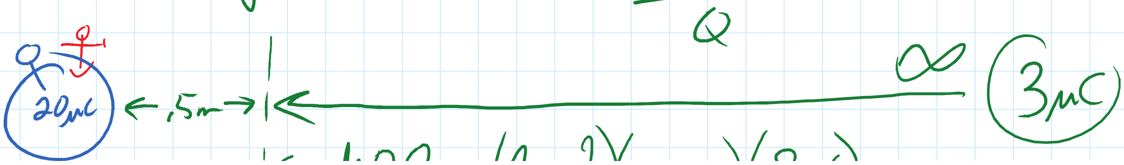


what is the potential at point P



$V = \frac{kQ}{r} = 135{,}000\,V$

$V = -75{,}000\,V$



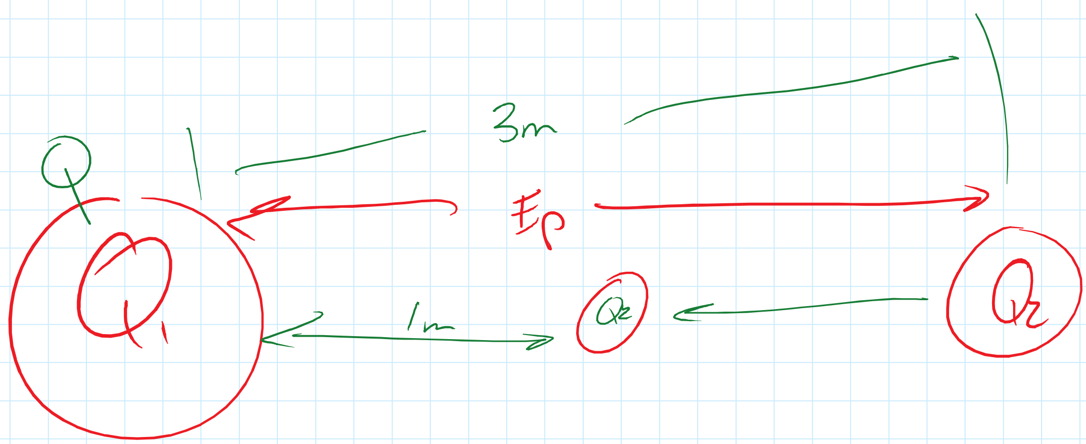
$$E_p = \frac{kQ_1Q_2}{r}$$

$E_p = \frac{kQ_1Q_2}{r} = \frac{(9\times10^9)(20\mu C)(3\mu C)}{.5m}$ $\quad E_p = 0$

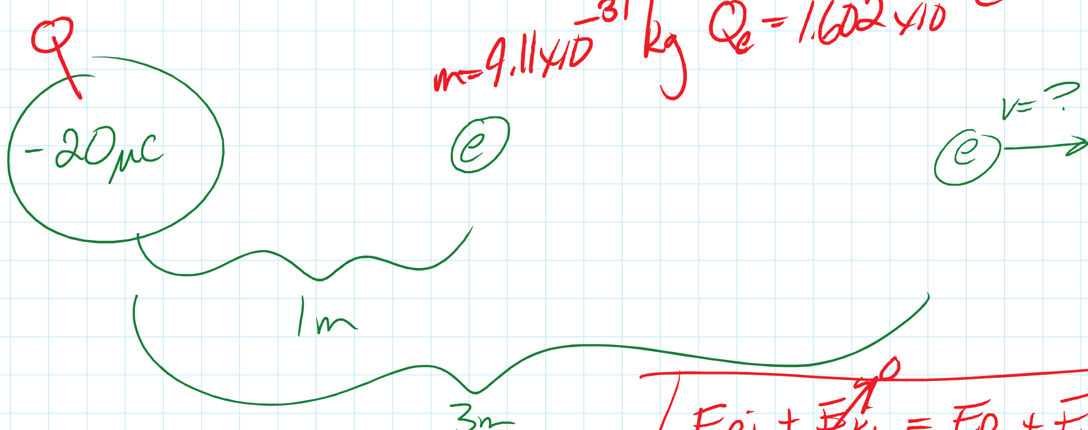
$E_p = 1.08\times10^{-5}\,J$

$\Delta E_p = 1.08\times10^{-5}\,J - 0\,J = \_\_\_\_$

$\Delta U = \frac{\Delta E_p}{Q}$



$m = 9.11\times10^{-31}\,kg \quad Q_e = 1.602\times10^{-19}\,C$



$$\boxed{E_{p_i} + \cancel{E_{k_i}}^{\,0} = E_{p_f} + E_{k_f}}$$

$$\frac{kQ_1Q_2}{r_i} = \frac{kQ_1Q_2}{r_f} + \frac{1}{2}mv^2$$

$$\sqrt{2\left(kQ_1Q_2\left(\frac{1}{r_i} - \frac{1}{r_f}\right)\right) \ldots} = v = 205{,}436{,}538.2\,m/s$$

