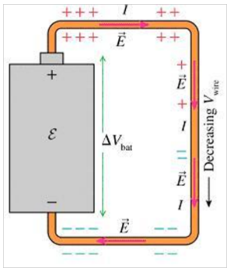
3.B.1 - Electric Potential Energy



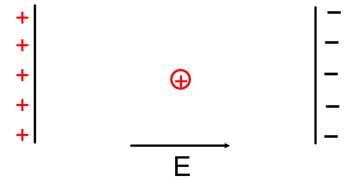
Electric Potential Energy

(Electric Potential)

Imagine a positive charge between two oppositely charged parallel plates.

The charge is forced towards the negative plate by the electric field, gaining speed as it goes.

Finally, the charge collides with the negative plate, unable to move further.



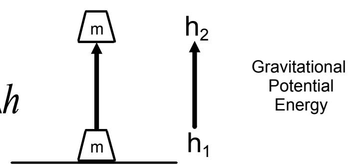
Gravity Analogy

The charge in the field is analogous to a mass held above the earth.

Both charge and mass have potential energy: when released, they move to an area of lower potential energy, gaining kinetic energy as they go.

Remember:

$$\Delta U_g = mg\Delta h$$



Analogy: FAIL

The analogy fails in one fundamentally huge way: electric fields act on <u>both</u> positive and negative charges, moving them one way or another depending on charge.

However, ALL massive objects attract each other, so positive and negative designations are meaningless.

A <u>reference frame</u> for electric fields must be built to accommodate positive and negative charges, so calculations always work out.

Reference Frame Conventions

A positive charge (of any sort) has higher electric potential than a negative one (due to using a positive test charge for comparisons).

Positive charges accelerate toward negative ones.

Negative charges accelerate toward positive plates.

Electric potential increases when moving nearer to positive charges (OR farther from negative charges).

Electric potential decreases when moving farther from positive charges (OR closer to negative charges).

Electric Potential Difference

Comparing electric potential between two points in space gives the electric potential difference, called voltage, ΔV (symbol often abbreviated to V).

$\Delta U_E = q\Delta V$	ΔU_E = potential energy (J) q = charge (C) ΔV = Volts (J/C)

AP Equation

More Electric Potential Difference

For a point source of charge, the potential from it to some distance is given as:

$$V = \frac{kq}{r}$$

V = potential (J/C)
k = 9.0 E 9 Nm^2/C^2
q = charge (C)
r = radius (m)

AP Equation

One spin-off: from a point charge, potentials compared between two distances is thus:

Non-AP Equation

$$\Delta V = \frac{kq}{r_{Closer}} - \frac{kq}{r_{Farther}}$$

Electric Fields vs. Potential

An electric field can be defined by a change in electric potential per change in distance:

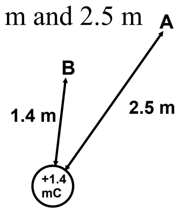
$$E = \frac{\Delta V}{\Delta r}$$

E = electric field (N/C)
V = voltage (J/C)
r = radius (m)

AP Equation

Electric Potential Difference Example

What is the electric potential difference (voltage) between points A and B, located 1.4 m and 2.5 m from a +1.4 mC point charge?



$$\Delta V = \frac{kq}{r_B} - \frac{kq}{r_A}$$

$$= \frac{9.0E9\,Nm^2/C^2 \bullet 1.4E-3C}{1.4\,m} - \frac{9.0E9\,Nm^2/C^2 \bullet 1.4E-3C}{2.5\,m}$$

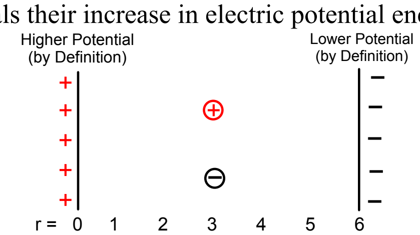
$$= 3.96E6\,V = 3.96\,MV$$

Work Done on Charges

It takes work to move a positive charge from an area of lower potential to higher potential (towards a positive charge).

Likewise, it takes work to move a negative charge towards a negative charge (towards lower potential).

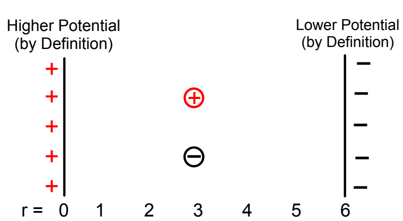
As these charges are moved, the work done on them equals their increase in electric potential energy.



Work Done on Charges

If any charge is allowed to move in its natural direction, it gains kinetic energy as it accelerates.

