Electrostatics Notes
1 – Charges and Coulomb's Law

- Matter is made of particles which are positively or negatively charged.
- The unit of charge is the Coulomb (C)
- Charges are Conserved, meaning that they cannot be… DESTORYED
  It is thought that the total charge of the entire universe is constant and neutral.
- Charges are also quantized, meaning that they occur in finite packages.
  The smallest unit of charge is called the elementary charge which is equal to the charge on one proton (+) or one electron (-).

$$\boxed{q = \pm 1.6 \times 10^{-19}\ C}$$

Coulomb determined that the force between two charged objects is proportional to their charges and inversely proportional to the square of their distances or:

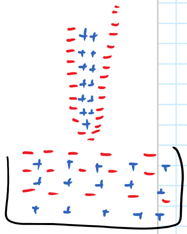
$$F_g = \frac{G m_1 m_2}{r^2}$$

$$\boxed{\vec{F}_E = \frac{k|Q_1 Q_2|}{r^2}}$$

for magnitude only
For Direction, use diagram.

Electric Force

Where:
- q_1 = 1st charge in C
- q_2 = 2nd charge in C
- r = distance (m)
- k = Coulomb's Constant $= 9 \times 10^9\ N\frac{m^2}{C^2}$



There are four important things to notice from this equation.

- Electrostatic Force can be attractive or repulsive
- " " depends on "Charge" not mass.
- " " gets significantly small as r ↑
- The constant "k" is much LARGER than the constant "G"

There is a very important difference between gravitational and electrostatic forces:

Gravity ALWAYS… Attracts

Electrostatic force can… Attract OR Repel

When solving for electrostatic forces we will NOT… use ± Signs !!

Instead we will determine the direction of the force based on… attraction or repulsion

$\mu = 10^{-6}$
$n = 10^{-9}$

$k = 9 \times 10^9\ N\frac{m^2}{C^2}$

Example:
Two 85 kg students are 1.0 m apart. What is the gravitational force between them?

$$F_g = \frac{6.67 \times 10^{-11}(85)(85)}{1^2} = \boxed{4.8 \times 10^{-7}\ N}$$

If these two students each have a charge of 2.0x10^{-3} C, what is the electrostatic force between them?

$$\vec{F}_E = \frac{kQ_1Q_2}{r^2} = \frac{(9\times10^9)(2\times10^{-3})(2\times10^{-3})}{1^2}$$

$$= \boxed{36000\ N}\ \text{repel}$$

Example:
Two point charges of 1.8x10^{-6} C and 2.4x10^{-6} C produce a force of 2.2x10^{-3} N on each other. How far apart are these two charges?

μC

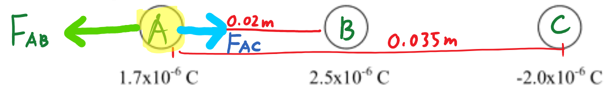
$$\vec{F}_E = \frac{kQ_1Q_2}{r^2} \qquad r = \sqrt{\frac{kQ_1Q_2}{F_E}}$$

$$r = \sqrt{\frac{9\times10^9(1.8\times10^{-6})(2.4\times10^{-6})}{2.2\times10^{-3}}}$$

$$\boxed{r = 4.2\,m}$$

Example:

A charge of 1.7×10^{-6} C is placed 2.0×10^{-2} m from a charge of 2.5×10^{-6} C and 3.5×10^{-2} m from a charge of -2.0×10^{-6} as shown.



What is the net electric force on the 1.7×10^{-6} charge?

$F_{AB} \leftarrow (A) \rightarrow F_{AC}$

$$F_{AB} = \frac{k Q_A Q_B}{r_{AB}^2} = \frac{k(1.7\times10^{-6})(2.5\times10^{-6})}{0.02^2} = 95.625 \text{ N}$$ Left

$$F_{AC} = \frac{k\left|(1.7\times10^{-6})(-2\times10^{-6})\right|}{0.035^2} = 25 \text{ N}$$ Right.

$$F_{net} = 95.625 - 25 \approx \boxed{71 \text{ N Left}}$$

Electrostatics Notes

2 – Electric Field on a Single Charge

There are many similarities between **gravitational** and *electrostatic* forces. One such similarity is that both forces can be exerted on objects that are not in contact.

In the same way that any mass is surrounded by a **gravitational field**, we will imagine that any charged object is surrounded by an **electric field**.

Similar to gravitational fields, an electric field will depend on:
distance from and size of the charge.

In fact we define an electric field as the force per unit charge:

$$\boxed{\vec{E} = \frac{\vec{F}_E}{Q}}$$

Where:
E = Electric Field $(\frac{N}{C})$
F_E = Electrostatic Force (N)
q = Charge (C)

$$F_E = \frac{kQ_1Q_2}{r^2}$$

We can substitute in Coloumb's Law to get:

$$E = \frac{\frac{kQ_1\cancel{Q_2}}{r^2}}{\cancel{Q}}$$

$$\boxed{\vec{E} = \frac{k|Q|}{r^2}}$$ mag. only
for Dir, use diagram.

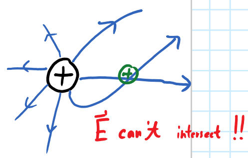
In the case of electric fields we are dealing with another example of a force field.

Therefore the field is a vector quantity.

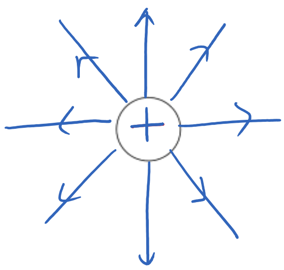
In order to show this we always draw the field lines as ______________.

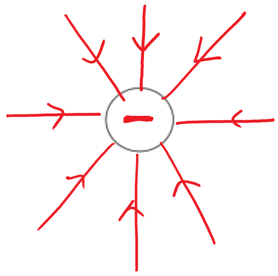
the direction that a positive test charge would move in the field.