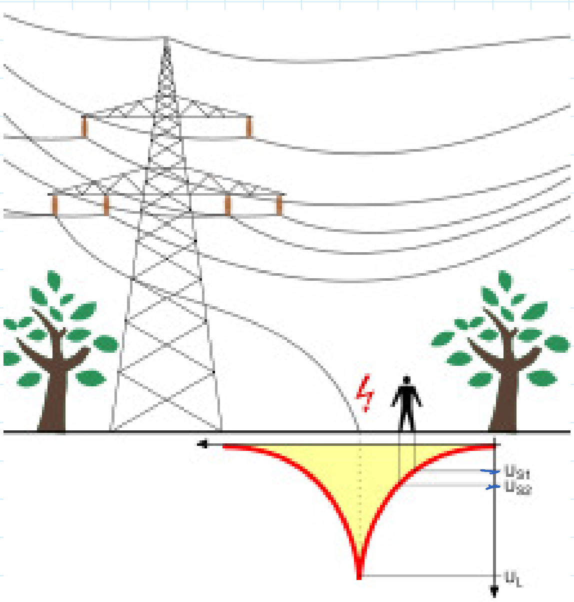
$$\sqrt{\frac{2\left(kQ_1Q_2\left(\frac{1}{r_i}-\frac{1}{r_f}\right)\right)}{m}} = v = 205{,}436{,}530.2\ m/s$$

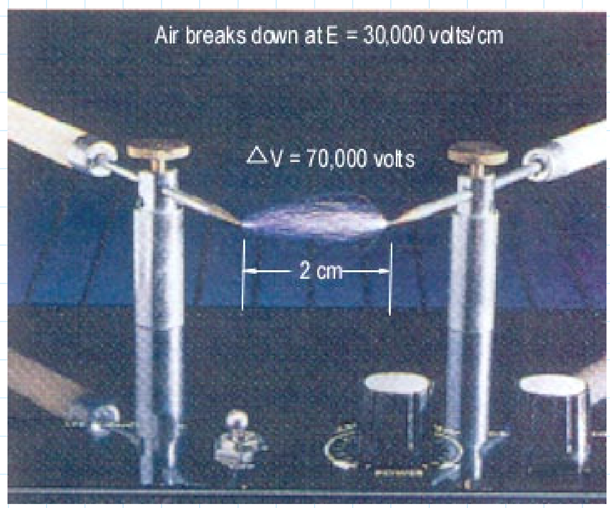
e) How close does a 10g particle (+100μC) moving at 600m/s come to a stationary +300μC particle, from ∞

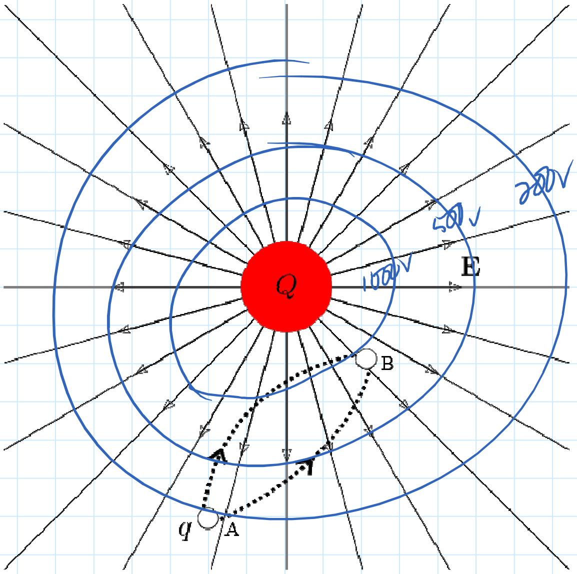
$$\cancel{E_{p_i}}^{0} + E_{k_i} = E_{p_f} + \cancel{E_{k_f}}^{0}$$

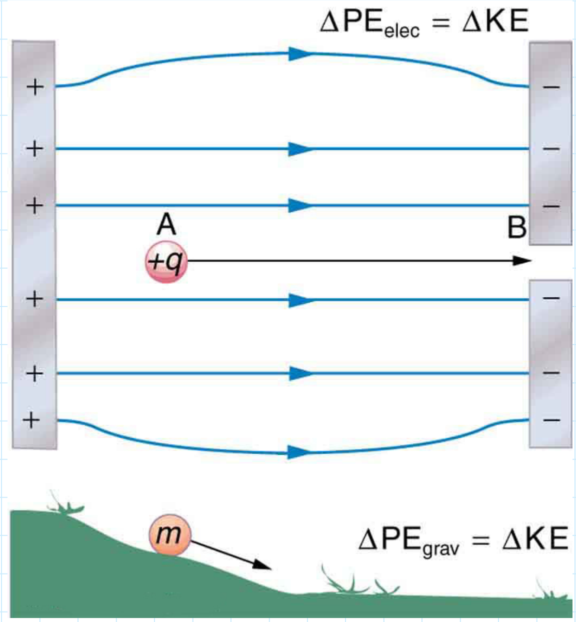
$$\cancel{\frac{kQ_1Q_2}{\infty}}^{0} + \frac{1}{2}mv^2 = \frac{kQQ_1}{r} \qquad \frac{1}{r} = \frac{mv^2}{2kQQ_1} \qquad r = \frac{2kQQ_1}{mv^2}$$

