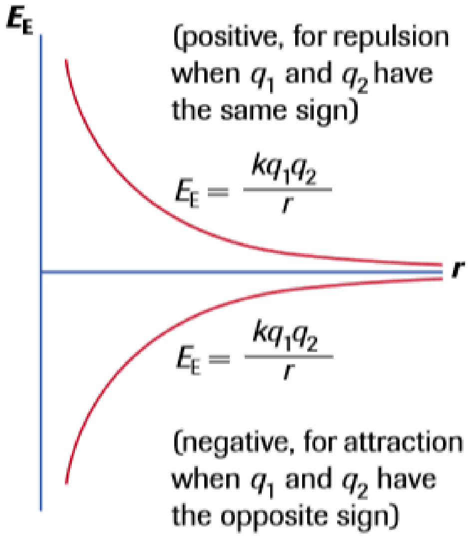
Sec. 7.4 - Electric Potential

Learning Goal: By the end of today, I will be able to connect gravitational potential energy to electrical potential energy concepts, and solve electrical potential energy problems.

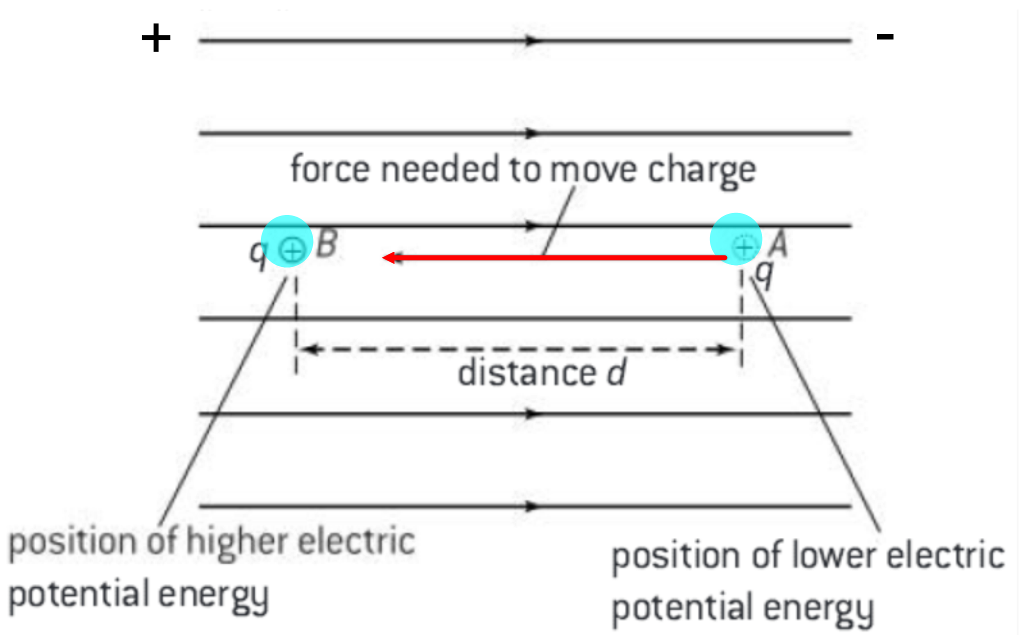
Gravity	Electric
$F_g = \frac{Gm_1m_2}{r^2}$	$F_E = \frac{kq_1q_2}{r^2}$
$E_g = -\frac{Gm_1m_2}{r}$	$E_E = \frac{kq_1q_2}{r}$

Always attractive

As r-> infinity, E goes to zero for both cases.



When placed in an electric field, a charge feels a force. This means that if it moves around in an electric field work will be done. As a result, the charge will either gain or lose electric potential energy. Electric potential energy is the energy that a charge has as a result of its position in an electric field. This is the same idea as a mass in a gravitational field. If we lift a mass up, its gravitational potential energy increases. If the mass falls, its gravitational potential energy decreases



To look at the concept of electric potential energy in a systematic way, we consider the electric potential energy not just of any charge q_2 but of a UNIT positive test charge when in the field of any other charge q_1.

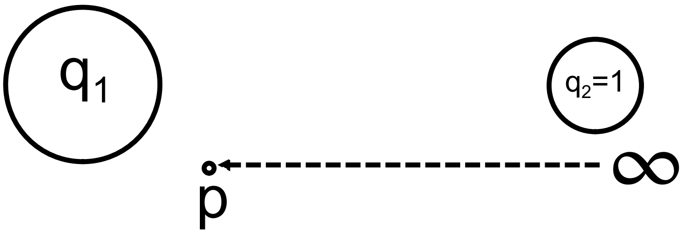
We call this value of potential energy per unit positive charge the **electric potential,V**.

It is a property of the electric field of the charge q_1 and represents the amount of work necessary to move a unit positive test charge from rest at infinity to rest at any specific point in the field of q_1. Thus,at a distance **r** from a spherical point charge q_1,the electric potential is given by

$$V = \frac{E_E}{q}$$ Joules/Coulomb

$$= \frac{\frac{kq_1q}{r}}{q}$$

$$V = \frac{kq_1}{r}$$ Joules/Coulomb



The units of electric potential are joules per coulomb, or volts, and

> 1 V is the electric potential at a point in an electric field if 1 J of work is required to move 1 C of charge from infinity to that point; 1 V = 1 J/C.

