FRESHER'S ONLINE BRIDGE COURSES: PHYSICS

VIT-AP UNIVERSITY

by

Dr. Vivek Shukla

Assistant Professor,

Department of Physics,
Vellore Institute of Technology,
Andhra Pradesh (VIT-AP University)
Amaravati, Andhra Pradesh-522237, India
mail- vivek.shukla@vitap.ac.in

Modules to discuss

- Electricity
- Magnetism
- Optics
- Laws of Motion
- Periodic Motion
- Heat and Thermodynamics

Basic Electricity

BASIC ELECTRICAL CONCEPTS

Review

- There are two types of charge: negative and positive.
- Most objects are electrically neutral; they have equal numbers of negative and positive charges (net charge is 0).
- An object becomes charged by adding or removing electrons.
- An electron carries negative charge of magnitude $e = 1.602\times10^{-19}$ C.

Law of Charges

- Like charges repel and opposite charges attract.

Law of charge conservation

- The total charge of an isolated system is strictly conserved.

Conductors are materials where some of the electrons can move freely.
Insulators are materials where none of the charges can move freely.

Electromagnetism

Electromagnetism → Electricity
Electromagnetism → Magnetism
Electromagnetism → Optics

In this course we are going to discuss the fundamental concepts of electromagnetism:

charge	force	field	potential	current
electric circuit	magnetic field	induction	alternating currents	waves
reflection	refraction	image	interference	diffraction

Once you master these basic concepts, you will be ready to move forward, into more ad[illegible]ld of interest

Electromagnetism

Electromagnetism is one of the fundamental forces in nature, and the dominant force in a vast range of natural and technological phenomena

- The electromagnetic force is solely responsible for the structure of matter, organic, or inorganic
- Physics, chemistry, biology, materials science
- The operation of most technological devices is based on electromagnetic forces. From lights, motors, and batteries, to communication and broadcasting systems, as well as microelectronic devices.
- Engineering

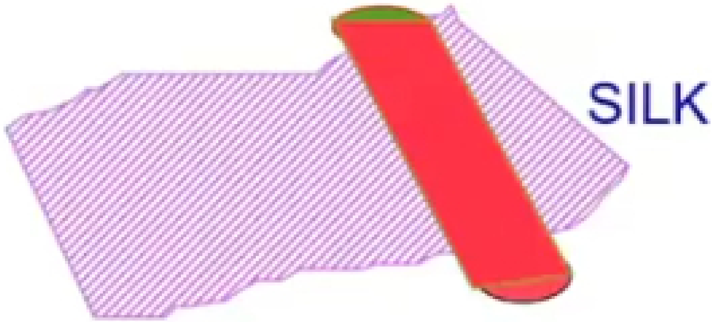
Electric Charge

History

600 BC	Greeks first discover attractive properties of amber when rubbed.
1600 AD	Electric bodies repel as well as attract
1735 AD	du Fay: Two distinct types of electricity
1750 AD	Franklin: Positive and Negative Charge
1770 AD	Coulomb: "Inverse Square Law"
1890 AD	J.J. Thompson: Quantization of electric charge - "Electron"

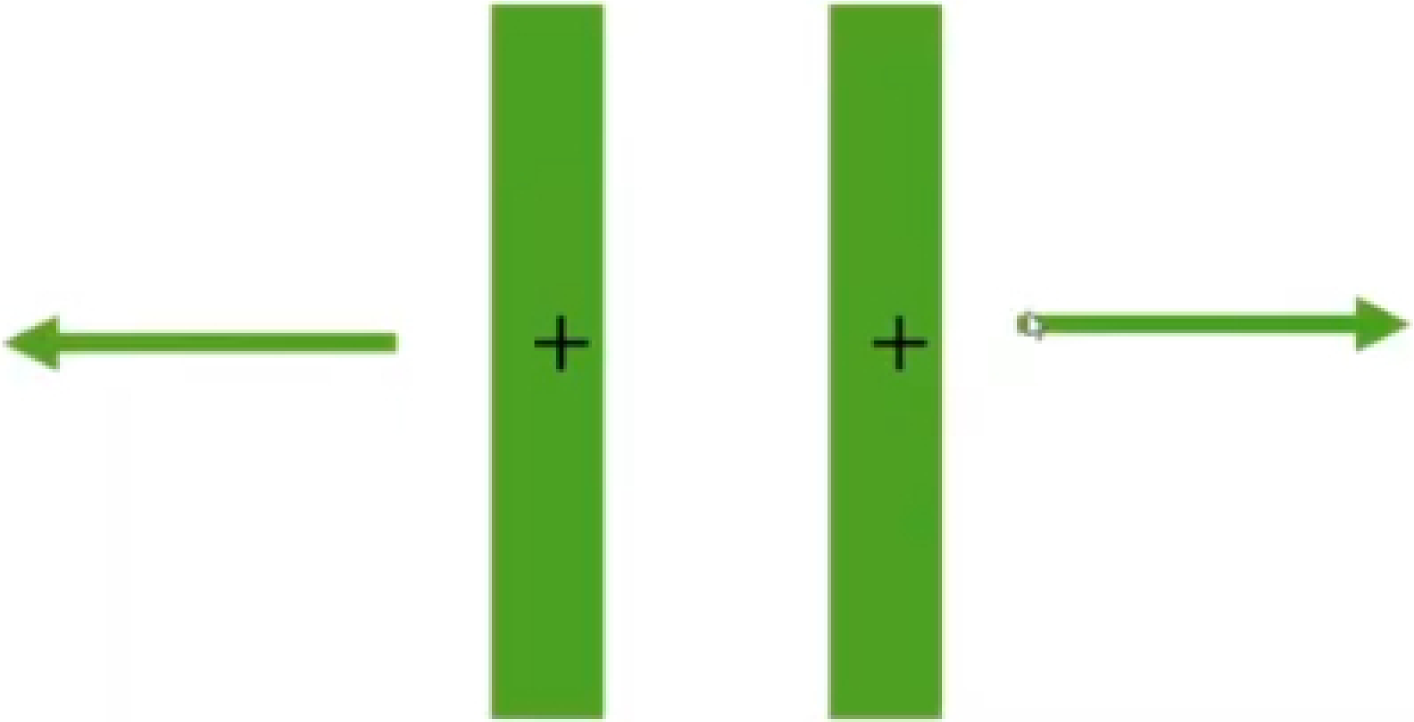
Electric Charge

The Transfer of Charge



Some materials attract electrons more than others.

