DEVIL PHYSICS
THE BADDEST CLASS ON CAMPUS
IB PHYSICS

Faraday Cage Experiment

LSN 16-1: STATIC ELECTRICITY; ELECTRIC CHARGE AND ITS CONSERVATION
LSN 16-2: ELECTRIC CHARGE IN THE ATOM
LSN 16-3: INSULATORS AND CONDUCTORS
LSN 16-4: INDUCED CHARGE; THE ELECTROSCOPE

Introductory Video

Electrical Charge and Potential

Big Idea(s):

- Objects and systems have properties such as mass and charge. Systems may have internal structure.
- The interactions of an object with other objects can be described by forces.
- Changes that occur as a result of interactions are constrained by conservation laws.

Enduring Understanding(s):

- Electric charge is a property of an object or system that affects its interactions with other objects or systems containing charge.
- Materials have many macroscopic properties that result from the arrangement and interactions of the atoms and molecules that make up the material.

Enduring Understanding(s):

- At the macroscopic level, forces can be categorized as either long-range (action-at-a-distance) forces or contact forces.
- The energy of a system is conserved.
- The electric charge of a system is conserved.

Essential Knowledge(s):

- There are only two kinds of electric charge. Neutral objects or systems contain equal quantities of positive and negative charge, with the exception of some fundamental particles that have no electric charge.
  - Like-charged objects and systems repel, and unlikecharged objects and systems attract.
  - Charged objects or systems may attract neutral systems by changing the distribution of charge in the neutral system.

Essential Knowledge(s):

- The smallest observed unit of charge that can be isolated is the electron charge, also known as the elementary charge.
  - The magnitude of the elementary charge is equal to 1.6 ×10–19 coulombs.
  - Electrons have a negative elementary charge; protons have a positive elementary charge of equal magnitude, although the mass of a proton is much larger than the mass of an electron.

Essential Knowledge(s):

- Matter has a property called electric permittivity.
  - Free space has a constant value of the permittivity that appears in physical relationships.
  - The permittivity of matter has a value different from that of free space.

Essential Knowledge(s):

- Electric force results from the interaction of one object that has an electric charge with another object that has an electric charge.
  - Electric forces dominate the properties of the objects in our everyday experiences. However, the large number of particle interactions that occur make it more convenient to treat everyday forces in terms of nonfundamental forces called contact forces, such as normal force, friction, and tension.
  - Electric forces may be attractive or repulsive, depending upon the charges on the objects involved.

Essential Knowledge(s):

- A system with internal structure can have potential energy. Potential energy exists within a system if the objects within that system interact with conservative forces.
  - The change in electric potential in a circuit is the change in potential energy per unit charge. [Physics 1: only in the context of circuits.]

Essential Knowledge(s):

- The exchange of electric charges among a set of objects in a system conserves electric charge.
  - Charging by conduction between objects in a system conserves the electric charge of the entire system.
  - Charge separation in a neutral system can be induced by an external charged object placed close to the neutral system.
  - Grounding involves the transfer of excess charge to another larger system (e.g., the earth).

Learning Objective(s):

- The student is able to construct an explanation of the two-charge model of electric charge based on evidence produced through scientific practices.
- The student is able to make a qualitative prediction about the distribution of positive and negative electric charges within neutral systems as they undergo various processes.
- The student is able to challenge claims that polarization of electric charge or separation of charge must result in a net charge on the object.

Learning Objective(s):

- The student is able to challenge the claim that an electric charge smaller than the elementary charge has been isolated.
- The student is able to use Coulomb's law qualitatively and quantitatively to make predictions about the interaction between two electric point charges (interactions between collections of electric point charges are not covered in Physics 1 and instead are restricted to Physics 2).
- The student is able to describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy.

Learning Objective(s):

- The student is able to connect the concepts of gravitational force and electric force to compare similarities and differences between the forces.
- The student is able to make quantitative calculations of the internal potential energy of a system from a description or diagram of that system.
- The student is able to apply mathematical reasoning to create a description of the internal potential energy of a system from a description or diagram of the objects and interactions in that system.