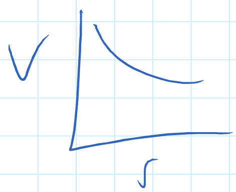
$$r = \frac{2kQ_1Q_2}{mv^2} = \underline{0.15\ m}$$



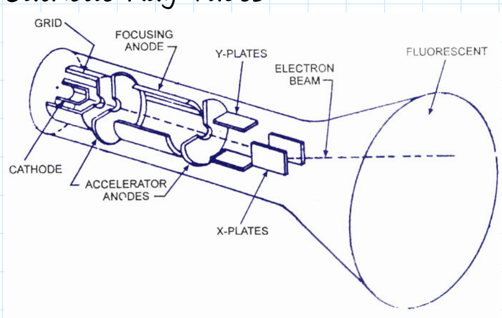




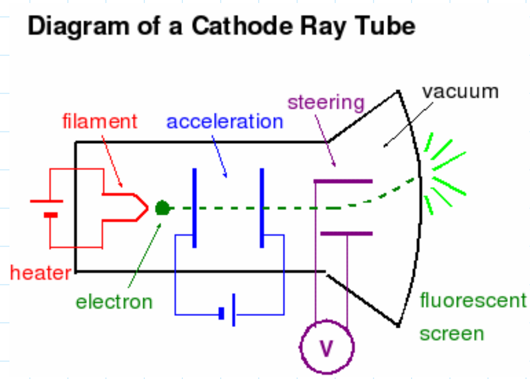


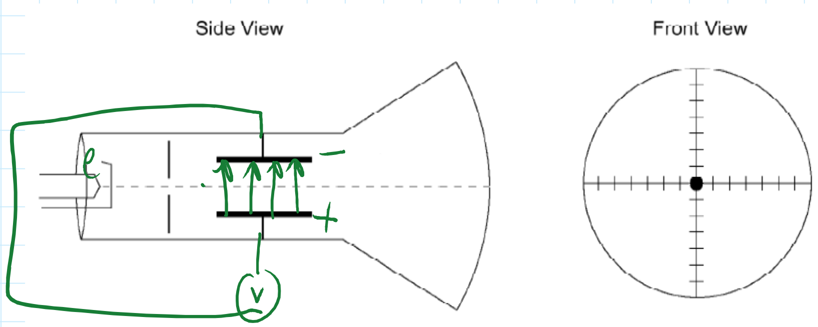


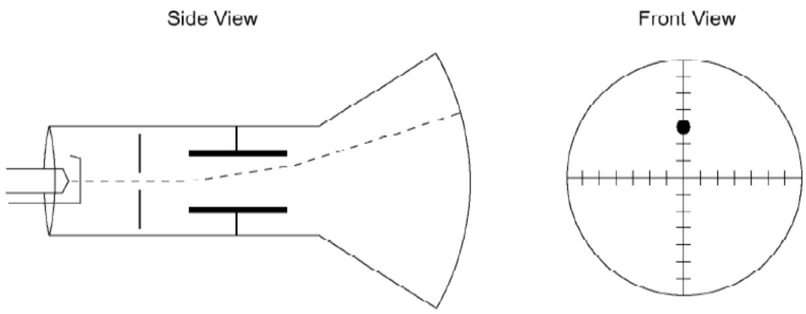
Cathode Ray Tubes



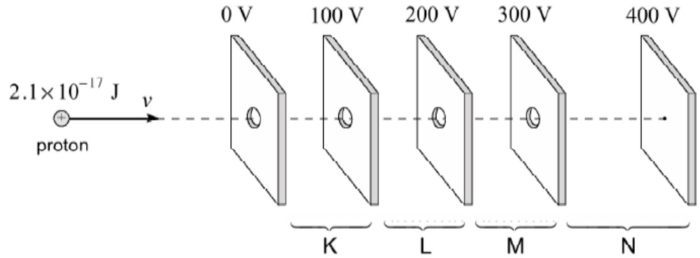
Cathode Ray Tube







A proton with kinetic energy of 2.1×10^{-17} J is moving into a region of charged parallel plates. The proton will be stopped momentarily in what region?



A. Region K
B. Region L
C. Region M
D. Region N

http://vnatsci.ltu.edu/s_schneider/physlets/main/equipotentials.shtml