Electric Charge



Two positively charged rods repel each other.

Forces Between Charges

We observe that

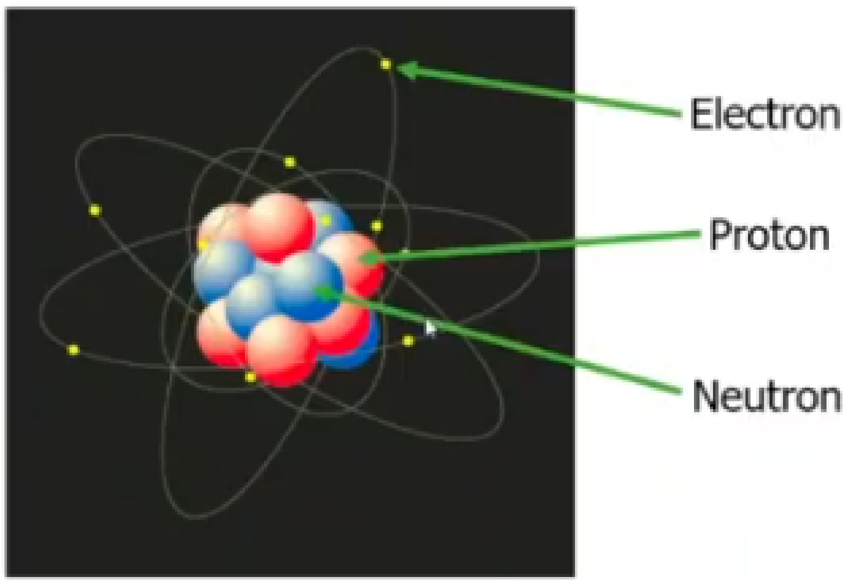
Like charges repel each other

The importance of the atom

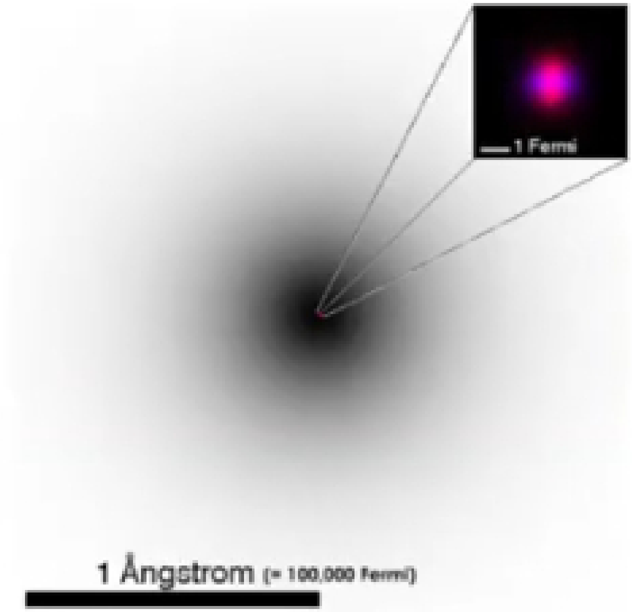
- Atom Structure
  - Made up of electrons, protons, and neutrons
  - The nucleus contains the protons and neutrons.
  - The shell contains the electrons, which orbit the nucleus.
  - The building blocks of matter
- The atomic structure of a material will help to determine the ease of current flow
  - Atoms can be charged.
  - Positive
  - Negative
  - Neutral
- Law of Charges: Like charges repel each other, and unlike charges attract each other.
  - A material that has an excess of electrons will take on a negative charge.
  - A material that has fewer electrons than protons will have a net positive charge.

The Atom

We now know that all atoms are made of positive charges in the nucleus, surrounded by a cloud of tiny electrons.



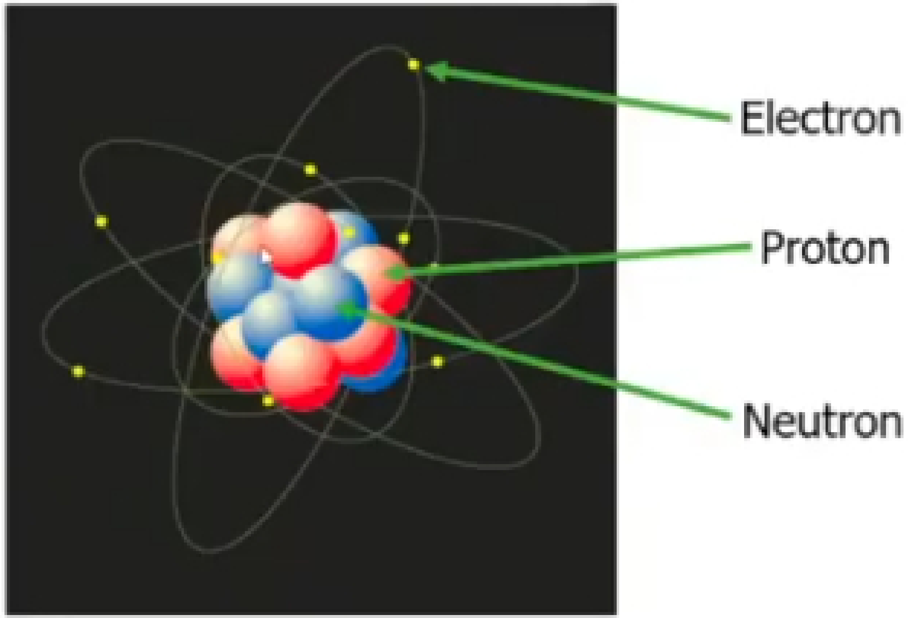
Proton charge +e, electron charge –e where e = 1.602×10^{-19} C



More accurate picture of the atom—the Helium atom

The Atom

We now know that all atoms are made of positive charges in the nucleus, surrounded by a cloud of tiny electrons.