Learning Objective(s):

- The student is able to predict electric charges on objects within a system by application of the principle of charge conservation within a system.
- The student is able to design a plan to collect data on the electrical charging of objects and electric charge induction on neutral objects and qualitatively analyze that data.
- The student is able to justify the selection of data relevant to an investigation of the electrical charging of objects and electric charge induction on neutral objects.

Electric Charge

- Electricity is the study of electric charge
- Two kinds of charges: positive and negative
  - Positive charge resides on protons
  - Negative charge resides on electrons

Electric Charge

- Electrons
  - Electrons are lighter, move easier and reside on the outer shell of the atom
  - Electrons can be stripped from an atom leaving a positively charged ion
  - Thus the flow of electricity in solid bodies is due to the motion of electrons
    - In liquids and gases, positive ions can also transport charge
  - Electrons carry the smallest unit of charge of any free particle

Electric Charge

- All materials are classified as either conductors or insulators (unless it is a semi-conductor)
  - Conductors have many free electrons so electricity flows freely through them
  - Insulators, well, don't
  - Semiconductors have properties of both
    - Tend to have greater conductive properties under certain circumstances

Electric Charge

- Electric charge is conserved like total energy – cannot be created or destroyed
  - Electrons are not destroyed
  - Charge is merely balanced
- The total charge of an isolated system cannot change

Electric Charge

- *If two identical conductors have charges of 7μC and -12μC respectively. If the two are allowed to touch and then separated, what will be the charge on each?*

Electric Charge

- *If two identical conductors have charges of 7μC and -12μC respectively. If the two are allowed to touch and then separated, what will be the charge on each?*
- *When the two spheres touch, the net charge will be -5μC. When they separate, each conductor will take half the charge, so each one will have a charge of -2.5μC.*

Electric Force

- Observation shows that there is a force between electric charges
  - Like charges repel each other
  - Opposite charges attract each other
  - Magnitude of the force is directly proportional to the size of the charge, AND inversely proportional to the square of the distance between them

Charging by Friction

- If two different materials are rubbed together, one will pass electrons to the other
- Based on respective triboelectric properties
  - One material is more apt to give up electrons, the other is more apt to capture electrons
  - When materials come in contact, they ‘adhere’ to each other chemically and electrons are passed
  - When they are separated, each has a net charge
  - Referred to as *static electricity* which is really just stored charge

Charging by Induction

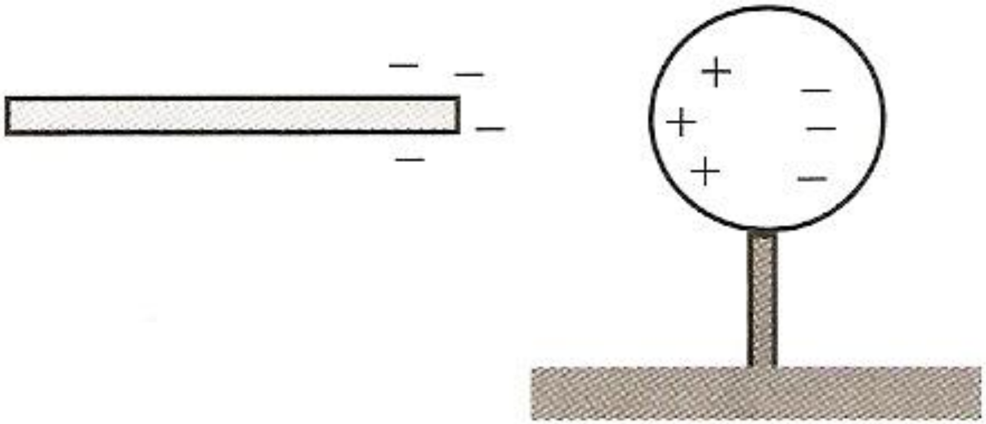

Figure 1.1 A negatively charged rod brought near to an insulated conductor forces electrons in the conductor to the side furthest from the rod.