Again there is an important difference between gravitational fields and electric fields due to the fact that…



We therefore define the direction of an electric field as…





Example:
What is the electric field strength at a point where a -2.00 μC charge experiences an electric force of 5.30×10^{-4} N?

$$\vec{E} = \frac{F_E}{|Q|} = \frac{5.3 \times 10^{-4}\ \text{N}}{2.00 \times 10^{-6}\ \text{C}} = \underline{265\ \text{N/C}}$$

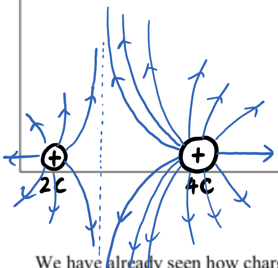
Example:
At a distance of 7.50×10^{-1} m from a small charged object the electric field strength is 2.10×10^{4} N/C. At what distance from this same object would the electric field strength be 4.20×10^{4} N/C?

Q ⊕ 0.75 m · $E_1 = 2.1 \times 10^4$ N/C

r_2 · $E_2 = 4.2 \times 10^4$ N/C

$$E_1 = \frac{kQ}{r^2} \qquad Q = \frac{E_1 r^2}{k} = \frac{2.1 \times 10^4 (0.75)^2}{9 \times 10^9} = 1.3125 \times 10^{-6}\ \text{C}$$

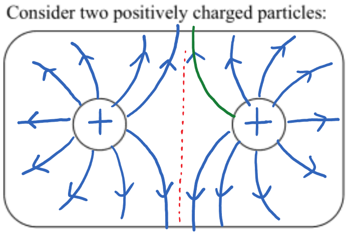
$$E_2 = \frac{kQ}{r_2^2} \qquad r_2 = \sqrt{\frac{kQ}{E_2}} = \sqrt{\frac{k(1.3125 \times 10^{-6})}{4.2 \times 10^4}} = \boxed{0.53\ \text{m}}$$



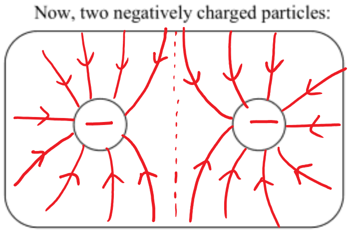
3 – Electric Field from Multiple Charges

We have already seen how charged particles emit electric fields, but how do these fields interact when two or more charges act on each other?

Consider two positively charged particles:

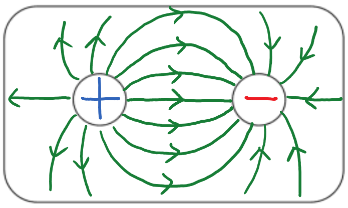


Now, two negatively charged particles:



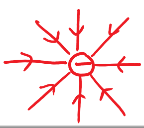
Note that the electric field lines point __in opposition to each other__. Because this electric field is a force field, it is a vector. So when multiple fields overlap we simply __add them up as a vector__

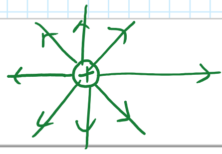
OK, now try two opposite charges:



Again the two fields interact, only this time they __Connect__

$$\vec{E} = \frac{k|Q|}{r^2}$$





Example:
What is the strength of an electric field midway between a 2.00 uC charge and a -4.00 uC that are 0.60 m apart?

A ⊕ 2 μC — 0.3 m — P (E_B, E_A) — 0.3 m — ⊖ B −4 μC

$$E_A = \frac{k(2 \times 10^{-6})}{0.3^2} = 200000\ \text{N/C}\ [R] \text{ toward (−) charge}$$

$$E_B = \frac{k(4 \times 10^{-6})}{0.3^2} = 400\,000\ \text{N/C}\ [R]$$

$$\therefore \boxed{\vec{E}_{Total} = 600\,000\ \text{N/C toward (−) charge}}$$

Example:
Two 5.25 uC charges are 0.40 m apart. What is the strength of the electric field between them at a point 0.10 m away from the first charge and 0.30 m away from the second?

A ⊕ 5.25 μC — 0.1 m — (E_B, E_A) — 0.3 m — ⊕ B 5.25 μC

$$E_A = \frac{k(5.25 \times 10^{-6})}{0.1^2} = 4725\,000\ \text{N/C}\ [R]$$

$$E_B = \frac{k(5.25 \times 10^{-6})}{0.3^2} = 525\,000\ \text{N/C}\ [L]$$

$$\boxed{\vec{E}_T = 4{,}200{,}000\ \text{N/C}\ [R]}$$

Q) Find location with zero $\vec{E}$

Ex) 4 μC ⊕ I — 0.6 m — II ⊖ −3 μC — x — E_{II} · E_I

$$E_I = \frac{k(4 \times 10^{-6})}{(0.6+x)^2} \qquad \frac{\cancel{k}(4 \times 10^{-6})}{\ldots} = \frac{\cancel{k}(3 \times 10^{-6})}{\ldots}$$

Example:
Find the magnitude and direction of the electric field at the point P due to the charges as shown.

12 μC

Example:

Find the magnitude and direction of the electric field at the point P due to the charges as shown.