Electric Potential Energy VERSUS Electric Potential

We must always be very careful to distinguish between E_E,the electric potential energy of a charge at a point,

and

V, the electric potential at the point (energy per unit).

They are related by the equation $E_E = q\,V$.

Jelly beans are $4.50/kg (voltage) if you buy 3kg, the cost is $13.50 (charge and Energy)

ie.

E_E = 30J and q = 2C then V = 15 J/C or 15 V

This electric energy is dependent on the amount of charge, just like gravitational potential energy is dependent on the mass of the object.

Unit measurements

g = (Gravitational field strength is N/kg)

$\mathcal{E}$ = (Electric field strength is N/C)

V = (Gravitational potential is J/kg) very seldom used

V = (Electric potential is J/C)

Electric Potential Difference is the amount of energy required to move a unit test charge from one point to another.

ie. moving from -15V to -10V is a change of +5V

For a point charge q,the electric potential difference between two points A and B can be found by subtracting the electric potentials due to the charge at each position:

$$\Delta V = V_B - V_A = \frac{kq}{r_B} - \frac{kq}{r_A} = kq\left(\frac{1}{r_B} - \frac{1}{r_A}\right)$$

* when r = infinity, what does the formula turn into?

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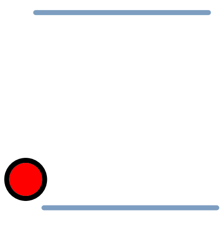
Working with Plates

When you lift a ball up with your hand, you apply a force over a distance, and the gravitational potential energy difference changes.



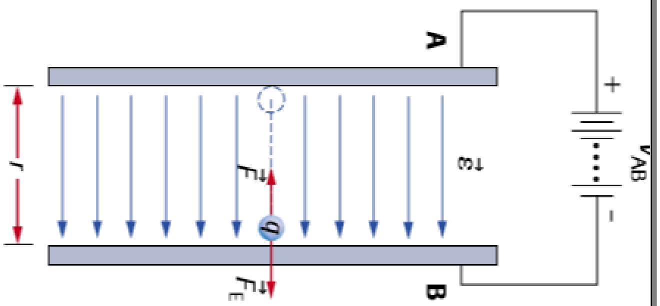
E_g=-80J

$$\Delta E_g = +20J \quad W = F * d$$

E_g=-100J

$$\vec{\varepsilon} = \frac{\vec{F}_E}{q}$$ field strength (N/C)

$$F_E = \varepsilon q$$



To move from B to A, work must be done.

$W = Fr$ since F and r are in the same direction

$W = q\varepsilon r$ since $F = F_E = q\varepsilon$

Therefore, since $W = \Delta E_E = q\,\Delta V$

$$q\Delta V = q\varepsilon r$$

or $\varepsilon = \frac{\Delta V}{r}$ or $\Delta V = \varepsilon r$

J/C N/C m

N*m/C

J/C

Example

What are we looking for?

Calculate the electric potential a distance of 0.40 m from a spherical point charge of $+6.4 \times 10^{-6}$ C. (Take $V = 0$ at infinity.)

Solution

$r = 0.40$ m

$q = +6.4 \times 10^{-6}$ C

$V = ?$

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

$$= \frac{(9.0 \times 10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2)(6.4 \times 10^{-6}\ \text{C})}{0.40\ \text{m}}$$

$$V = 1.5 \times 10^{5}\ \text{V}$$

The electric potential is 1.5×10^{5} V.

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How much work must be done to increase the potential of a charge of 3.0×10^{-7} C by 120 V?

Solution

$q = 3.0 \times 10^{-7}$ C

$\Delta V = 120$ V

$W = ?$

$$
\begin{aligned}
W &= \Delta E_E \\
&= q\Delta V \\
&= (3.0 \times 10^{-7}\ \text{C})(120\ \text{V}) \\
W &= 3.6 \times 10^{-5}\ \text{J}
\end{aligned}
$$

The amount of work that must be done is 3.6×10^{-5} J.

In a uniform electric field, the potential difference between two points 12.0 cm apart is 1.50×10^2 V. Calculate the magnitude of the electric field strength.

Solution

$r = 12.0$ cm

$\Delta V = 1.50 \times 10^2$ V

$\varepsilon = ?$

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

$$= \frac{1.50 \times 10^2 \text{ V}}{1.20 \text{ x } 10^{-1} \text{ m}}$$

$$\varepsilon = 1.25 \times 10^3 \text{ N/C}$$

The magnitude of the electric field strength is 1.25×10^3 N/C.

SUMMARY Electric Potential

- The electric potential energy stored in the system of two charges q_1 and q_2 is $E_E = \frac{kq_1q_2}{r}$.
- The electric potential a distance r from a charge q is given by $V = \frac{kq}{r}$.
- The potential difference between two points in an electric field is given by the change in the electric potential energy of a positive charge as it moves from one point to another: $\Delta V = \frac{\Delta E_E}{q}$
- The magnitude of the electric field is the change in potential difference per unit radius: $\varepsilon = \frac{\Delta V}{r}$

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Homework

Read 349 - 359 (good healthcare examples)

page 354 #1-4

page 358 #5 (top)

page 358 #1,3,4,7

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