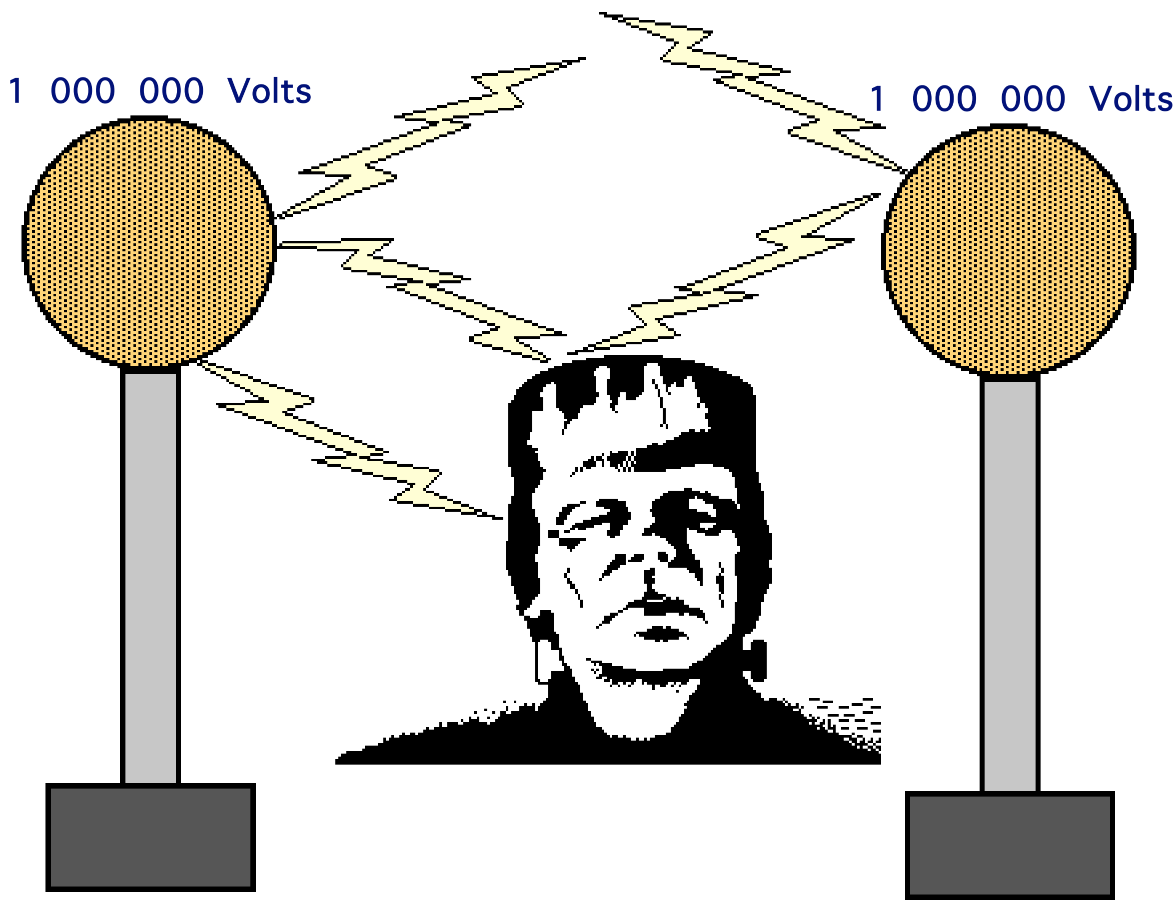
Physics 12

ELECTROSTATICS

$$\mathbf{F} = \frac{kQ_1Q_2}{r^2} \qquad \mathbf{E} = \frac{V}{d} \qquad V = \frac{kQ}{r}$$

$$E_p = \frac{kQ_1Q_2}{r} \qquad \mathbf{F} = q\mathbf{E} \qquad V = \frac{\Delta E_p}{Q}$$



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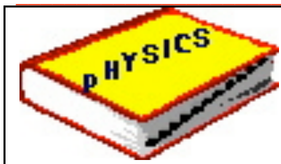


Text References

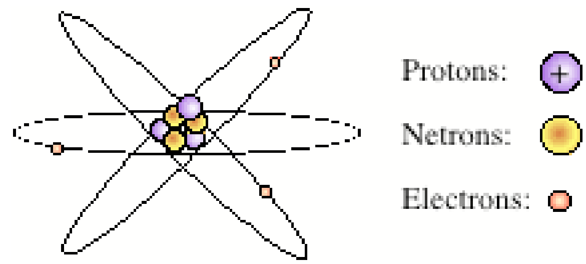
3^{rd} Ed. Giancolli Pg. 416-30
4^{th} Ed. Giancolli Pg. 455-70
5^{th} Ed. Giancolli Pg. 476-91

ELECTROSTATICS

ELECTRIC FORCE & FIELD

Objectives: • solve problems involving Coulomb's Law and Electric Field

Electric Charge



Electrical charges are caused by the numbers of electrons and protons present in the atoms of a material.