I 0.6m II x Zero $\vec{E}$

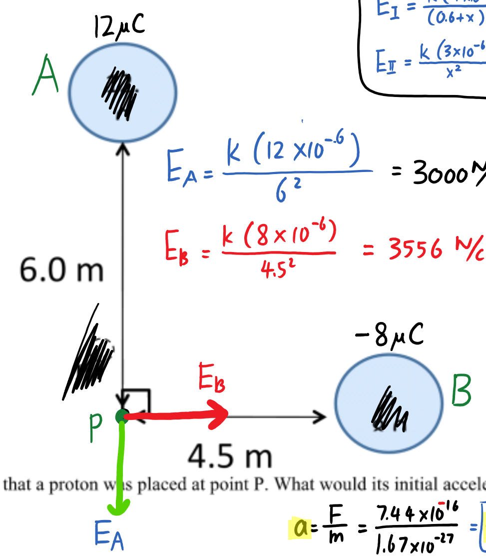
$E_I = \frac{k(4\times10^{-6})}{(0.6+x)^2}$

$E_{II} = \frac{k(3\times10^{-6})}{x^2}$

$\frac{\cancel{k}(4\times10^{-6})}{(0.6+x)^2} = \frac{\cancel{k}(3\times10^{-6})}{x^2}$

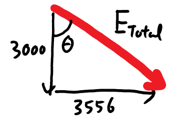
$4x^2 = 3(0.6+x)^2$

$4x^2 = 3(0.36 + 1.2x + x^2)$



$E_A = \frac{k(12\times10^{-6})}{6^2} = 3000\,N/C$ [Down]

$E_B = \frac{k(8\times10^{-6})}{4.5^2} = 3556\,N/C$ [Right]



$\vec{E}_{Total} = \sqrt{3000^2 + 3556^2} = 4652\,N/C$

$\tan\theta = \frac{3556}{3000}$ $\theta = 50°$ E of S

Suppose that a proton was placed at point P. What would its initial acceleration be?

$a = \frac{F}{m} = \frac{7.44\times10^{-16}}{1.67\times10^{-27}}$ (proton) $= \boxed{4.46\times10^{11}\,m/s^2}$

$E_T = 4652\,N/C$

$F_E = E_T Q = 4652(1.6\times10^{-19})$ (proton) $= 7.44\times10^{-16}\,N$

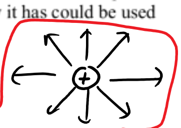
$\boxed{WS\#3}$

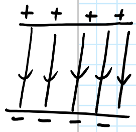
Electrostatics Notes

4 – Electric Potential and Electric Potential Energy

First let's examine electric potential energy. If a charged object is in an electric field it has electric potential energy - that is it has the potential to move in that field. Note that the potential energy it has could be used to… attract or repel depending on the charges.

A non-uniform field, such as that provided by a point, is one which has a different…





In this case we can derive a formula for the electric potential energy in a NON-UNIFORM FIELD:

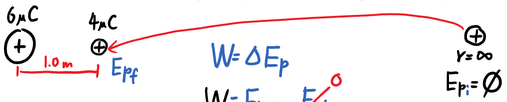
$$W = E_p = Fd$$

$$= \frac{kQ_1Q_2}{r^{\cancel{2}}} \cdot \cancel{d}$$

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

Again note the similarities between…

Example:
How much work must be done to bring a 4.0 uC charged object to within 1.0 m of a 6.0 uC charged object from a long way away?



$$W = \Delta E_p$$

$$W = E_{pf} - \cancel{E_{pi}}^{\,0}$$

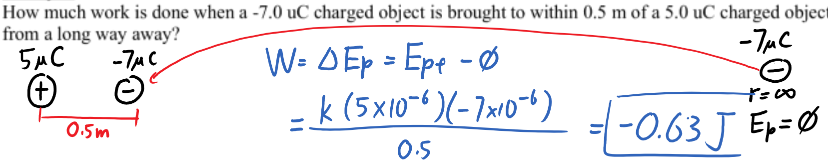
$$W = \frac{kQ_1Q_2}{r}$$

$$W = \frac{k(4\times10^{-6})(6\times10^{-6})}{1\text{m}} = 0.216\text{ J}$$

NOTE:
1. Potential energy is a … Scalar
2. We **WILL** … use + and − signs of charges

In this case, bringing a positive charge near another positive charge requires Input therefore the work is positive.

Example:
How much work is done when a -7.0 uC charged object is brought to within 0.5 m of a 5.0 uC charged object from a long way away?



$$W = \Delta E_p = E_{pf} - \varnothing$$

$$= \frac{k(5\times10^{-6})(-7\times10^{-6})}{0.5} = \boxed{-0.63\text{ J}}$$

In this case, bringing a negative charge near a positive charge releases energy therefore work is negative.

potential difference, E.m.f. → V ← Voltage, Electric Potential, Potential

Electric Potential

Now we need to consider a new quantity, electric potential (V). Electric potential is defined as the electric potential energy per unit charge.

$\div Q$

$\vec{F}_E = \frac{k\|Q_1 Q_2\|}{r^2}$	$\vec{E} = \frac{k\|Q\|}{r^2}$
$E_p = \frac{kQ_1Q_2}{r}$	$V = \frac{kQ}{r}$

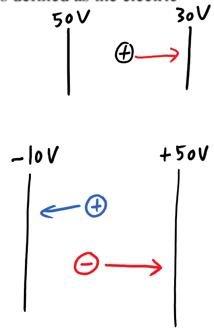
Point Charges

$\times r$

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

Which becomes,

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



NOTE:

(1) The electric potential is defined in terms of the moving of a positive charge. Therefore…
+ charges… move towards Low potential
- charges... move towards high potential.

(2) The unit for potential is… Volts (V)

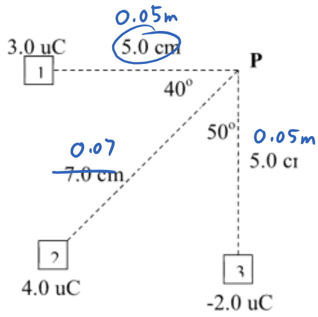
Example:
Calculate the potential at point P as shown in the diagram.

$$V_T = V_1 + V_2 + V_3 = \boxed{694286\ V}$$

$$V_1 = \frac{kQ_1}{r_1} = \frac{k(3\times10^{-6})}{0.05} = 540{,}000$$

$$V_2 = \frac{k(4\times10^{-6})}{0.07} = 514{,}286$$

$$V_3 = \frac{k(-2\times10^{-6})}{0.05} = -360{,}000$$



WS #4

NOTE:
(1) Potentials are… Scalar quantities
(2) We WILL use… + and − sign of charges.