Proton charge +e, electron charge –e where $e = 1.602\times10^{-19}$ C

- Atoms are normally neutral, meaning that they have exactly the same number of protons as they do electrons.
- The charges balance, and the atom has no net charge.

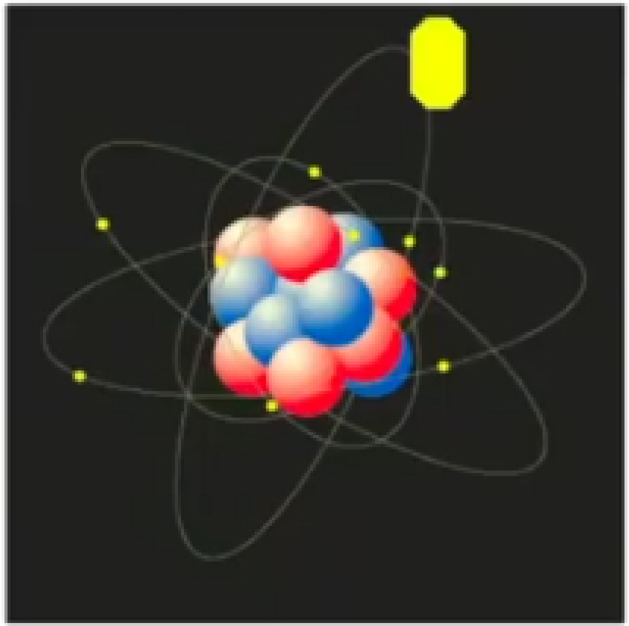
2. Which type of charge is easiest to remove from an atom?

A. Proton

B. Electron

The Atom

In fact, protons are VASTLY more difficult to remove, and for all practical purposes it NEVER happens except in radioactive materials. We will ignore this case. Only electrons can be removed.



3. If we remove an electron, what is the net charge on the atom?

A. Positive

B. Negative

Proton charge +e, electron charge –e
where $e = 1.602\times10^{-19}$ C

Electric Charge

Summary of things we know:

- There is a property of matter called electric charge. (In the SI system its units are Coulombs.)
- Charges can be negative (like electrons) or positive (like protons).
- In matter, the positive charges are stuck in place in the nuclei. Matter is negatively charged when extra electrons are added, and positively charged when electrons are removed.
- Like charges repel, unlike charges attract.
- Charges travel in conductors, not in insulators
- Force of attraction or repulsion ~ $1 / r^2$

Charge is Quantized

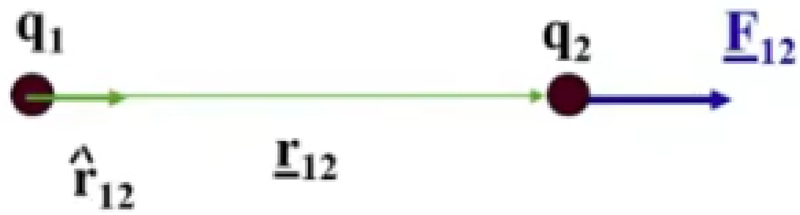
q = multiple of an elementary charge e:

$e = 1.6 \times 10^{-19}$ Coulombs

	Charge	Mass	Diameter
electron	- e	1	0
proton	+e	1836	$\sim 10^{-15}$m
neutron	0	1839	$\sim 10^{-15}$m
positron	+e	1	0

(Protons and neutrons are made up of quarks, whose charge is quantized in multi[illegible] lated.)

Coulomb's Law



$$\underline{\mathbf{F}}_{12} = \frac{k q_1 q_2}{r_{12}^{\ 2}} \hat{\mathbf{r}}_{12}$$ **Force on 2 due to 1**

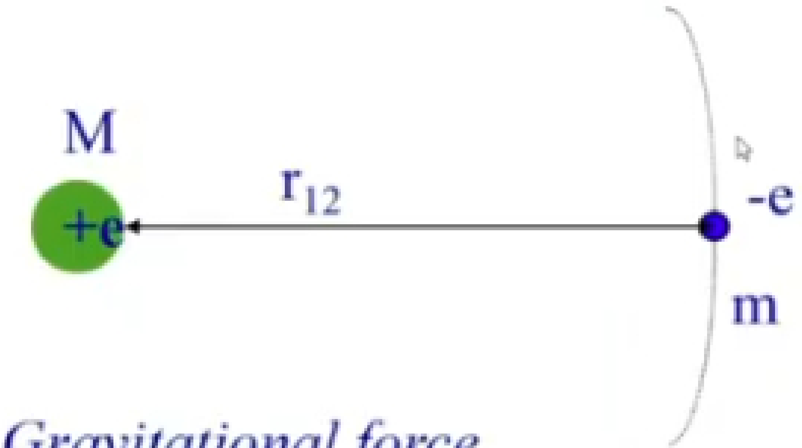
$k = (4\pi\varepsilon_0)^{-1} = 9.0 \times 10^9\ \mathrm{Nm^2/C^2}$

