DAY 4

PHYSICS → Dr. Vivek Shukla

- Electricity
- Magnetism
- optics
- NLM
- Periodic Motion
- Heat & Thermodynamics

BASIC ELECTRICITY

Basic Electrical Concept

Review

→ There are two types of charge : −ve & +ve

→ most objects are electrically neutral ; ⇒ equal no. of −ve & +ve char (net charge = 0)

→ An object becomes charged by adding or removing electrons

→ An e^- carries −ve charge of magnitude $e = 1.602 \times 10^{-19}$ C

Law of Charges

- Like charges repel & opposite charges attract

Law of charge conservation

- The total charge of an isolated system is strictly conserved

Conductors → materials where some e's can move freely

Insulators → materials where none of the charges can move freely

ELECTROMAGNETISM

- Electricity
- Magnetism
- Optics

Fundamental Concepts of electromagnetism

- Charge
- Force
- field
- potential
- current
- Electric circuit
- magnetic field
- induction
- alternating current
- waves
- reflection
- refraction
- image
- interference
- diffraction

Electromagnetism

Electromagnetism	→ fundamental force of nature
	→ dominant force in a vast range of natural & technological phenomena

→ The electromagnetic force is solely responsible for the structure of matter, organic, or inorganic.

→ Physics, chemistry, biology, material 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 microelectric devices

→ Engineering.

History of Electric Charge

600 BC → Greeks → attractive properties of amber when rubbed

1600 AD → electric bodies attract as well as repel

1735 AD → du Fay: Two distinct types of electricity

1750 AD → Franklin: +ve & -ve charges

1770 AD → Coulomb: "Inverse Square law"

1890 AD → J. J. Thompson: Quantization of electric charge - "electron"

Transfer of Charge

Some materials attract electrons more than other.

Like charges repel: ←⊕ ⊕→ ←⊖ ⊖→

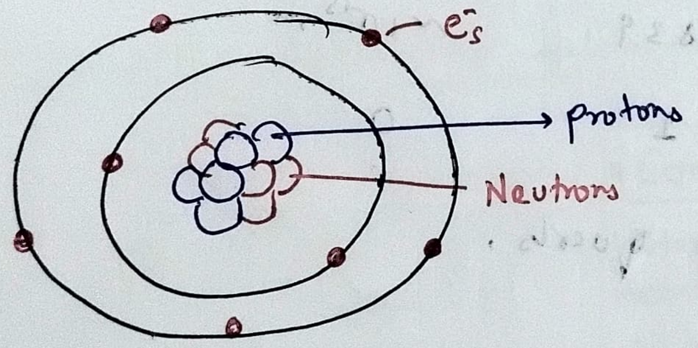
unlike charges attract ⊕→←⊖

The Importance of the ATOM

- Atom structure.
  - Made up of e^-, p^+, and neutron.
  - nucleus contain protons (p) & neutrons.
  - shells contain the e^-s which orbit the nucleus
  - 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. unlike charges attract
- A material that has an excess of e^- ⇒ −ve charge
- A material that has fewer electrons ⇒ +ve charge



THE ATOM :

— made of +ve charges in Nucleus & surrounded by cloud of e^-.

proton → $+e^+$
electron → $(-e)$
$[e = 1.602 \times 10^{-19}\ C]$

- Atoms are normally neutral, → no of e^- = no of protons
- Charges balance, atom has no net charge.
- e^- → easily removable from atom.
- removal of e^- → +ve charged atom.

Electric Charge Summary

- property of matter — SI unit: Coulomb (C)
- can be (−ve) or (+ve)
- +ve charges → nuclei, e's orbit around nucleus
- add^n of e^- → −ve charge
- removal of e^- → +ve charge
- Like charges repel, opposite attract
- Charges travel in conductors, not in insulators
- Force of attr^n OR repulsion $\propto \frac{1}{r^2}$

Charge is Quantized

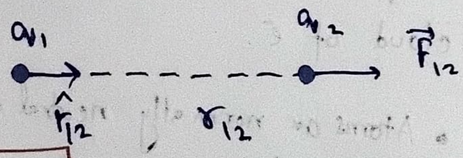
$$\boxed{Q = ne}$$

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

	Charge	mass	Diameter
electron	−e	1	0
proton	+e	1836	~ 10^{-15} m
neutron	0	1839	~ 10^{-15} m
positron	+e	1	0

protons, neutrons → made up of quarks.