Quiz on Force and Field (Note 1-3)

Electrostatics Notes

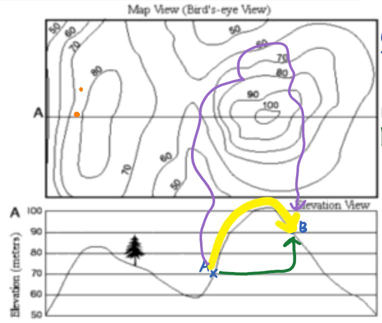
5 – Equipotential Lines and Changes in Energy

Equipotential Lines

- As a charge moves along an electric field line, work is done by the electrical force. The energy gained or lost by this charge moving in the field is a form of *potential energy*, and so associated with the electric field is an *electric potential*, V, which has units of Energy per charge or Joules per Coulomb (also call Volts).
- Since voltage is potential energy per unit charge, voltage increases when going from a negative charge towards a positive charge. (The kinetic energy of a positive charge would increase when going from a higher potential to a lower potential.)
- A surface along which the potential is constant is called an *Equipotential*. On a piece of paper, the equipotential is represented by a line on which the voltage is constant.

Topographical Maps:

- Since gravitational potential energy depends on height, lines of constant height would be gravitational equipotentials. A map of such lines is called a topographical map. Typically, a topographical map shows equally spaced lines of constant elevation.
- Where the lines are most closely spaced the elevation is changing most sharply, in other words the terrain is steep.

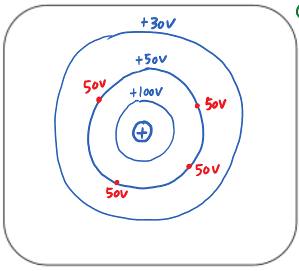


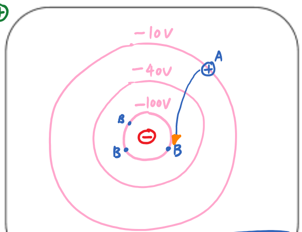
F_g F_E

G E

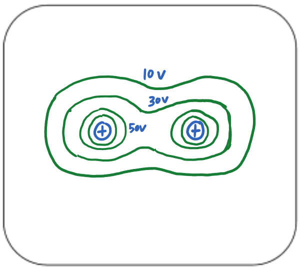
$h \rightarrow V$

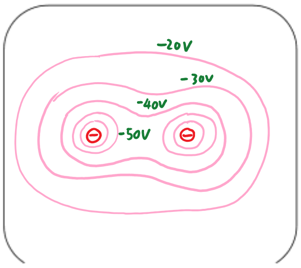
$E_{p_g} \rightarrow E_{p_E}$

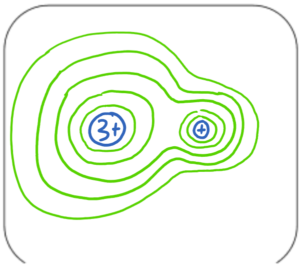


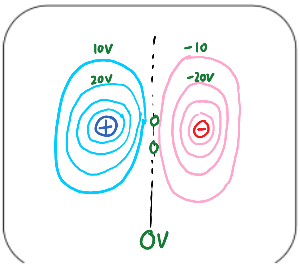


$\Delta V_{A \rightarrow B} = V_B - V_A = \boxed{-90\,V}$







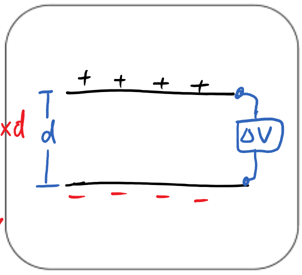


Parallel Plates $\div Q$

$\vec{F}_E = \frac{\Delta V Q}{d}$ | $\vec{E} = \frac{\Delta V}{d}$

$\times d$

$E_p = \Delta V Q$ | ΔV



Potential Difference

We sometimes want to determine the electric potential between two points. This is known as the **potential difference**.

For example, given two points A and B, the potential difference between A and B is:

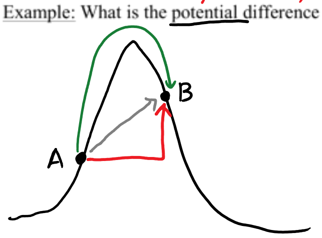
V

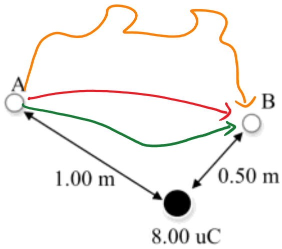
$$\boxed{\Delta V = V_f - V_i}$$

NOTE: When we talk about potential at a point we are talking about the potential difference between that point and infinity, where the potential at infinity is ZERO.

Example: What is the potential difference between points A and B due to the charge shown?

height (Gravity)



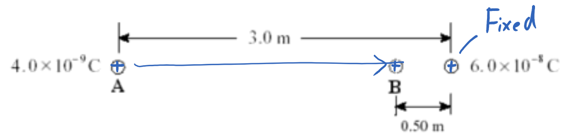


$$\Delta V = V_B - V_A = \frac{kQ}{0.5m} - \frac{kQ}{1m}$$

$$= k(8 \times 10^{-6})\left[\frac{1}{0.5} - \frac{1}{1}\right]$$

$$= \boxed{72{,}000\ V}$$

Changes in Energy



A 4.0 x10^{-9} C charge of mass 2.4 x10^{-21} kg, is initially located at point **A**, 3.0 m from a stationary 6.0x10^{-8} C charge.