Charging by Induction

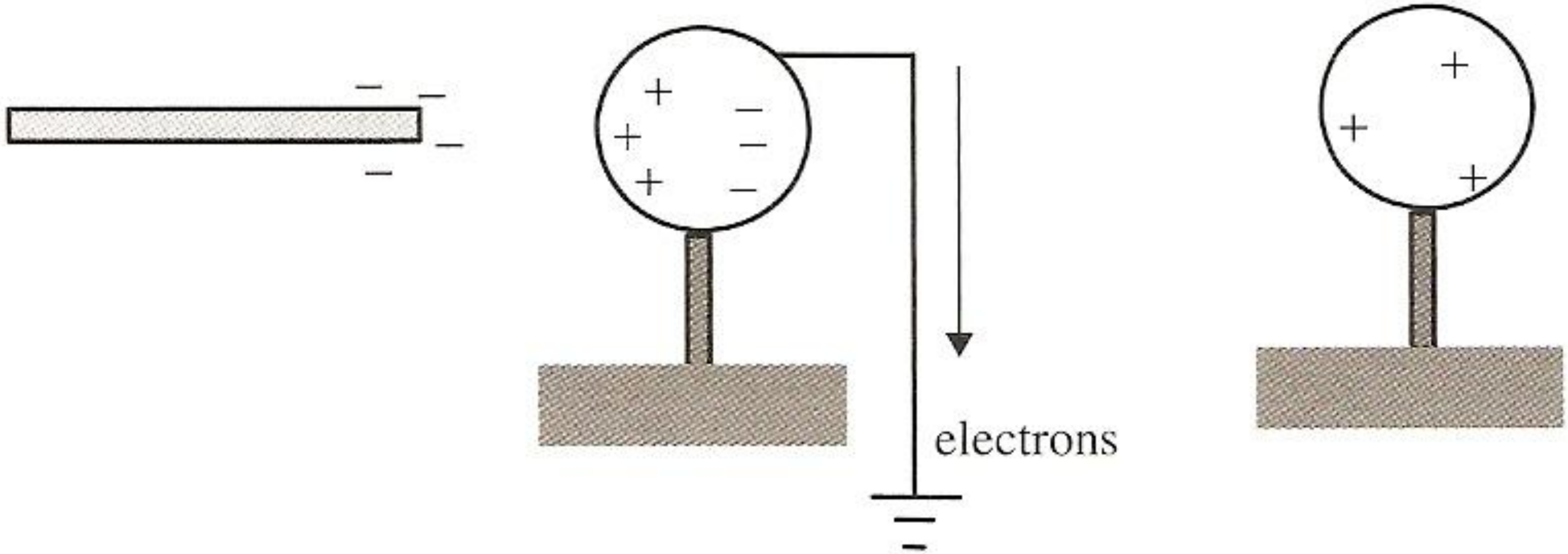

Figure 1.2 If the conductor is earthed, electrons from the conductor flow into the earth, leaving the conductor positively charged.

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left

Charging by Induction

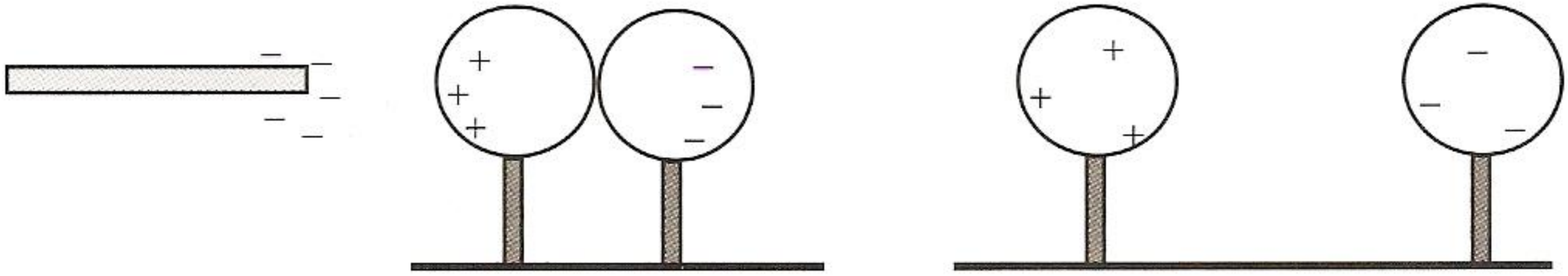


Figure 1.3 A negatively charged rod brought near two touching conductors will induce equal and opposite charges when the conductors are separated (in the presence of the rod).