ε_0 = permitivity of free space

$= 8.86 \times 10^{-12}\ \mathrm{C^2/Nm^2}$

Coulomb's law describe … dies due to their charges

Gravitational and Electric Forces in the Hydrogen Atom

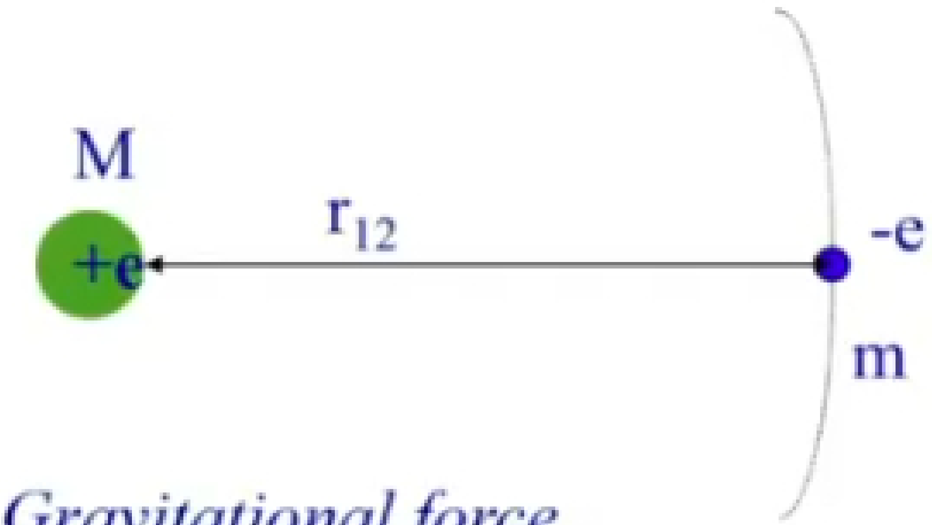


$m = 9.1\ 10^{-31}$ kg
$M = 1.7\ 10^{-27}$ kg
$r_{12} = 5.3\ 10^{-11}$ m

Gravitational force

Electric Force

Gravitational and Electric Forces in the Hydrogen Atom



$m = 9.1\ 10^{-31}$ kg
$M = 1.7\ 10^{-27}$ kg
$r_{12} = 5.3\ 10^{-11}$ m

Gravitational force

$$\vec{F}_g = G\frac{Mm}{r_{12}^2}\hat{r}$$

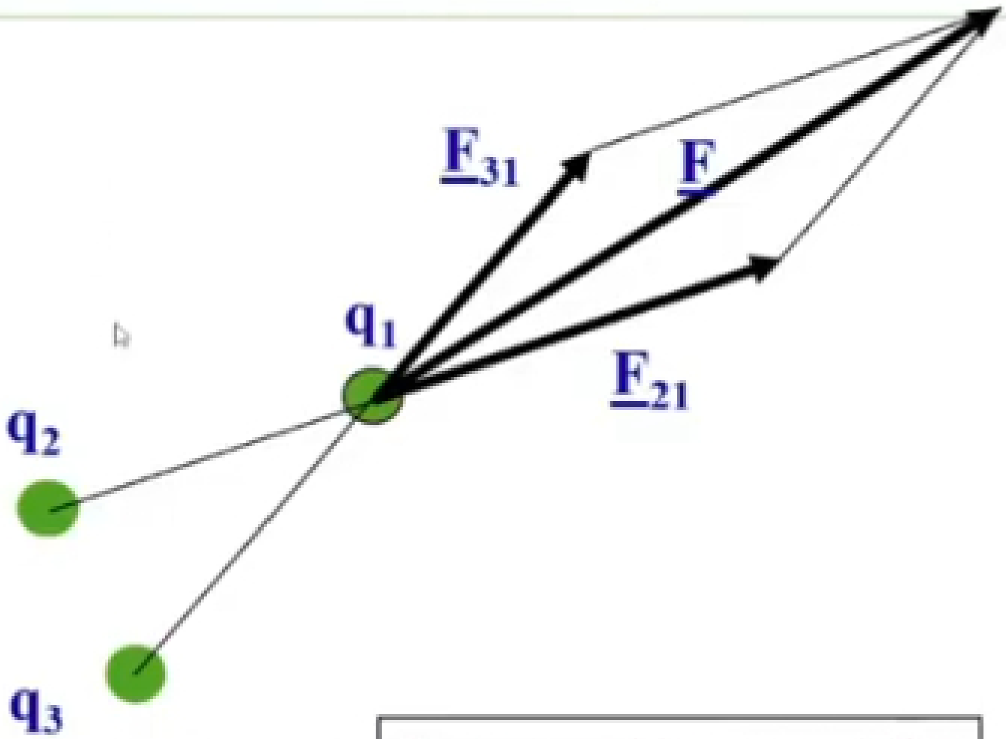
$\boxed{F_g = 3.6\ 10^{-47}\ N}$

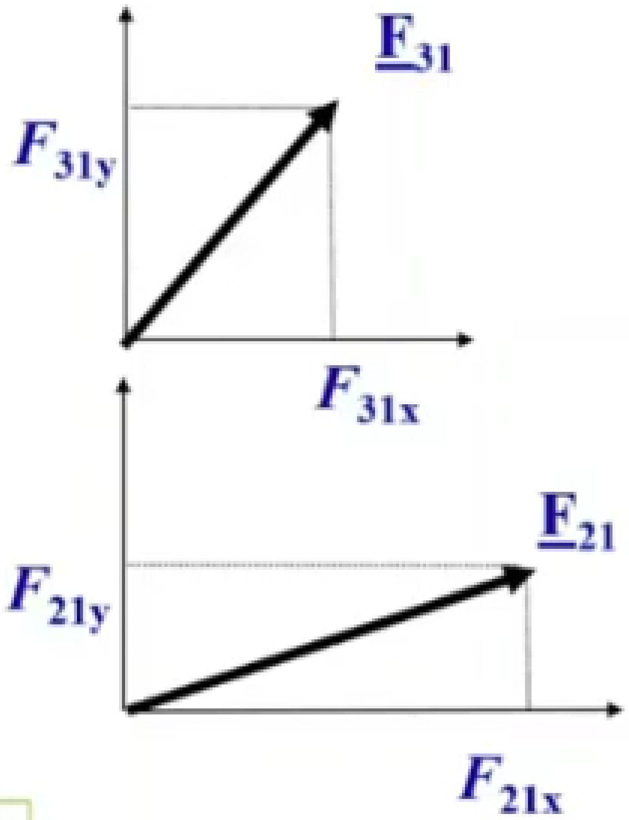
Electric Force

$$\vec{F}_e = \left(\frac{1}{4\pi\varepsilon_0}\right)\frac{Qq}{r_{12}^2}\hat{r}$$