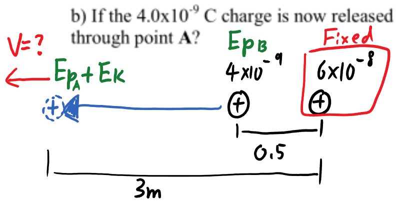
a) How much work is required, by an external agent, to move the 4.0x10^{-9} C charge to a point **B**, 0.50 m from the stationary charge?

$$W = \Delta E_p = \underset{B}{E_{pf}} - \underset{A}{E_{pi}} = \frac{kQ_1Q_2}{0.5\,m} - \frac{kQ_1Q_2}{3\,m}$$

$$= k(4\times10^{-9})(6\times10^{-8})\left[\frac{1}{0.5} - \frac{1}{3}\right]$$

$$= \boxed{3.6\times10^{-6}\,J}$$

b) If the 4.0x10^{-9} C charge is now released from point **B**, what will be its velocity when it passes back through point **A**?



$$E_{pB} = E_{pA} + E_k$$

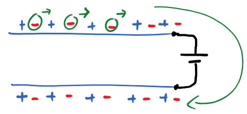
$$E_{pB} - E_{pA} = E_k$$

$$3.6\times10^{-6}\,J = \frac{1}{2}mv^2$$

$$3.6\times10^{-6} = \frac{1}{2}(2.4\times10^{-21})\,v^2$$

$$V = 5.48\times10^{7}\,m/s$$

Quiz #2 (Note 4 - 5)

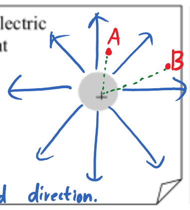


Electrostatics Notes

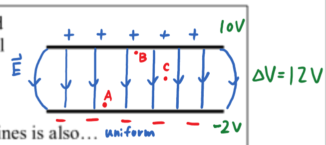
6 – Electric Potential in Uniform Electric Fields

We have seen that the electric field surrounding a point charge is not uniform – that it… varying strength and direction.

$\vec{E}_B < \vec{E}_A$



If we examine the electric field between charged plates we will find that it is… uniform in strength and direction



Notice that the density of the lines is also… uniform

$\vec{E}_A = \vec{E}_B = \vec{E}_C$

In a uniform electric field we cannot use our previous formula: $\vec{E} = \frac{kQ}{r^2}$

This formula is only valid for describing the strength of non-uniform fields (point charges only!!!)

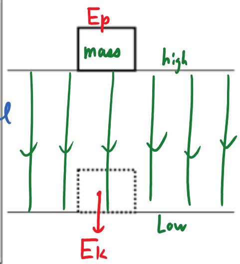
To find an equation for uniform fields, we will once again draw a parallel with gravitational potential energy.

Consider a mass sitting in a uniform *gravitational* field at some height.

The mass will tend to move from… high potential (height) to Low Potential

As it does it… E_p is converted into Kinetic Energy.

If we allow the mass to fall the work done on it ($W = \Delta E_p$) is negative. If we want to lift the mass to a certain height we need to do positive work on it.



A charged object in an electric field will behave in the same way, accelerating from an area of… high potential (Voltage) to low potential.

As it does it… E_p is converted into E_k

In the same way that we would do positive work on an object to lift it against gravity, we need to do work to bring a positive charge near a plate with positive potential.

To calculate the work done in this case we can use the formula:

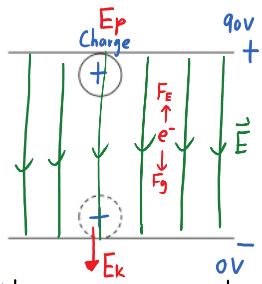
$$W = \Delta E_p = Fd$$

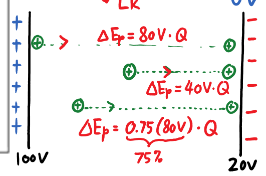
It is often easier, however, to describe the work done in a uniform field using the potential difference between the two plates.

Recall that potential difference:

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

A potential difference is generated any time we have areas of high and low potential energy, just like those generated by gravitational fields.





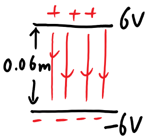
$\Delta V = 80V$

In order to determine the electric field between two charged plates we must use the formula:

$$\vec{E} = \frac{\Delta V}{d}$$

Where: E = Electric field (N/C)
ΔV = Voltage (V)
d = distance between plates (m)

Example:
Calculate the electric field strength between two parallel plates that are 6.00×10^{-2} m apart. The potential of the top plate is 6.0 V and the bottom plate is -6.0 V.

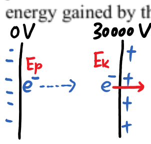


$$\vec{E} = \frac{\Delta V}{d}$$

$$\vec{E} = \frac{12}{0.06} = \boxed{200 \text{ N/C}}$$

[bottom]

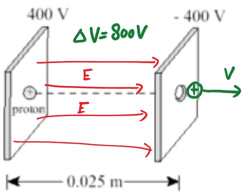
Example:
An electron is accelerated from rest through a potential difference of 3.00×10^4 V. What is the kinetic energy gained by the electron?



$$\Delta E_p = \Delta V Q = (30000)(1.6 \times 10^{-19})$$
$$= 4.8 \times 10^{-15} \text{ J}$$

$$\boxed{\Delta E_k = 4.8 \times 10^{-15} \text{ J}}$$

Example:
A proton, initially at rest, is released between two parallel plates as shown.
a) What is the magnitude and direction of the electric field?



$$\vec{E} = \boxed{\frac{\Delta V}{d}} = \frac{800 \text{ V}}{0.025 \text{ m}} = 32000 \text{ N/C}$$

Field is + → − ∴ [Right]

b) What is the magnitude of the electrostatic force acting on the proton?