Charging by Induction Electroscope

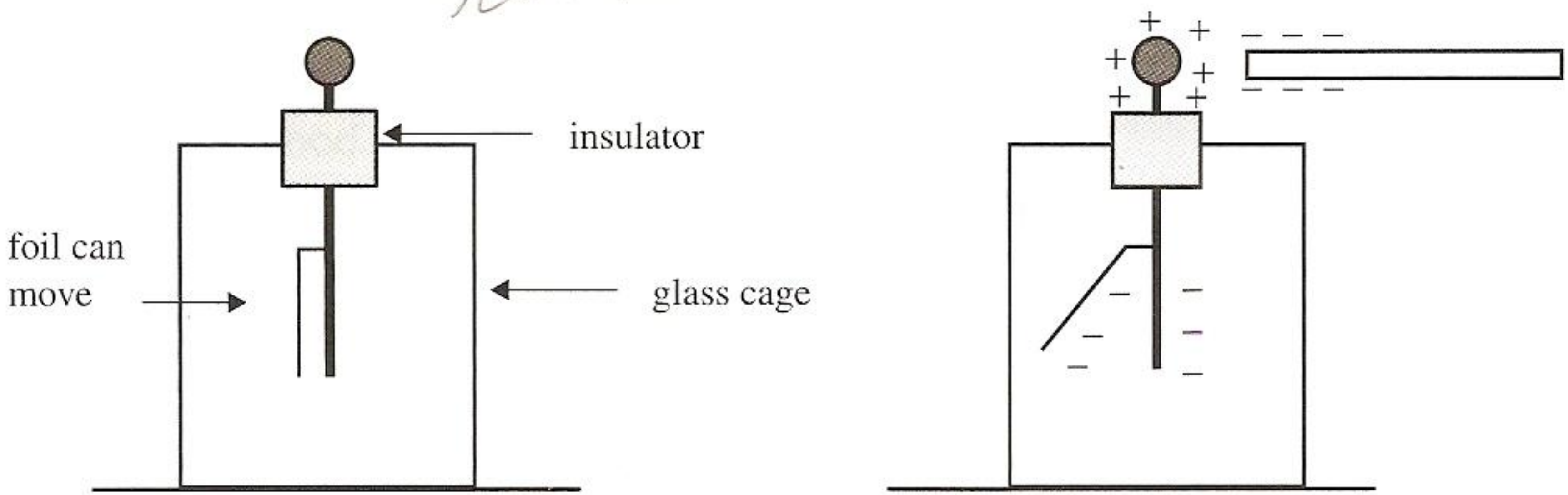


Figure 1.4 A negatively charged rod placed near the ball of the electroscope forces electrons from the ball down to the foil, causing it to diverge.