The increase in kinetic energy equals the loss of potential energy.

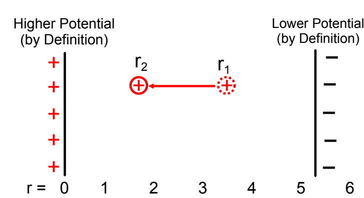


Work Mathematics

Earlier, change in electric potential energy was considered in terms of potential difference (voltage).

We now expand on that: work done **on** a charge equals its change in electric potential energy:

$$W_E = \Delta U_E = q\Delta V$$



Work Mathematics: Postive Charge

When a **positive** charge is moved closer to an area of higher potential, work done **on** it is positive (gains potential energy):

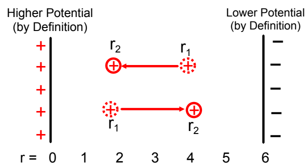
$$W_E = \Delta U_E = q\Delta V$$

$$= (+)(+) = +$$

When moved closer to an area of lower potential, work is negative (loses potential energy):

$$W_E = \Delta U_E = q\Delta V$$

$$= (+)(-) = -$$



Work Mathematics: Negative Charge

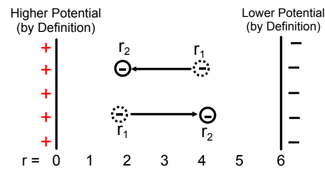
When a **negative** charge is moved closer to an area of higher potential, work done **on** it is negative:

$$W_E = \Delta U_E = q\Delta V$$

$$= (-)(+) = -$$

When moved closer to an area of lower potential, work is positive: $W_E = \Delta U_E = q\Delta V$

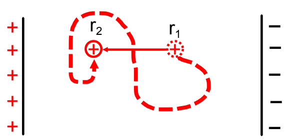
$$= (-)(-) = +$$



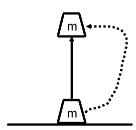
A Note on Path

Any charge moved in an electric field results in **conservative** work done: path doesn't matter.

Like moving an object in a gravitational field: a raised object gains potential energy regardless of whether it moved straight up, or along an incline.



Electrical Potential



Gravitational Potential

Work Example

+1.3 E -5 C of charge is moved in an electric field, and loses 3.4 E -6 Joules of potential energy.

1. Through what potential difference did it move?
2. Did it go towards a positive, or negative charge?

$$W_E = \Delta U_E = q\Delta V$$

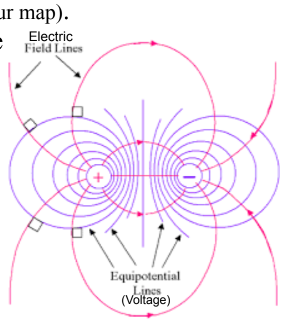
$$\Delta V = \frac{\Delta U_E}{q} = \frac{3.4E-6J}{1.3E-5C} = 0.26V$$

Towards negative charge: a positive charge loses potential energy as it moves towards an area of lower potential.

Voltage Mapping

Since electric potential is calculable at any point from a charged surface, one can make a map of voltage (like a topographic contour map).

The contours of this map are a series of 'parallel' shapes (which are perpendicular to electric field lines) of <u>equipotential</u> (same voltage):



AP Question 1

Negative charges are accelerated by electric fields toward points(A) At lower electric potential
(B) At higher electric potential
(C) Where the electric field is zero
(D) Where the electric field is weaker
(E) Where the electric field is stronger

Answer: B. An electric field accelerates a negative charge towards a positive one. By definition, electric potential is greater closer to a positive charge.

AP Question 2.

If the electric field does negative work on a negative charge as the charge undergoes a displacement from Position A to Position B an electric field, then the electrical potential energy

(A) is negative (B) Is positive (C) Increases
(D) Decreases (E) Cannot be determined from the information

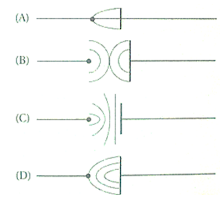
$$\Delta U_E = -W_E$$

Answer: C. If W_E is negative, then change in electrical potential energy is positive. This implies that the potential energy increases.

AP Question 3.

Which of the following diagrams represents the equipotential curves in the region between a positive point charge and a negatively charged parallel plate?

a. b. c. d.



Answer = C

AP Question 4.

If 10 J of work is required to move 2 C of charge in a uniform electric field, the potential difference present is equal to

a. 20 V b. 12 V c. 8 V d. 5 V

$$V = \frac{W}{q} = \frac{10\,J}{2\,C} = 5V$$

Homework

3.B.1 Problems.
Due: Next Class.