Coulomb's Law



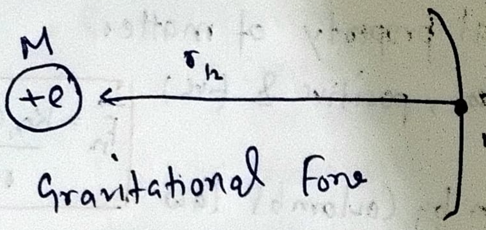
$$\boxed{\vec{F}_{12} = \frac{k q_1 q_2}{r_{12}^2}\,\hat{r}_{12}}$$

$K = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9$ Nm^2/C^2

ϵ_0 = permittivity of free space

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

GRAVITATIONAL AND ELECTRIC FORCES IN HYDROGEN ATOM



Gravitational Force

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

Electric Force

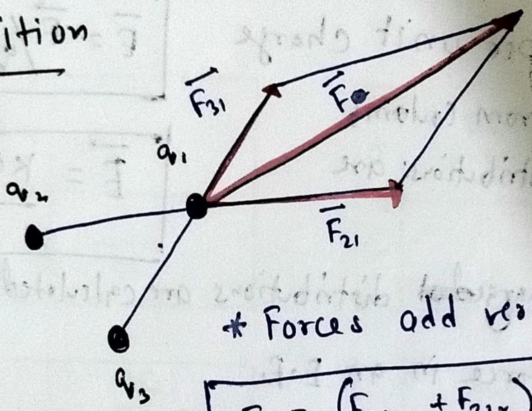
$$\vec{F}_g = G \frac{Mm}{r_{12}^2} \hat{r}$$

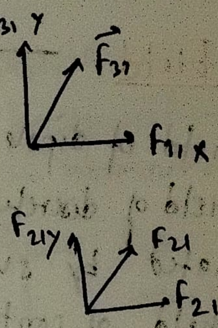
$$\boxed{F_g = 3.6 \times 10^{-47} \text{ N}}$$

$$\vec{F}_e = \left(\frac{1}{4\pi\epsilon_0}\right) \frac{q q}{r_{12}^2} \hat{r}$$

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

Superposition Principle

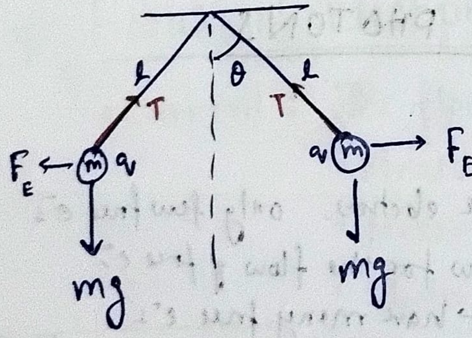




* Forces add vectorically

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

Example: Electricity balancing gravity



• Conductors, insulators and dielectrics

Materials in which charge is free to move — Conductors
Materials in which charge isn't free to move — Insulators

- Insulators generally contain molecular dipoles, which torques and forces in E.F.
- such materials are called dielectrics

Even if molecules aren't intrinsically dipoles, they aquire 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 variables, positive & (-ve)
- charge → conserved
- Force b/w 2 charges is given by Coulomb's law

$$\boxed{\vec{F}_{12} = \frac{K q_1 q_2}{r^2}\hat{r}}$$

- Electric force obeys Superposition Principle,
  ↳ forces due to individual charges sum vectorially.

Electric Field: → Force per unit charge $\boxed{\vec{E} = \vec{F}/q}$

- The field of dipole follows from Coulomb
- The field of discrete charges distributions are calculated by summation.
- The field of continuous charged distributions are calculated by integration

$$\boxed{\vec{E} = \frac{Kq}{r^2}\hat{r}}$$

→ A point charge experiences a force in an E.F.
→ A dipole experiences a torque in an EF & a force if the field is not uniform. $\boxed{\vec{F} = q\vec{E}}$

ELECTRICAL MATERIALS AND PHOTONS

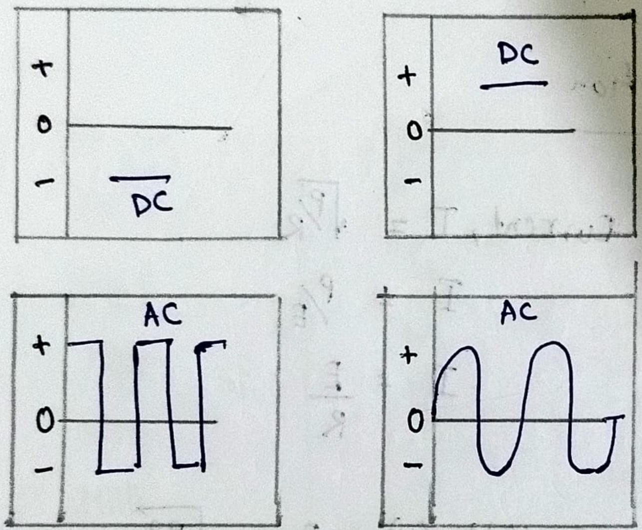
Electrical Materials Used:

- Insulators: inhibit the flow of free electrons, only few free e^-s
- Conductors: Materials → readily allow for the flow of free e^-
  ↳ have many free e^-s.
- Semiconductors: more free e^-s than insulator but less than conductor

Photons:
- The basic unit of light energy
- ~~Light~~ Light → stream of tiny particles of energy → photons
- Used in Solar Photovoltaics and helps with the creation of electricity
- P-N Junction could be considered the heart of solar cell

Electricity for Renewables

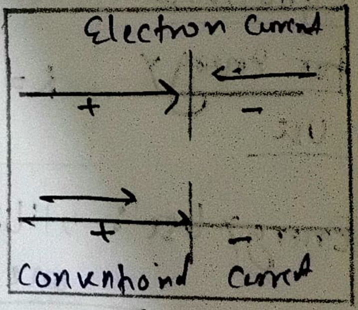
- Direct Current - DC
  - → Current flows in on direction only
  - → car battery
  - → photovoltaic cells
- Alternating Current - AC
  - → Current flows in one direction, then the other and alternates back and forth.
  - → This is what is used in one's home single phase.
  - → Can be transformed.