Due to the configuration of an atom (the Bohr model is shown), *only* the ____________________ can be moved easily as these particles are located in the external regions of the atom. Therefore, when an object is charged, it has an excess or shortage of _________________.

An electron stores the smallest individual unit of charge, **q** = 1.6×10^{-19} C. The total charge on an object is calculated using the formula Q = nq , where Q represents the total charge and *n* represents the number of electrons. All electrical charges are due to an ______________ or ______________ of electrons.

When charged objects are brought near each other, they will either be attracted or repelled according to the Fundamental Law of Electric Charges.

1. Oppositely charged objects will _________________ each other.

2. Objects with the same charge will _________________ each other.

3. Charged objects will _________________ neutral objects.

Coulomb's Law: This law gives the force of attraction (or repulsion) between charged objects. Define the variables involved in this law in the space below and state their units.

$$F = \frac{kQq}{r^2}$$

where:

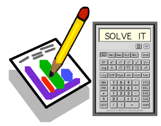
F: ____

k: ____

Q: ____

q: ____

r: ____

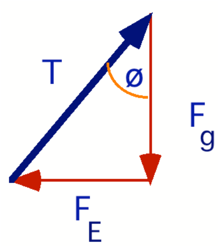


Sample Problem: Using Coulomb's Law

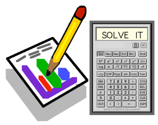
Two cork balls of mass 5×10^{-4} kg hang from the same support point by massless insulating threads 0.1 m in length. A total charge of 2.0×10^{-7} C is added to the system, which is distributed equally between the two charges. The cork balls come to rest in equilibrium with 0.14 m between their centers.

a) Draw a free body diagram for each ball, clearly labeling all the forces on each ball?

b) What is the value of the angle that the threads make with the vertical when the system is in equilibrium? (Isolate one of the objects and draw a vector force diagram.)

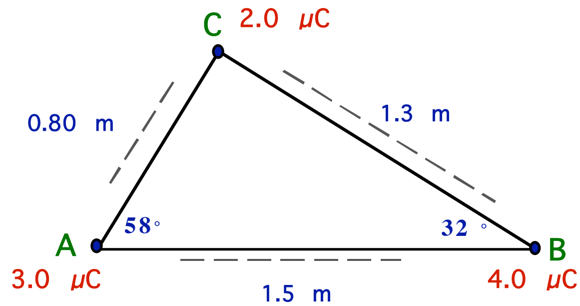


$F_E = 4.6 \times 10^{-3}$ N
$F_g = 4.9 \times 10^{-3}$ N
$\theta = 43.1°$



Sample Problem: Using Coulomb's Law

Calculate the electric force on charge 'C' due to charges 'A' and 'B'. Remember to determine both the magnitude and direction!



Step 1. Determine the magnitude of the force exerted by each of charges 'A' and 'B' on 'C'.

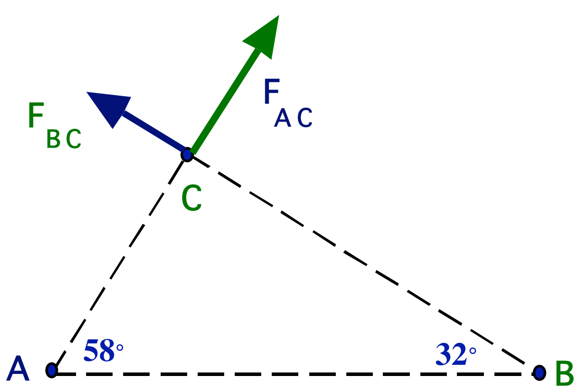
Between A and C

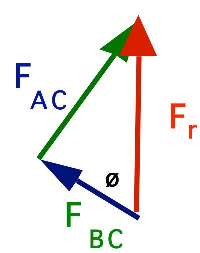
8.4×10^{-2} N

Between B and C

$4.3. \times 10^{-2}$ N

Step 2. Construct a vector diagram and calculate the resultant force.