$$\vec{F} = \boxed{\frac{\Delta V}{d}} Q = (32000 \text{ N/C}) \cdot (1.6 \times 10^{-19} \text{ C}) = 5.12 \times 10^{-15} \text{ N}$$

c) What is the velocity of the proton when it exits the - 400 V plate?

$$\Delta E_p = \Delta V Q$$
$$= (800 \text{ V})(1.6 \times 10^{-19} \text{ C})$$
$$= \boxed{1.28 \times 10^{-16} \text{ J}}$$

Ep lost → Ek gain

$$E_k = 1.28 \times 10^{-16} = \frac{1}{2} m v^2$$

1.67×10^{-27} kg

$$\boxed{v = 3.92 \times 10^5 \text{ m/s}}$$

Worksheet 6.1 – Coulomb's Law $\mu = 10^{-6}$

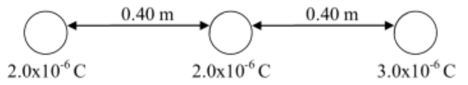
1. Calculate the electric force between two point charges of 4.00 μC and 3.00 μC when they are 2.00 cm apart.

2. Two points of equal charge produce an electric force on each other of $3.40\text{x}10^{-2}$ N when placed 0.100 m apart. What is the charge on each point?

3. How far apart are two point charges of $2.0\text{x}10^{-6}$ C and $4.0\text{x}10^{-6}$ C if they produce an electric force of 0.56 N?

4. Two point charged objects produce an electric force on each other of $6.20\text{x}10^{-2}$ N. What will the force between them be if the distance between increases three-fold?

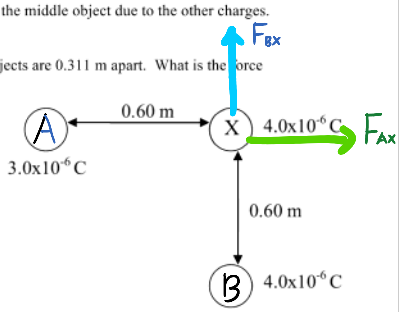
5. Two point charges produce a force between on each other of $4.5\text{x}10^{-3}$ N. What is the force between them if the charge on each triples and the distance between them doubles?

6. 

Three charged objects are placed in a line as shown. Calculate the force on the middle object due to the other charges.

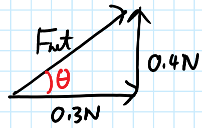
7. The electric force between two charged particles is $5.2\text{x}10^{-4}$ N when the objects are 0.311 m apart. What is the force between these objects if the distance changed to 0.404 m?

8. Three point charges are placed at the corner of a right angle triangle as shown. Calculate the magnitude of the net electric force on the object marked X due to the other two charges.



$F_{AX} = \dfrac{k(3\times10^{-6})(4\times10^{-6})}{0.6^2} = 0.3\,N$ right

$F_{BX} = \dfrac{k(4\times10^{-6})(4\times10^{-6})}{0.6^2} = 0.4\,N$ up

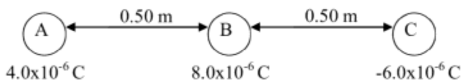


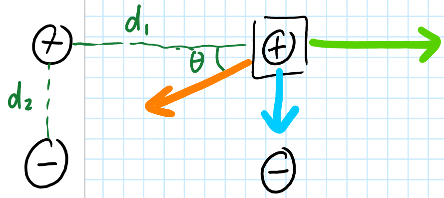
$\boxed{F_{net} = 0.5N}$

$\sqrt{0.3^2 + 0.4^2}$

9. Two small spheres, each with a mass of $2.00\text{x}10^{-5}$ kg are placed $3.50\text{x}10^{-1}$ m apart. One sphere has a charge of -2.00 μC and is fixed in position. The other sphere has a charge of -3.00 μC but is free to move without friction. What is the initial acceleration of the free object?

Use the following diagram to answer questions 10-12





10. What is the net force on A?

11. What is the net force on B?

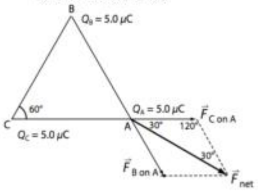
12. What is the net force on C?

CHALLENGE!

Three tiny spheres with identical charges of +5.0 μC are situated at the corners of an equilateral triangle with sides 0.20 m long. What is the net force on any one of the charged spheres?

Answers:

1. (270 N) 2. (1.94x10^{-7} C) 3. (0.36 m) 4. (6.89x10^{-3} N) 5. (1.0x10^{-2} N)
6. (1.1x10^{-1} N left) 7. (3.1x10^{-4}) 8. (5.0x10^{-1} N) 9. (2.20x10^{4} m/s^{2}) 10. 0.94 N to the left
11. 2.9 N to the right 12. 1.9 N to the left



Challenge! 9.80 N

Worksheet 6.2 – Electric Field on a Single on a Single Charge

He

Alpha particle

2+

$Q = 2 \times \underbrace{1.6\times10^{-19}}_{\text{proton}} = 3.2\times10^{-19}\ C$

$m = 4 \times m_p = 4 \times 1.67\times10^{-27}\ kg$

$m = 6.68\times10^{-27}\ kg$

⑥ $F_E = EQ = 7.6\times10^{4}\ (3.2\times10^{-19}) = 2.432\times10^{-14}\ N$

$F_{net} = ma \quad 2.43\times10^{-14} = 6.68\times10^{-27}(a)$

$a = 3.6\times10^{12}\ m/s^2$

1) What is the electric field strength 0.750 m from an 8.00 µC charged object?

2) Calculate the gravitational field strength on the surface of Mars. Mars has a radius of 3.43x10^{6} m and a mass of 6.37x10^{23} kg.

3) At a point a short distance from a 4.60x10^{-6} C charged object, there is an electric field strength of 2.75x10^{5} N/C. What is the distance to the charged object producing this field?