Charging by Induction Electroscope

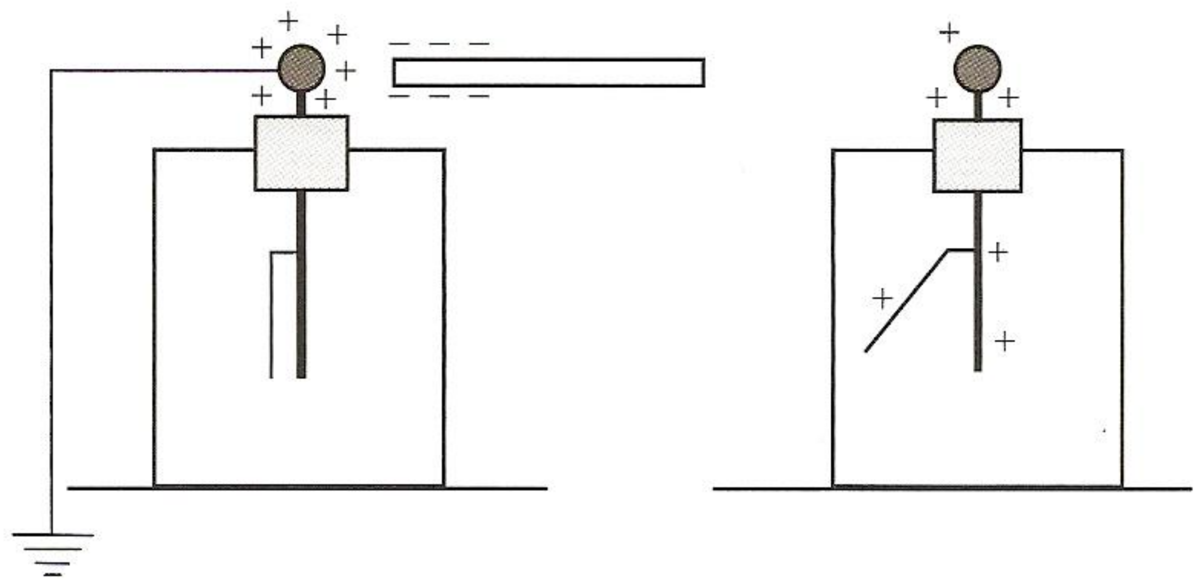
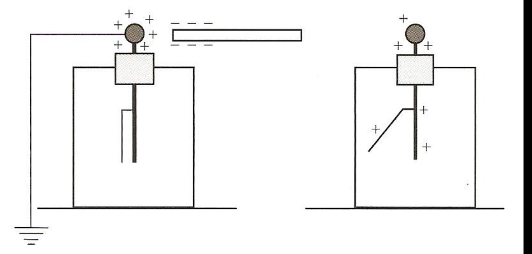


Figure 1.5 If the electroscope is earthed (a) and the rod then removed (b), the electroscope stays positively charged. A positively charged rod would result in a negatively charged electroscope.

Charging by Induction Electroscope



(a) (b)

Figure 1.5 If the electroscope is earthed (a) and the rod then removed (b), the electroscope stays positively charged. A positively charged rod would result in a negatively charged electroscope.

- ***Why did the electrons move to ground?***

Charging by Induction Electroscope

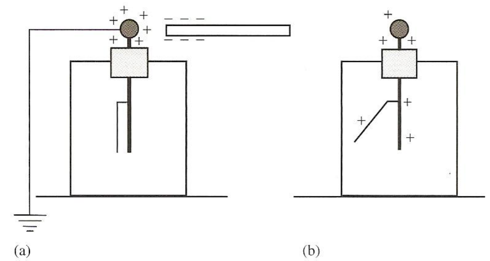


Figure 1.5 If the electroscope is earthed (a) and the rod then removed (b), the electroscope stays positively charged. A positively charged rod would result in a negatively charged electroscope.

- ***Why did the electrons move to ground?***
  - Electrons will always move to *higher potential*
  - When the negatively charged rod was brought near, positive moved to the ball while negative charge moved to the leaves giving them a negative charge
  - Ground, by definition, has a charge of zero
  - When *grounded*, charge will flow from negative *potential* to the higher zero *potential*

Electrostatic Experiments

- In static electricity, i.e. a material is holding a charge, the charge on the conductor resides on the outside of the conductor
- The net charge in the center remains zero