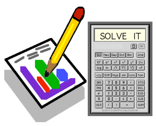
Fr = 0.094 N
θ = 63.2 °
Angle is 85° above the horizontal

Electric Field

The electric field at each point in space is defined to be ____

____ .

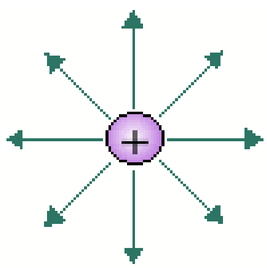
Note that electric field is a **vector**, so it has both magnitude and ________________. Electric fields are represented by electric field lines, that are directed away from positive charges and towards negative charges. A stronger electric field is shown by more field lines, drawn closer together.



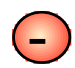
Sample Problem: Electric Field Lines

Draw the electric field lines for the charge combinations below.
Hint: look in your textbook for examples...

Positive point charge

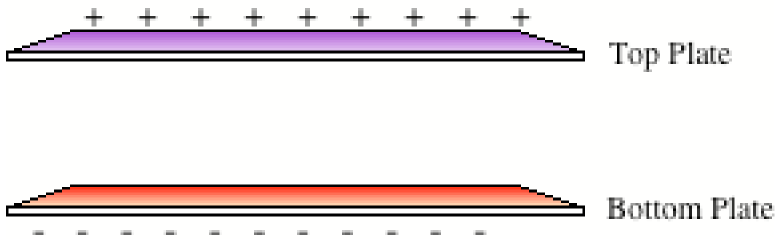


Negative point charge



Electric field lines between <u>and</u> around and between **positive** and **negative** point charges

Electric field lines between two parallel plates, the top with a **positive** charge and the bottom with a **negative** charge.



Note that the electric field strength in the **interior** region between two oppositely charged parallel plates is **constant**; the field is <u>not</u> stronger as you get closer to either plate.

Electric Field Strength

The electric field strength 'E' is defined as the *force per unit charge* on a test charge placed in an electric field.

$$E = \frac{F}{Q} = \frac{\frac{kQ_1Q_2}{R^2}}{Q_1} = \frac{kQ_2}{R^2}$$

Define the variables involved in this equation in the space below and state their units.

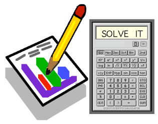
$$E = \frac{kQ}{r^2}$$ where:

E: ______________________________

k: ______________________________

Q: ______________________________

r: ______________________________

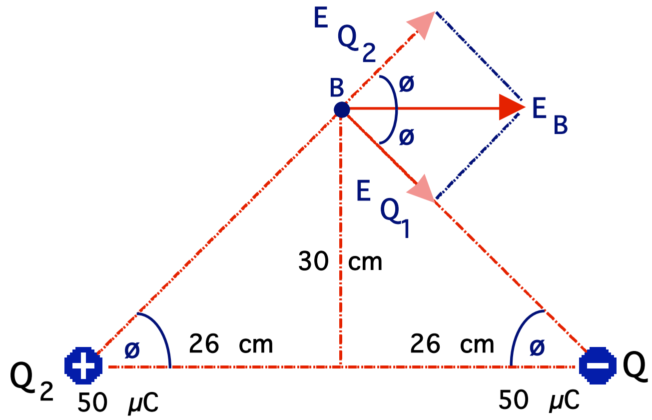


Sample Problem: Electric Field

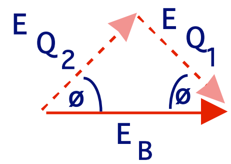
Calculate the magnitude and direction of the electric field at a point '**B**' as shown in the diagram below. Each point charge (Q_1 and Q_2) has a charge of 50 μC.

Step 1. Construct a vector diagram showing the direction of each electric field.

Step 2. Calculate the electric field strength due to each charge.

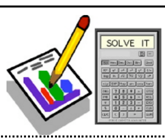


Step 3. The electric field at B is the vector sum of the fields E_{Q2} and E_{Q1}.
Note that E_{Q2} is away from Q_2 and E_{Q1} is towards Q_1



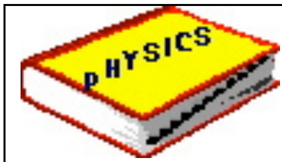
Use the cosine law to determine E_B:

$E = 3.7 \times 10^6$ N/C to the right.