4) If an alpha particle experiences an electric force of 0.250 N at a point in space, what electric force would a proton experience at the same point?

5) What is the electric field strength at a point in space where a 5.20x10^{-6} C charged object experiences an electric force of 7.11x10^{-3} N?

6) What is the initial acceleration of an alpha particle when it is placed at a point in space where the electric field strength is 7.60x10^{4} N/C?

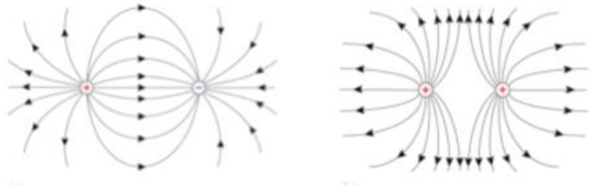
7) What is the electric field strength at a point in space where an electron experiences an initial acceleration of 7.50x10^{12} m/s^{2}?

8) The electric field strength at a distance of 3.00x10^{-1} m from a charged object is 3.60x10^{5} N/C. What is the electric field strength at a distance of 45 cm from the same object?

Answers:

1. (1.28x10^{5} N/C)
2. (3.61 N/kg)
3. (0.388 m)
4. (0.125 N)
5. (1370 N/C)
6. (3.66x10^{12} m/s^{2})
7. (42.7 N/C)
8.

Worksheet 6.3 Electric Fields on Multiple Charges

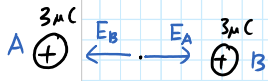


6.3 Questions 8-13

9) Calculate the electric field strength midway between a 4.50 μC charged object and a -4.50 μC charged object if the two charges are 50 cm apart.

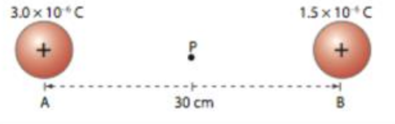
10) Calculate the electric field strength midway between a 3.0 μC charged object and a 6.0 μC object if they are 0.80 m apart.

11) Calculate the electric field strength midway between two 3.0 μC objects if they are 90 cm apart.

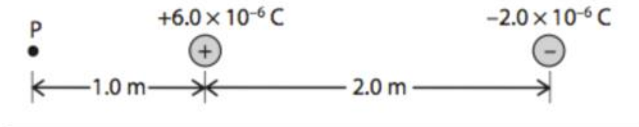


$\vec{E}_{Total} = \emptyset$

12) Two negatively charge spheres, A and B, are 30 cm apart and have the following charges of 3.0×10^{-6} C and 1.5×10^{-6} C as in the figure below. What is the net electric field at a point P, which is exactly in the middle between the two charges?



13) What is the magnitude and direction of the electric field at point P in the figure below?



Answers:

9. $(1.30 \times 10^6$ N/C)
10. $(1.7 \times 10^5$ N/C)
11. ~~$(1.60 \times 10^5$ N/C)~~ ∅ N/C
12. $(6.0 \times 10^5$ N/C to the right)
13. $(-5.2 \times 10^4$ N/C to the left)
    +

Quiz next day

Note / WS # 1 – 3

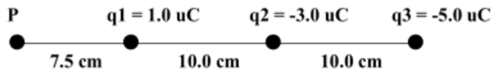
$\vec{E}$ and $\vec{F}_E$

Worksheet 6.4 – Electric Potential

1) What is the potential at a distance of 6.0 cm from a 2.5 uC charge?

2) What is the potential at a distance of 25 cm from a -2.5 uC charge?

3) Three charges are located in a line as shown.
Find the potential at point P.



4) How much work is done against the electric field produced by a 5.0 uC charged object when a 0.030 uC charge is moved from a distance of 45 cm to 15 cm.

5) A proton is released 2.0×10^{-11} m from the centre of a 6.4×10^{-18} C fixed charge. What is the speed of the proton when it is 0.50 m from the charge

6) The centers of two alpha particles are held 2.5×10^{-12} m apart, when they are released. Calculate the speed of each alpha particle when they are 0.75 m apart.

7) 4.4×10^{-5} J of work is done moving a 3.00 uC charge at a constant speed from point A to point B. If A and B are 2.4 cm apart, what is the potential difference between A and B?

8) Two parallel plates are connected to a 12.0 V battery. If the plates are 9.00×10^{-2} m apart, what is the electric field strength between them?

9) The electric field between two parallel plates is 5.0×10^{3} N/C. If the potential difference between the plates is 2.0×10^{2} V, how far apart are the plates?

10) Two parallel plates are 7.3 cm apart. If the electric field strength between the plates is 2.0×10^{3} V/m, what is the potential difference between the plates?

11) An alpha particle gains 1.5×10^{-15} J of kinetic energy. Through what potential difference was it accelerated?

12) A proton is accelerated by a potential difference of 7.20×10^{2} V. What is the change in its kinetic energy?

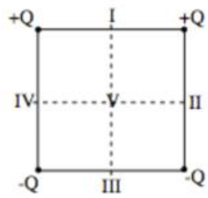
13) What maximum speed will an alpha particle reach if it moves from rest through a potential difference of -7.50×10^{3} V?

Answers:

1. (3.8×10^{5} V)
2. (-9.0×10^{4} V)
3. (-2.0x105 V)
4. (6.0×10^{-3} J)
5. (7.4×10^{5} m/s)
6. (2.4×10^{5} m/s)
7. (14.7 V)
8. (1.33×10^{2} N/C)
9. (4.0×10^{-2} m)
10. (1.5×10^{2} V)
11. (4.69×10^{3} V)
12. (1.15×10^{-16} J)
13. (8.50×10^{5} m/s)

Worksheet 6.5 – Equipotential Lines and more Electric Potential!