$\boxed{F_e = 3.6\ 10^{-8} N}$

Superposition Principle





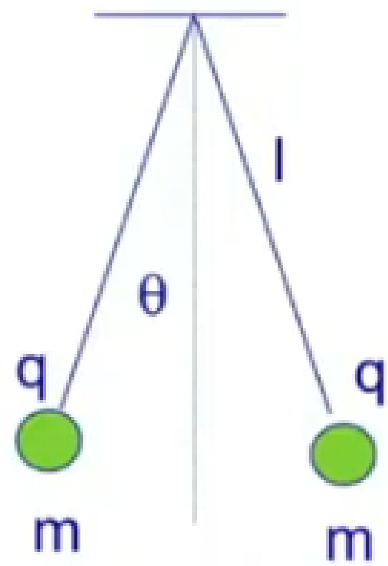
Forces add vectorially

$$\underline{F} = (F_{21x} + F_{31x})\,\underline{x} + (F_{21y} + F_{31y})\,\underline{y}$$

Example: electricity balancing gravity

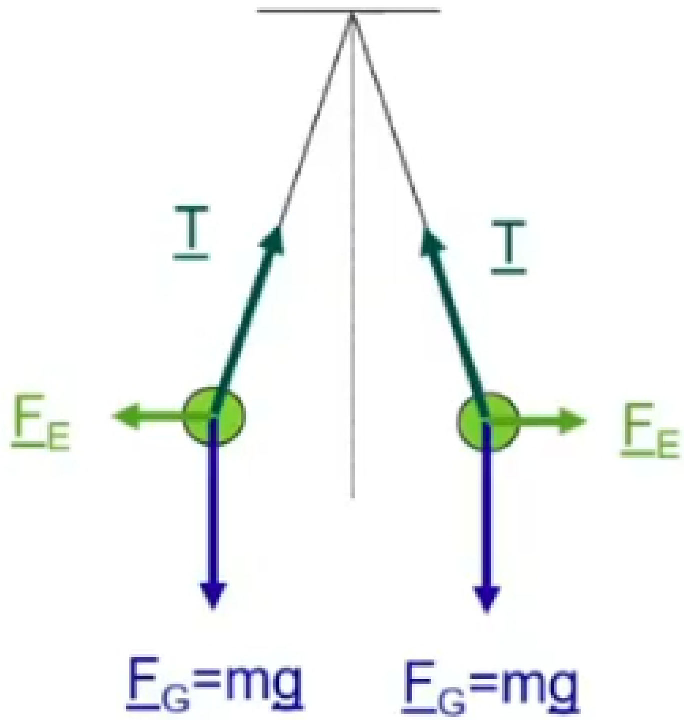
Two identical balls, with mass m and charge q, hang from similar strings of length l.

After equilibrium is reached, find the charge q as a function of θ and l



Example: electricity balancing gravity

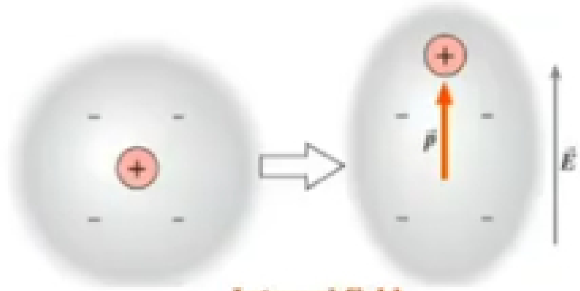
Draw vector force diagram while identifying the forces.
Apply Newton's 3rd Law, for a system in equilibrium, to the components of the forces.



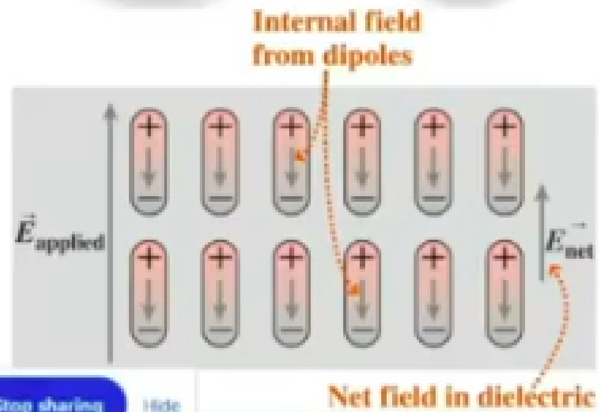
Conductors, insulators, and dielectrics

Materials in which charge is free to move are **conductors.**
Materials in which charge isn't free to move are **insulators.**

- Insulators generally contain molecular dipoles, which experience torques and forces in electric fields.
  - Such materials are called **dielectrics.**



- Even if molecules aren't intrinsically dipoles, they acquire **induced dipole moments** as a result of electric forces stretching the molecule.
- Alignment of molecular dipoles reduces an externally applied field.



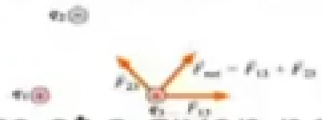
Summary

Electric charge is a fundamental property of matter.

- Charge comes in two varieties, positive and negative.
- Charge is conserved.
- The force between two charges is given by Coulomb's law:

$$\vec{F}_{12} = \frac{kq_1q_2}{r^2}\hat{r}.$$

The electric force obeys the **superposition principle**, meaning the forces due to individual charges sum vectorially.



The **electric field** describes the force per unit charge at a given point: $\vec{E} = \vec{F}/q$.

- The field of a dipole follows from Coulomb's law:
- The fields of discrete charge distributions are calculated by summation.
- The fields of continuous charge distributions are calculated by integration.

$$\vec{E} = \frac{kq}{r^2}\hat{r}.$$

A point charge experiences a force in an electric field.