Problem Set #1: Coulomb's Law and Electric Field

3rd Ed. Giancolli Pg. **436 - 439**	4th Ed. Giancolli Pg. **474 - 476**	5th Ed. Giancolli Pg. **496 - 497**
Questions #11, 20	Questions # 8, 12, 19	Questions #9, 17
Problems #1, 2, 3, 7, 10, 14, 17, 21, 26*, 37*, 40	Problems # 5, 6, 12, 19, 22, 25, 37, 42	Problems #1-4, 11, 14, 22, 26, 35, 45, 53



Text References

3^{rd} Ed. Giancolli Pg. 440-47
4^{th} Ed. Giancolli Pg. 479-87
5^{th} Ed. Giancolli Pg. 502-11

ELECTROSTATICS
ELECTRIC POTENTIAL AND ENERGY

Objectives: • solve problems involving electric potential and electric potential energy

Electric Potential: is the potential energy per unit charge and commonly know as voltage. The electric potential has a particular value at one location near a point charge. Electric potential can be calculated, but not physically measured.

Electric Potential Difference: is the difference in electric potential per unit charge between two points in an electric field. Electric potential difference, commonly referred to as potential difference, can be physically measured. Potential difference is equal to the work done by the electric force to move the charge between two points in an electric field.

Define all variables in the equation for potential difference below and give the units for each variable.

$$V = \frac{\Delta E_p}{q}$$ where:

V: ______________________________

ΔE_{p}: ______________________________

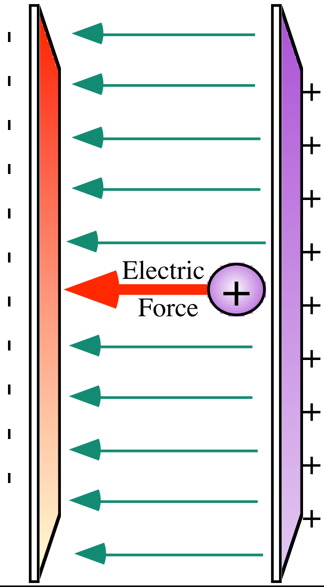
q: ______________________________

The unit for electric potential (and potential difference) is $\frac{J}{C}$, commonly known as the _______________.

When a particle is accelerated through a potential difference, such as between two parallel charged plates, the particle's electric potential energy near one plate is transformed into _______________ energy near the other plate.

The two diagrams on the next page illustrate how a charged particle can have kinetic or potential energy as it moves between two charged plates.

- In the diagram on the left, the positive particle is next to the _______________ charged plate, and therefore has _____________ energy. When it is 'released', the electric force pushes (and pulls) the charge towards the negative plate, and the potential energy is converted into _____________ energy.
- In the diagram on the right, the negative particle is in a low energy state, next to the positive plate. An applied force is required to push it towards the negative plate. In this case work is done on the charge, increasing its _____________ energy.



potential energy is converted into kinetic energy...

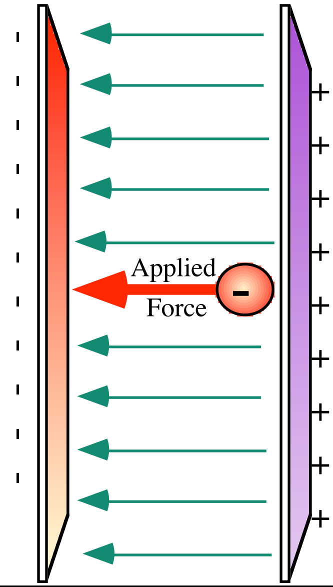
$$\Delta E_k = qV$$

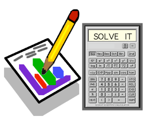
$$\tfrac{1}{2}mv^2 = qV$$

work is done on the charge, supplying potential energy...

$$W = \Delta E_p$$

$$\Delta E_p = qV$$





Sample Problem: Speed of an Electron

An electron is accelerated through a potential difference of 5000 V between two parallel plates. Determine...

a) the change in potential energy of the electron.

b) the speed of the electron as a result of the acceleration.

a)

