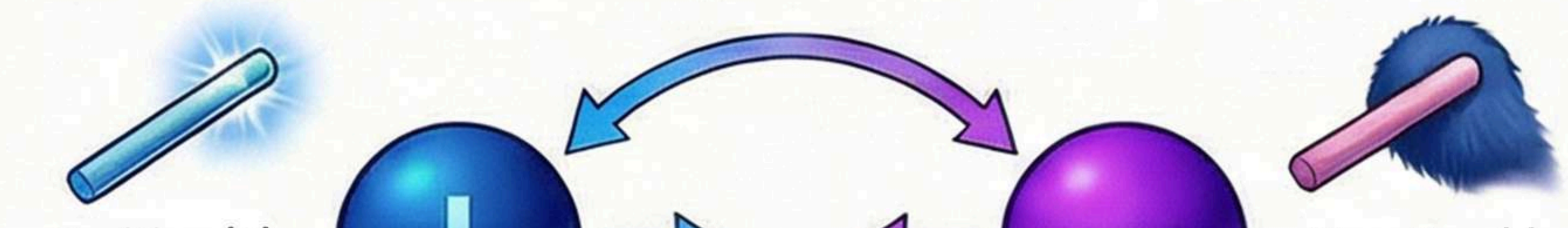
Electric Charges & Fields

1. The Nature of Electric Charge

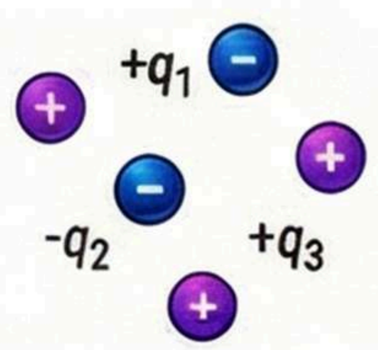


Positive (+) Convention: Glass rod ubbed with silk.

Fundamental interaction: Like charges repel, unlike charges attract.

Negative (-)

Property 1: Additivity



$Q_{total} = q_1 + q_2 + q_3 + ...$

Property 3: Quantization

$q = ne$

(where n is an integer)

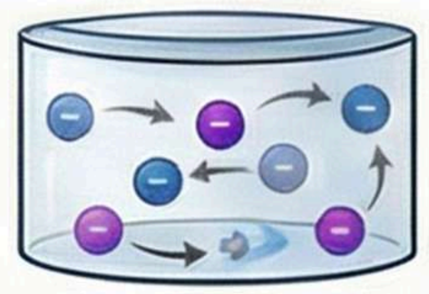
Basic Unit of Charge (e)

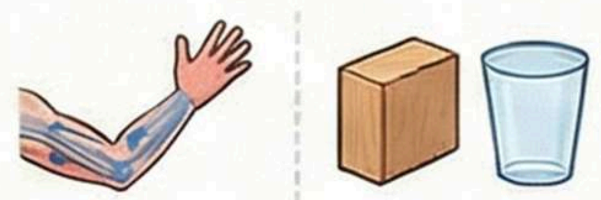
$e = 1.602 \times 10^{-19}$ C

Property 2: Conservation

The total charge of an isolated system remains constant. Charges are transferred, not created or destroyed.

Conductors vs. Insulators





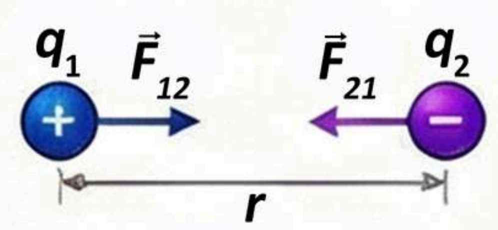
Conductors (e.g., metals, human body)

Insulators (e.g., glass, plastic, wood)

2. Coulomb's Law & Superposition

Force Between Two Point Charges (q_1,q_2)

$$F = k\frac{|q_1 q_2|}{r^2}$$



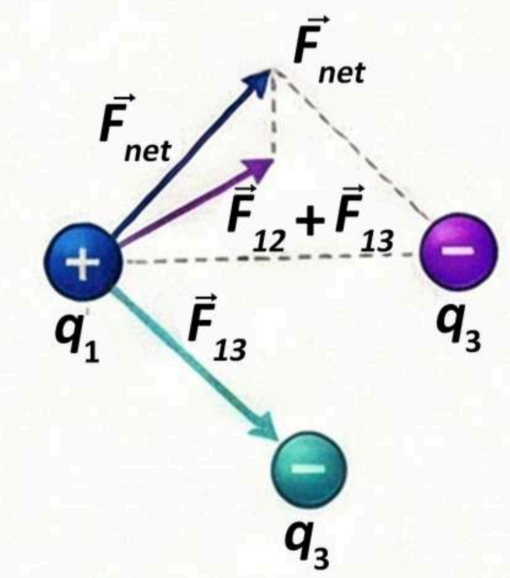
Magnitudes are equal, directions opposite.