Electrostatic Experiments

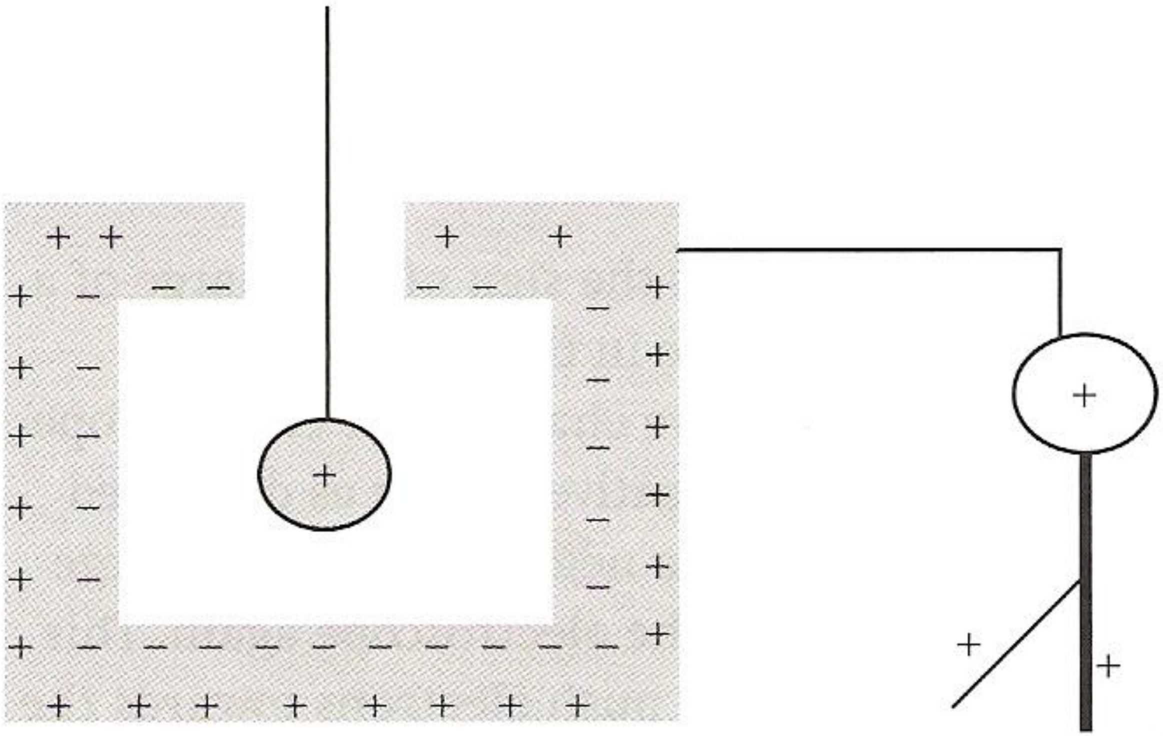


Figure 1.6 A positively charged sphere is lowered into a conducting bucket. Negative charge is induced in the interior of the bucket and an equal amount of positive charge is induced on the outside.

LSN 16-5: COULOMB'S LAW
LSN 16-2: SOLVING PROBLEMS INVOLVING COULOMB'S LAW AND VECTORS

Coulomb's Law

- **Magnitude of the force between charges is directly proportional to the size of the charge, AND inversely proportional to the square of the distance between them**

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

Coulomb's Law

- ε_o is the electric permittivity of a vacuum
- $\varepsilon_o = 8.85x10^{-12}\ C^2\ N^{-1}\ m^{-2}$
- $k = 8.99x10^9\ N\ m^2\ C^{-2}$
- *Notice the similarity to Newton's Law of Universal Gravitation?*

$$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r^2}$$

$$\varepsilon_0 = 8.85x10^{-12}\ C^2/N\cdot m^2$$

$$k = \frac{1}{4\pi\varepsilon_0}$$

$$k = 8.99x10^9\ N\cdot m^2/C^2$$

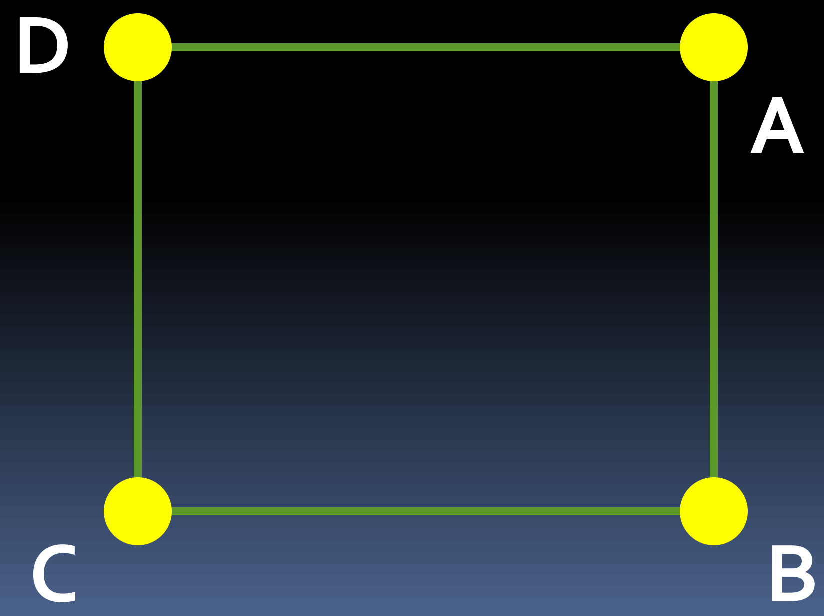
$$F = k\frac{q_1q_2}{r^2}$$

Coulomb's Law

- Sample Problem

Coulomb’s Law

- How about with 4 particles arranged in a square 8 nm to a side, each with a +2 μC charge? What is the net force on A?