- Resistance : opposiⁿ to current flow
  - L. Measured in (Ω)
  - L. ohmmeter
- Power: Rate of work or energy consumption
  - L. Watts
  - L. rate at which energy is used in a circuit

Flow of Electrons through Conductors

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



Understanding the circuit

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

Ohm's Law

- It requires one volt to push one ampere 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.

- Examples: $\boxed{V = IR} \rightarrow \boxed{I = \frac{V}{R}} \rightarrow \boxed{R = \frac{V}{I}}$

$V = 12V$, $R = 3$ ohms, then

$I = \frac{12\ V}{3\ ohms} = 4$ amps

- Indentifying the Equation

Power; $P = IE = VI$ Current, $I = \sqrt{P/R}$

$P = I^2 R$ $I = P/E$

$P = \frac{E^2}{R}$ $I = \frac{E}{R}$

Resistance, $R = E/I$ Volty (V) or $E = \sqrt{PR}$

$E = IR$

Equations for Energy Use

$R = \frac{P}{I^2}$ $E = P/I$

$R = \frac{E^2}{P}$

- Energy Use: utility companies sell energy consumption. Any power one can generate on one's own is money saved

$\boxed{\text{Energy} = \text{Power} \times \text{Time}}$

- To determine energy consumed, multiply watts times hours of operation

$\boxed{\text{Energy Consumed} = \text{Watts} \times \text{Hours} = \text{Watt Hours (wh)}}$

Q- drawing 0.71 amp current with 120 V. time = 4 hours Energy used = ?

- $P = V \times I = 0.71\ A \times 120\ V = 85.2$ Watts
- Energy $= P \times T = 85.2$ watts $\times$ 4 hours $= 340.8$ W.hrs

Conversions

- Necessary conversions one needs to know in electrical production kilo watt-hrs (kWh) and megawatt-hours (MWh)

- To convert watts to kilowatts, divide by 1000....
  - 1kWh = 1000 watts for 1 hr
  - 1MWh = 1000 000 watts used for 1 hr.
  - Example: if a circuit uses 11500 Wh of energy, a power company will charge the following:

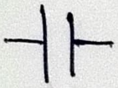
$$\frac{11,500}{1000} \text{ WH} = 11.5 \text{ kWh}$$

Engineering notation with metric prefixes

Prefix	Symbol	Value
Tera	T	one Trillion (10^{12})
Giga	G	one Billion (10^{9})
Mega	M	one million (10^{6})
Kilo	k	one thousand (10^{3})
Milli	m	one thousandth (10^{-3})
Micro	μ	one millionth (10^{-6})
Nano	n	one billionth (10^{-9})
Pico	p	one trillionth (10^{-12})

- $1000\,W = 1\,KW = \frac{1000}{1000}\,kW$
- $1500\,000\,W = 1.5\,MW = \frac{1500\,000}{10^{6}}\,MW$
- $0.032\,A = 3.2\,mA$
- $0.00004\,A$ = 40 micro Amp. = $40\,\mu A$

Capacitors



- device used to store electrical charge (a surprisingly useful thing to do in circuit)
- consist of a pair of conducting plates separated by an insulator. The insulator is called a dielectric and is often air, paper, or oil.

Capacitance & Applications

- Capacitance is the ability of a system to store electric charge.
- depends on plate area, seperation dist., and dielectric material
- $C = \frac{K \epsilon_0 A}{d}$
- Application : – Energy storage (e.g. camera flash)
  – Filtering signals in circuits
  – Timing and tuning in radios

Capacitance

$\boxed{C = \frac{Q}{V}}$ measure of extent to which a capacitor can store charge is called its capacitance.

C → Farad
Q → Coulomb
V → volts

In reality → Net charge on cap. = 0
+ve charge = −ve charge.
Q → excess +ve charge on the +ve plate

CONCLUSION

- ~~Up~~ Protons and neutrons do not move from atom to atom
- Current → movement of e^-
- insulators → resist flow of e^-, conductors → allow flow of e^-, semiconductor → b/w both.
- Photons → energy particles from sun used in production of electricity in PV cell
- Voltage, current, resistance → used in circuit calc. (ohms law) design
- Energy consumed → Watt-hrs, (PV systems)
- electrical has four requirements, including switch, load, power supply & conductors,
- Circuit → only 2 diff items : a swith to pass power or a load to consume power