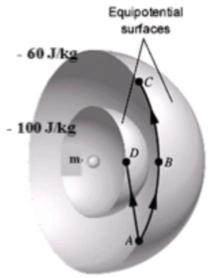
Equipotential Surfaces

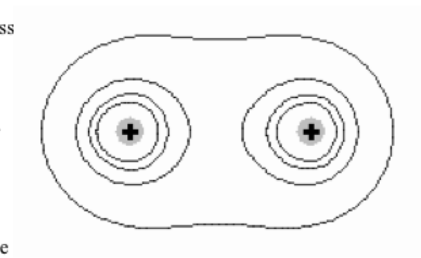
Equipotential surface: a surface on which the potential is the same everywhere

Gravitational Equipotentials



one point mass

1. The gravitational force does no work as a mass moves on along equipotential surface.
2. The work done in moving a mass between equipotential surfaces is **path independent**.
3. The work done in moving a mass along a closed path is zero.
4. The field lines are always perpendicular to the equipotential surfaces and point in the direction of decreasing potential.

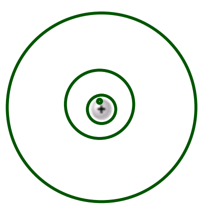


two point masses

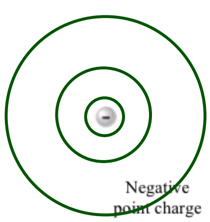
Gravitational potential gradient: The gravitational field is the negative gradient of the gravitational potential with respect to distance.

Formula: $$g = -\frac{\Delta V}{\Delta r}$$

Electric Equipotentials

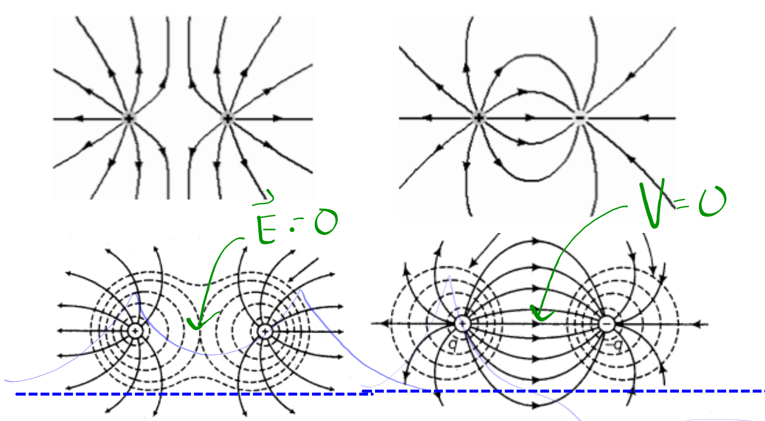


Positive point charge



Negative point charge

For each electric field shown, sketch in equipotential surfaces.



Like equal charges

Opposite equal charges

Electric potential gradient: The electric field is the negative gradient of the electric potential with respect to distance.

Formula: $\vec{E} = -\frac{\Delta V}{d}$

Relationship between equipotential surfaces and electric field lines: The field lines are always perpendicular to the equipotential surfaces and point in the direction of decreasing potential.

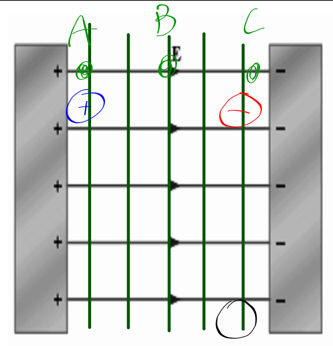
http://wps.aw.com/aw_young_physics_11/0,8076,898593-,00.html

http://www.surendranath.org/Applets.html

Electric Potential Difference (ΔV) – work done per unit charge moving a small positive test charge between two points in an electric field

Formula: $\Delta V = \Delta E_p / q$ $\quad \Delta E_p = q \Delta V$

Units: $[J/C]$



High and Low Potential

1. a) Which plate is at a higher electric potential? +

   b) Which plate is at a lower electric potential? −

   c) What is the electric potential of each plate? arbitrary

   d) What is the potential difference between the plates? not arbitrary

   e) Where will: a proton have the most electric potential energy? A

   an electron? C a neutron? an alpha particle? A

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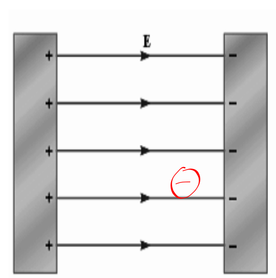
2. An electron is released from rest near the negative plate and allowed to accelerate until it hits the positive plate. The distance between the plates is 2.00 cm and the potential difference between them is 100. volts.



a) Calculate how fast the electron strikes the positive plate.