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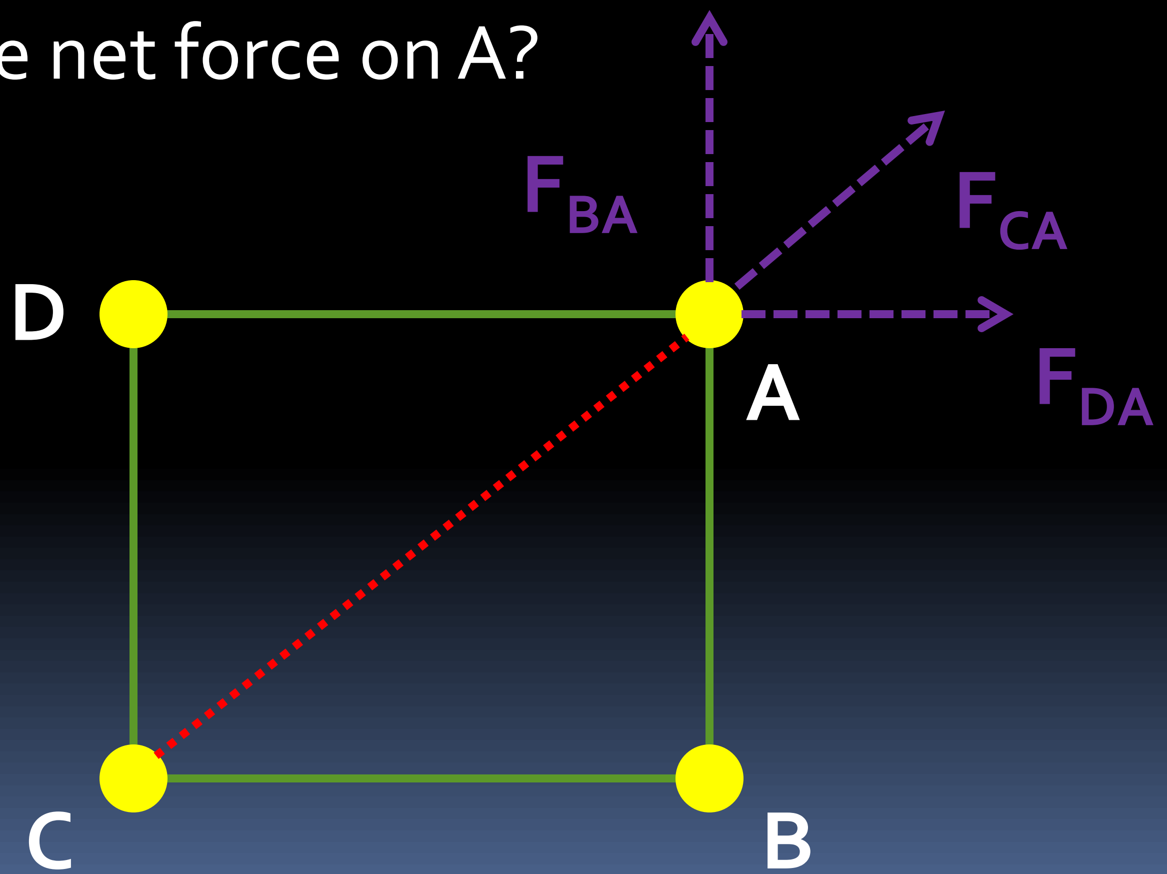

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- The interactions of an object with other objects can be described by forces.
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QUESTIONS?

Homework

- None!!! . . . but, there's 17 problems in the next section

STOPPED HERE ON 8/27/14