$\Delta E_p = 8.0 \times 10^{-16}$ J

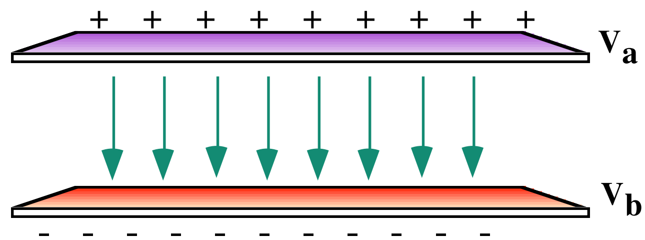
b)

$v = 4.2 \times 10^{7}$ m/s

The electric potential and potential difference are <u>scalar</u> quantities. The potential near a **positive charge** is large and **decreases** toward zero at r = ∞, while near a **negative charge,** the potential is less than zero and **increases** toward zero at r = ∞.

Electric Potential and Electric Field

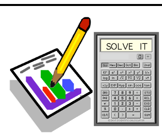
There is a relationship between the electric potential on charged plates and the electric field strength between them. For the parallel plates shown to the right, the potential difference would be (V_a - V_b) which we will abbreviate as V_{ab}.



The electric field between charged parallel plates is given by the equation: $E = \frac{V_{ab}}{d}$

'V' is the potential between the plates and 'd' is the plate separation.
From this equation we see that the units for the electric field can be V/m as well as the earlier unit of N/C.

Therefore: $$1\frac{N}{C} = 1\frac{N \times m}{C \times m} = 1\frac{J}{C \times m} = 1\left(\frac{J}{C}\right) \times \frac{1}{m} = 1\frac{V}{m}$$



Sample Problems: Electric Potential

Solve the problems below. Remember that these will be samples for you to study from later. Hint: look in your textbook for example problems...

1. Calculate the electric potential relative to infinity for (i) a proton and (ii) an electron 0.50 m away.

i)

V = 0

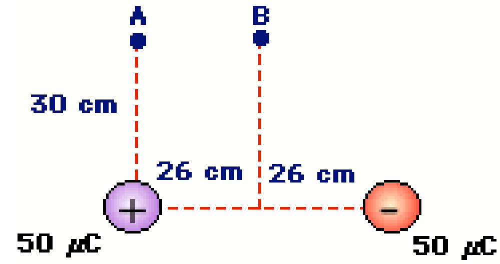
ii)

V = 2.9 x 10^{-9} J/C

2. What work is required to bring a charge q = 3.00 μC from infinity to within 50 cm of a 20 μC charge?

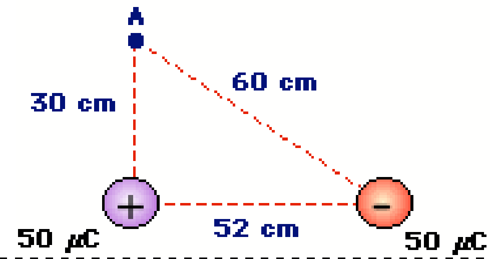
W = 1.08 J

3. Calculate the electric potential at points A and B due to the two 50 µC charges.



Point 'A':

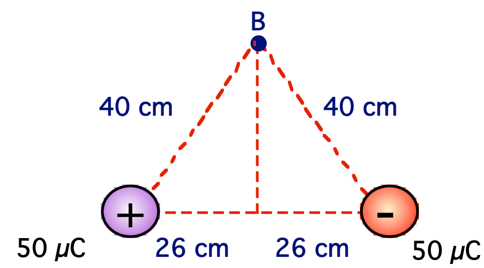
The potential at 'A' is the sum of the potentials due to each charge. Note that potential is <u>not</u> a vector, so we can just add the magnitudes...



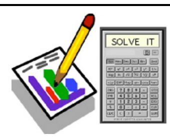
7.5×10^5 V

Point 'B':

The potential at 'B' is the sum of the potentials due to each charge. Note that potential is <u>not</u> a vector, so we can just add the magnitudes...



V = 0.0V



Problem Set #2: Electric Potential and Potential energy

Note: *'rd questions have a simulation to help you solve the problem.

3rd Ed. Giancolli Pg. **455-57** Questions # 1, 6, 9 Problems # 1, 3-5, 7, 9-13*, 41*, 50	4th Ed. Giancolli Pg. **498-502** Questions # 1, 5, 8 Problems # 1-4, 11, 14, 20, 56	5th Ed. Giancolli Pg. **522-25** Questions # 1, 5, 8 Problems # 1, 4, 6-8, 10, 13, 14, 16, 17, 56