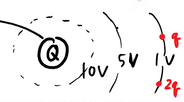
1. When +3.0 C of charge moves from point A to point B in an electric field, the potential energy is decreased by 27 J. It can be concluded that point B is:
   a. 9.0 V lower in potential than point A.
   b. 9.0 V higher in potential than point A.
   c. 81 V higher in potential than point A.
   d. 81 V lower in potential than point A.

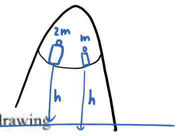


2. Four charges are arranged on the four corners of a square as shown in the diagram. If the electric potential is defined to be zero at infinity then it is also zero at:
   a. point V only
   b. points II and IV and V
   c. pointes I and III
   d. none of the labeled points.

3. A small positive charge q is brought from far away to a distance r from a positive charge Q. In order to pass through the same potential difference a charge 2q should be brought how close to charge Q.
   a. a distance r/2
   b. a distance r
   c. a distance 2r
   d. a distance 4r

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





4. Illustrate how equipotential lines are drawn to represent the properties of the electric potential by drawing equipotential lines for the following charge configurations:

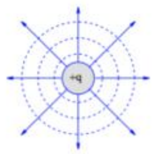
   a. A small sphere for radius r and positive charge +q.
   b. a small sphere with radius r and negative charge –q a distance 8r from a sphere of radius r with a charge of 3q.

5. A gold nucleus has a radius of 3.0 x 10^{-15} m and carries a charge of 79 electrons.
   a. What is the electric field strength at its surface (let's pretend atoms have surfaces ☺)?
   b. What is the potential at its surface (☺)?
   c. How much energy (in joules) would be required to bring a proton from a large distance (infinity) up to the surface (☺) of the gold nucleus?
   d. What would the initial velocity of the proton need to be in order to come close to the gold nucleus.

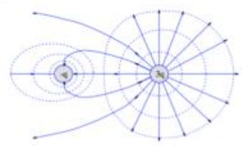
Answers:

1. (a) lower since a positive charge has decreased its potential energy
2. (b) these points lie halfway between the positive and negative charges
3. (b) electric potential difference depends only on the charge Q, not on the charge moving through it
4. See below

a.



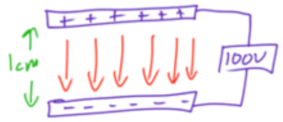
b.



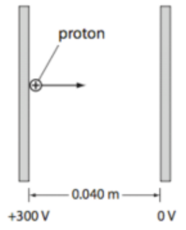
5. See below.
   a. 1.3 x 10^{22} N/C directed away from the nucleus
   b. 3.8 x 10^{7} V
   c. 6.6 x 10^{-12} J
   d. 8.5 x 10^{7} m/s

Worksheet 6.6

6. Find the Electric Field strength of the uniform field below:



7. A proton at rest is accelerated between two parallel plates with a potential difference of 300V as shown below. What is the maximum speed of the proton?



8. A voltmeter measures the potential difference between two large parallel plates to be 50.0 volts. The plates are 3.0 cm apart. What is the magnitude of the electric field strength between the plates?

9. Two large parallel metal plates are 5.0 cm apart. The magnitude of the electric field between them is 800. N/C.

   a. What is the potential difference between the plates?

   b. What work is done when one electron is moved from the positive to the negative plate?

10. The magnitude of the electric field strength between two parallel plates is 4.0×10^{3} N/C. The plates are connected to a battery with an electric potential difference of 12 V. What is the plate separation?

11. The electric field between two charged parallel plates separated by a distance of 1.8 cm has a uniform value of 2.4×10^{4} N/C. Find the potential difference between the plates. How much kinetic energy would be gained by a deuteron in accelerating from the positive plate to the negative plate? (A deuteron is a particle with one proton and one neutron.)

12. A potential difference of 10, 000 V exists between two parallel plates which are separated by 10 cm. An electron is released from the negative plate at the same instant a proton is released from a positive plate.

   a. What is the kinetic energy of each particle as they reach the opposite sides? (Joules)
   b. With what velocity does each of the particles hit the opposite plates?
   c. What is the electric field strength between the plates? (Hint: think about the distance between the plates)
   d. What is the acceleration of each particle?

13. A CRT is used with an accelerating voltage of 750 V to accelerate electrons before they pass through deflecting plates, to which a deflecting voltage of 50.0 V is applied.
    a. What speed do the electrons reach?
    b. When the electrons travel through the deflecting plates, which are separated by a distance of 2.0 cm, what is the electric field strength between the plates?
    c. What is the force that will deflect electrons as they pass through the plates?
    d. At what rate will the electrons accelerate as they pass through the plates?
    e. The plates have a length of 5.0 cm. For what length of time will the electrons be between the plates?
    f. What is the deflection in the y-direction of the electrons as they pass through the plates?

14. A proton is placed in an electric field between two parallel plates. If the plates are 6.0 cm apart and have a potential difference of 75 V, how much work is done against the electric field when the proton is moved 3.0 cm parallel to the plates?

15. In question 14, how much work is done against the electric field in moving the proton 3.0 cm perpendicular to the plates?

Answers:

6. 10,000 V/m (N/C)
7. 1.2×10^5 m/s
8. 1700 V/m (N/C)
9. See below.
    a. 40. V
    b. 6.4×10^{-18} J
10. 3.0×10^{-3} m
11. 432 V, 6.92×10^{-17} J
12. See below.
    a. 1.6×10^{-15} J for both!
    b. 5.9×10^7 m/s for the electron, 1.4×10^6 m/s for the proton
    c. 1.0×10^5 V/m (or J/C)
    d. -1.8×10^{16} m/s^2 for the electron, 9.6×10^{12} m/s^2 for the proton
13. a. 1.6×10^7 m/s b. 2.5×10^3 N/C c. 4.0×10^{-16} N d. 4.4×10^{14} m/s^2 e. 3.1×10^{-9} s f. 2.1 mm (0.0021 m)
14. 0 J
15. 6.0×10^{-18} J