A dipole experiences a torque in an electric field, and a force if the field is not uniform.

$$\vec{F} = q\vec{E}$$

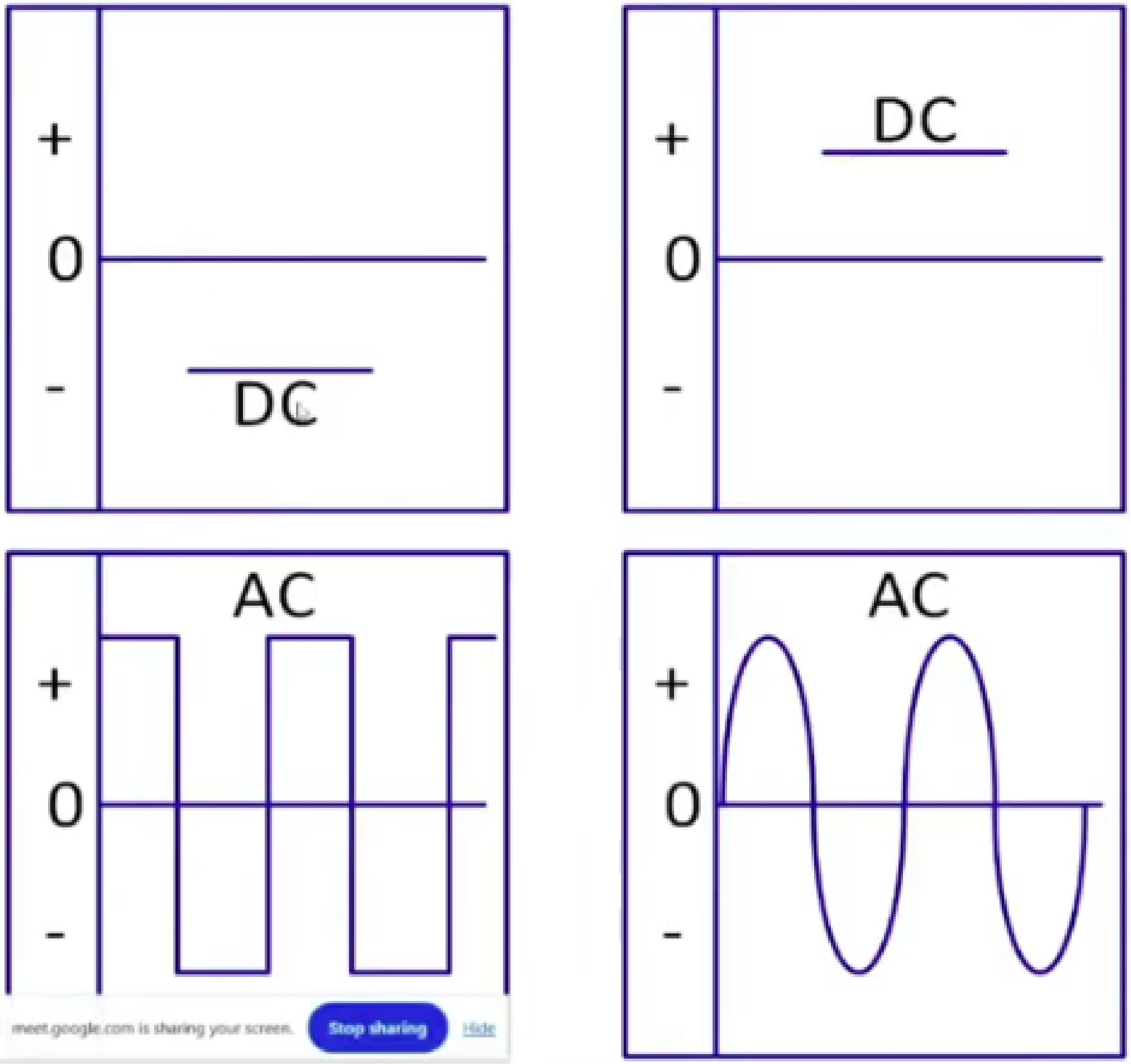
Electrical Materials & Photons

- Electrical materials used
  - Insulators: Materials that inhibit the flow of free electrons; this material has only a few free electrons
  - Conductor: Materials that readily allow for the flow of free electrons and have many free electrons
  - Semi-conductors: A material that has more free electrons than an insulator but fewer free electrons than a conductor
- Photons
  - The basic unit of light energy
  - Light can be considered to consist of a stream of tiny particles of energy called photons.
  - This is used in Solar Photovoltaics and helps with the creation of electricity.
  - P-N Junction could be considered the heart of the solar cell.

Electricity for Renewables

- Direct Current-DC
  - Current flows in one direction only.
  - Car Battery
  - Photovoltaic cells
- Alternating Current-AC
  - Current flows in one direction, then the other, and alternates back and forth.
  - This is what is used in one's home single phase.
  - Can be transformed