$q V = \frac{1}{2} m v^2$

$v = \sqrt{\frac{2 q V}{m}}$

$= \sqrt{\frac{2 \cdot 1.6 \times 10^{-19} C \cdot 100 J/C}{9.11 \times 10^{-31} kg}}$

$= 5.9 \times 10^{6} m/s$

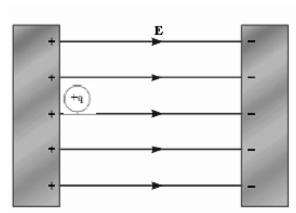
b) Calculate the strength of the electric field.

$\vec{E} = \frac{V}{d} = \frac{100 V}{.02 m} = 5000 V/m$

Formula: $E_p = qV = \frac{1}{2} m v^2$

Formula: $\vec{E} = \frac{V}{d}$

3. A proton is released from rest near the positive plate. The distance between the plates is 3.0 mm and the strength of the electric field is 4.0×10^3 N/C.



a) Describe the motion of the proton.

const. accl

b) Write an expression for the acceleration of the proton.

$a \xrightarrow{m} F \xrightarrow{q} \vec{E}$

$$\vec{a} = \frac{\vec{F}}{m} = \frac{q\vec{E}}{m} = \frac{1.6\times10^{-19}\,c \; 4000\,N/c}{1.67\times10^{-27}\,kg} = 3.8\times10^{11}\,m/s^2$$

d) Find the time it takes the proton to reach the negative plate.

$u = 0 \quad s = 3\times10^{-3}\,m$

$s = ut + \frac{1}{2}at^2$

$t = \sqrt{2s/a} = \sqrt{\frac{2 \cdot 3\times10^{-3}\,m}{3.8\times10^{11}\,m/s^2}} = 1.3\times10^{-7}\,s$

e) Find the speed of the proton when it reaches the negative plate.

$v = u + at$

$\vec{E} = V/d$

$v^2 = u^2 + 2as$

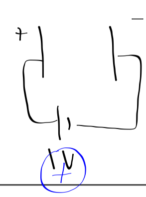
$v = \sqrt{2as} = \sqrt{2\frac{qE}{m}s}$

$v = \sqrt{\frac{2qV}{m}}$

Electronvolt:

energy gained by an electron moving through a potential difference of one volt

Derivation:



$1\,e.V. = 1.6\times10^{-19}\,J$

$(1\,e.c. = 1.6\times10^{-19}\,c)$

4. How much energy is gained by a proton moving through a potential difference of 150. V?

qV

$(1\,e.c.)(150\,V) = 150\,eV \left(\frac{1.6\times10^{-19}\,J}{eV}\right)$

5. A charged particle has 5.4×10^{-16} J of energy. How many electronvolts of energy is this?

$5.4\times10^{-16}\,J \left(\frac{1\,eV}{1.6\times10^{-19}\,J}\right)$

6. An electron gains 200 eV accelerating from rest in a uniform electric field of 150 N/C. Calculate the final speed of the electron.

$V = 200\,V$

$\vec{E} = V/d$

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

$v = \sqrt{2qV/m}$

7. A particle is shot with an initial speed through the two parallel plates as shown.

a) Sketch and describe the path it will take if it is a proton, an electron, or a neutron.

b) Which particle will experience a greater force?

Same q → same F

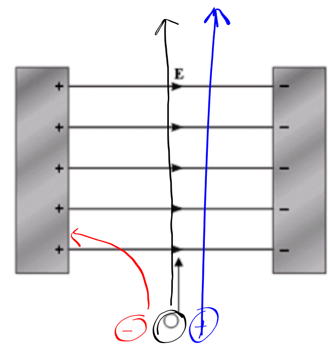
c) Which particle will experience a greater acceleration?

$a_{e^-} \sim 1000\, a_{p^+}$

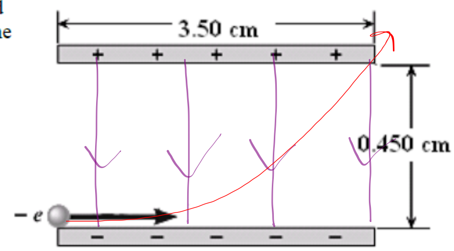
d) Which particle will experience a greater displacement?

(perpendicular)

e^-



8. In the figure, an electron enters the lower left side of a parallel plate capacitor and exits at the upper right side. The initial speed of the electron is 5.50×10^6 m/s. The plates are 3.50 cm long and are separated by 0.450 cm. Assume that the electric field between the plates is uniform everywhere and find its magnitude.



$\vec{a} \xrightarrow{m} \vec{F} \xrightarrow{q} \vec{E}$

	X	Y
s	.035 m	.0045 m
u	5.5×10^6 m/s	0
v	5.5×10^6 m/s	
a	0	
t		

① $t = ?$ 6.36×10^{-9} s

② $\vec{a}_y = ?$ 2.22×10^{14} m/s²

③ $\vec{E} = ?$ 1300 N/C