Examples of DC & AC Currents

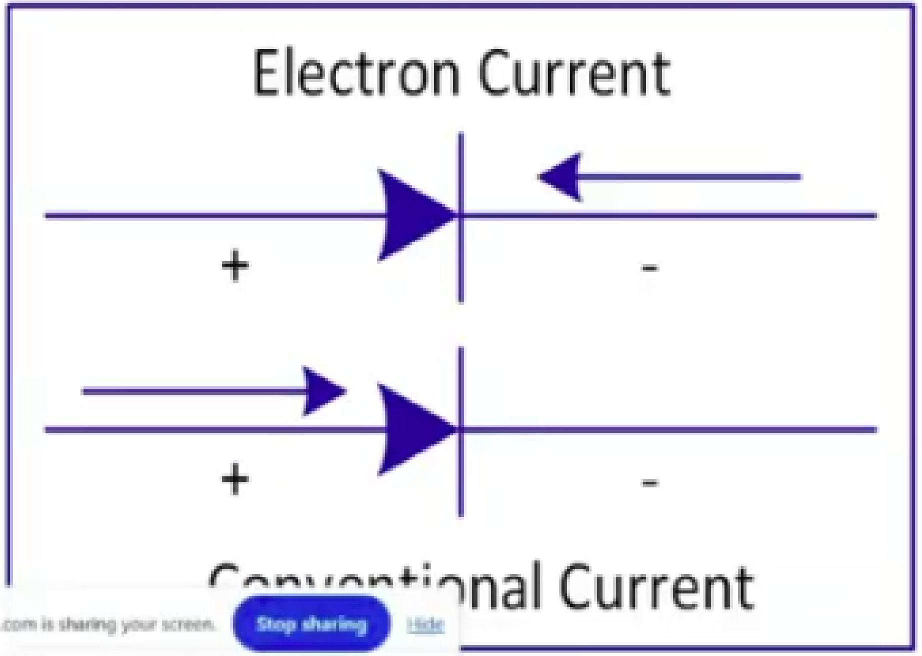


Electricity for Renewables

- Direct Current-DC
  - Current flows in one direction only.
  - Car Battery
  - Photovoltaic cells
- Alternating Current-AC
  - Current flows in one direction, then the other, and alternates back and forth.
  - This is what is used in one's home single phase.
  - Can be transformed

Flow of Electrons through Conductor

- Current: The flow of electrons through a conductor
  - Measure in Ampere
  - Measured with Amp Meter
  - Electron Current flow
    - Negative to positive flow
  - Conventional Current flow
    - Positive to negative flow

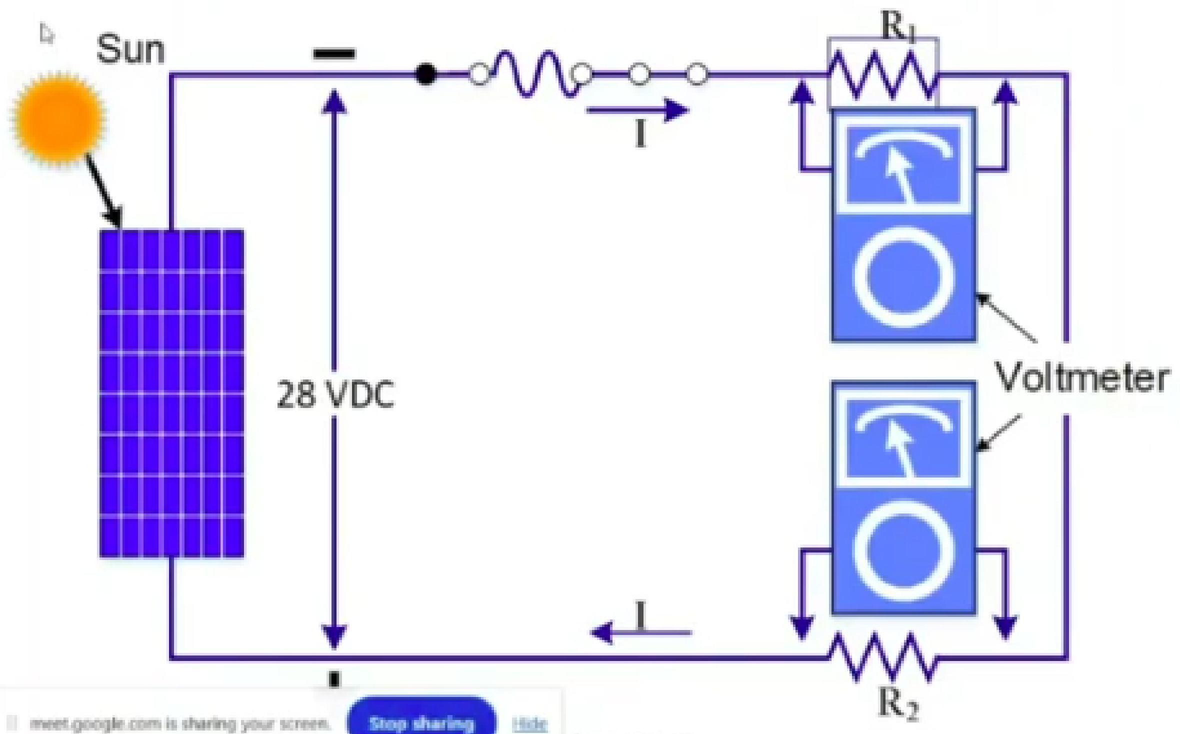


Electricity for Renewables

- Resistance: Opposition to current flow
  - Measured in ohms
  - Measured with ohmmeter
- Power: The rate of work or energy consumption
  - Measured in watts
  - Measures the rate at which energy is used in a circuit

Understanding the Circuit

- A practical circuit contains the four following characteristics:
  - Load: A load consumes power
  - A switch to control load for safety
  - Power supply: Photovoltaic source to produce potential
  - A path for electrons to flow - Wires in the circuit



Ohm's Law

- Ohm's Law
  - It requires one volt to push one amp of current through one ohm of resistance in a DC circuit.
  - It is a proportion that shows how voltage (V), current (I) and resistance (R) are related in a circuit.

$$V = I \, x \, \mathrm{R}$$

$$I = \frac{V}{R}$$

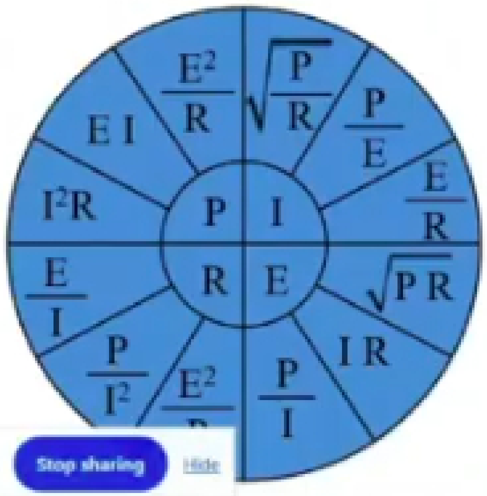
$$R = \frac{V}{I}$$

- Examples:
  - $V = 12V, R = 3ohms$ then
  - $I = ? \, \frac{12V}{3ohms} = 4 \; amps$

Identifying the Equation

- The chart is divided into four sections with formulas that can be utilized.
  - Power (P)
  - Resistance (R)
  - Voltage (V)
  - Current (I)
- Example: If the power is 180 watts and the voltage is 40 volts, then the formula we need to calculate current is:

$$I = \frac{P}{E} = \frac{180}{40} = 4.5\ Amps$$



Equations for Energy Use

- Energy Use: Utility companies sell energy consumption. Any power one can generate on one's own is money saved.
  - $Energy = Power\ x\ Time$
- To determine energy consumed, multiply watts times hours of operation.
  - $Energy\ \text{Consumed} = Watts\ x\ Hours = Watt - Hours\ (Wh)$
- A lighting fixture is drawing .71 amps with 120 volts applied. If the light is lit for 4 hours, how much energy is used?
  - $P = V\ x\ I =\ .71\ amps\ x\ 120\ volts = 85.2\ watts$
  - $Energy = P\ x\ Hours = 85.2\ watts\ x\ 4\ hours = 340.8\ Wh$

Conversions

- Necessary Conversions one needs to know in electrical production kilowatt-hours (kWh) and megawatt-hours (MWh):
  - 1kWh = 1000 watts for 1 hour
  - 1MWh = 1,000,000 watts used for 1 hour
- To convert watts to kilowatts, divide by 1000.
  - Example: If a circuit uses 11,500Wh of energy, a power company will charge the following:
  - $\frac{11{,}500WH}{1000} = 11.5kWh$

Engineering notation with metric prefixes

Prefix	Symbol	Value
Tera	T	One trillion (1,000,000,000,000)
Giga	G	One billion (1,000,000,000)
Mega	M	One million (1,000,000)
Kilo	k	One thousand (1,000)
Milli	m	One thousandth (0.001)
Micro	µ	One millionth (0.000001)
Nano	n	One billionth (0.000000001)
Pico	P	One trillionth (0.000000000001)

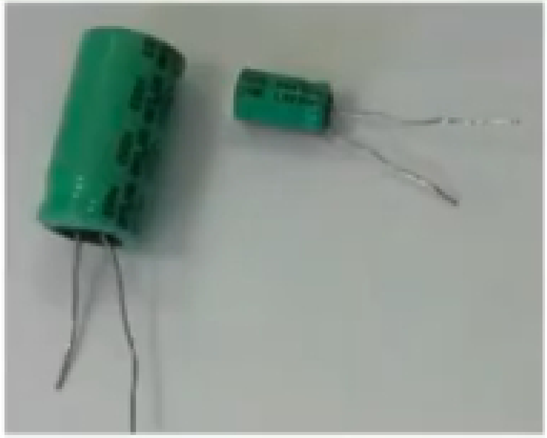
Examples of Conversions

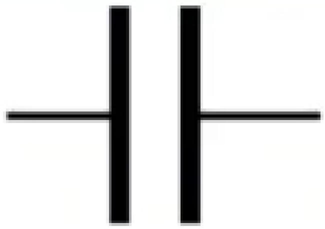
- $1000W = 1\ KW = \frac{1000}{1000}$
- $1{,}500{,}000\ W = 1.5\ MW = (\frac{1{,}500{,}000}{1{,}000{,}000})^*$
- $0.0032A = 3.2\ mA = (\frac{0.0032}{1000})$
- $0.00004A = 40\ microamps = (0.00004\ x\ 1{,}000{,}000)^*$

Capacitors

- A capacitor is a device which is used to store electrical charge (a surprisingly useful thing to do in circuits!).

- Effectively, any capacitor consists of a pair of conducting plates separated by an insulator. The insulator is called a dielectric and is often air, paper or oil.





Capacitance and Applications

- Capacitance is the ability of a system to store electric charge.
- It depends on plate area, separation distance, and dielectric material.
- Capacitance formula: $C = \kappa\varepsilon_0 A/d$
- Applications:
  - Energy storage (e.g., camera flash)
  - Filtering signals in circuits
  - Timing and tuning in radios

Capacitance

The measure of the extent to which a capacitor can store charge is called its **capacitance**. It is defined by

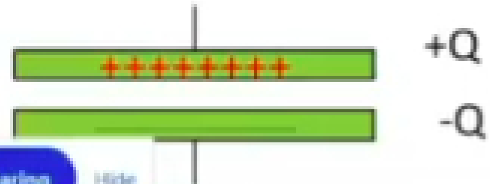
$$C = \frac{Q}{V}$$

C= capacitance (unit farad (F))

Q = the magnitude of the charge on one plate (unit coulombs (C))

V = the p.d. between the plates (unit volts (V))

Notice that in reality the total charge stored by the capacitor is actually zero because as much positive as negative charge is stored. When we talk about the charge stored (Q in this formula) it refers to the excess positive charge on on the positive plate of the capacitor.



Conclusions

Upon completion of this unit, students should be able to

- Protons and neutrons do not move from atom to atom.
- Current is the movement of electrons from one atom to another.
- Insulators inhibit the flow of electrons while conductors allow for free flow of electrons. Semi- conductors are somewhere in the middle and will become critical in PV cell design.
- Photons are energy particles from the sun used in the production of electricity in a PV module.
- Voltage, current, and resistance are all related and used in circuit calculations by incorporating ohms law.
- Energy consumed will be expressed in watt-hours, which is a calculation to use in determining a PV system and its requirements.
- An electrical circuit has four requirements, including switch, load, power supply and conductors.
- Any circuit contains only two different items: a switch to pass power or a load to consume power.
- When working with formulas, the answer is wrong if units are not identified.