Electrostatic Constant (k):

$$k = \frac{1}{4\pi\varepsilon_0} \approx 9 \times 10^9 \text{Nm}^2/\text{C}^2$$

Superposition Principle

Total force is the vector sum of all individual forces.



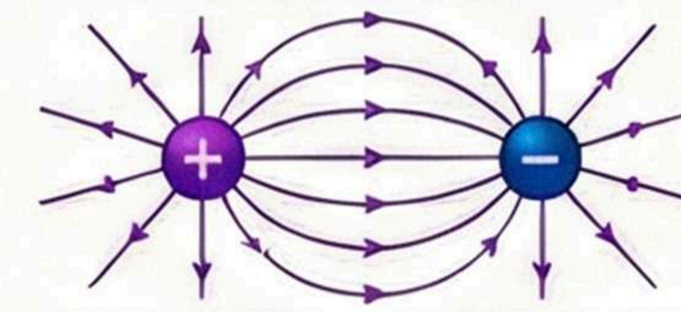
Comparison: Electrostatic vs. Gravitational Force

Property	Electrostatic Force	Gravitational Force
Dependence on Distance	Inverse square law ($1/r^2$)	Inverse square law ($1/r^2$)
Nature of Force	Attractive or Repulsive	Always Attractive
Relative Strength	Enormously stronger (F_{el}/F_g for proton-electron ≈ 2.4 10^{39})	Much weaker

3. The Electric Field & Flux

Electric Field (E):

The space around a charge where its influence is felt.



$E = F/Q$

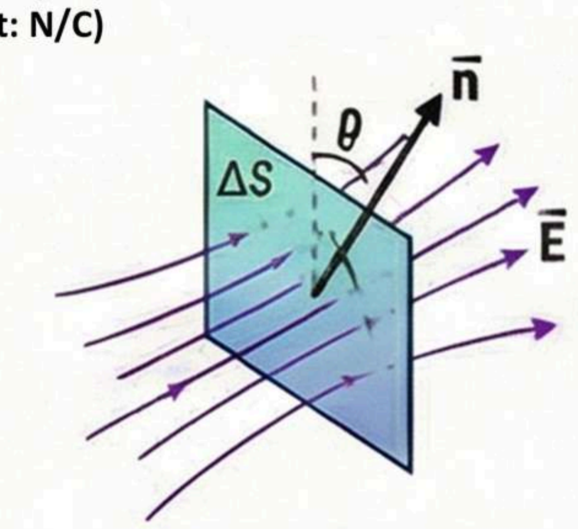
(Unit: N/C)

Field from a Point Charge (Q):

$$E = \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{r^2}$$

Properties of Field Lines:

1. Start from +, end on -.
2. Never cross each other.
3. Do not form closed loops.



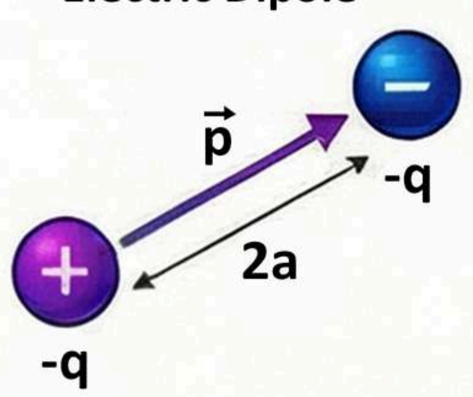
Electric Flux (Φ):

$$\Delta\Phi = \vec{E}\cdot\Delta\vec{S} = E\,\Delta S\cos\theta$$

A measure of field lines passing through a surface.

4. The Electric Dipole

Electric Dipole



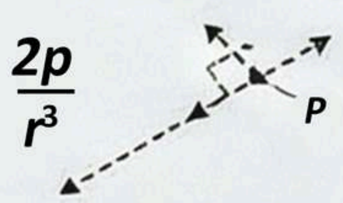
Dipole Moment (p):

$\vec{p} = q \times 2\vec{a}$

(Vector from - to +)

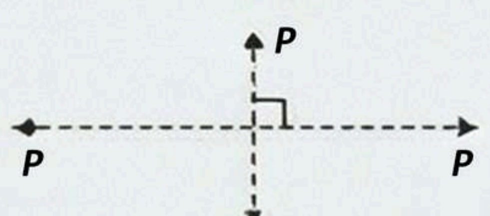
Field on the Axial Line (r > a):

$$E = \frac{1}{4\pi\varepsilon_0} \times \frac{2p}{r^3}$$

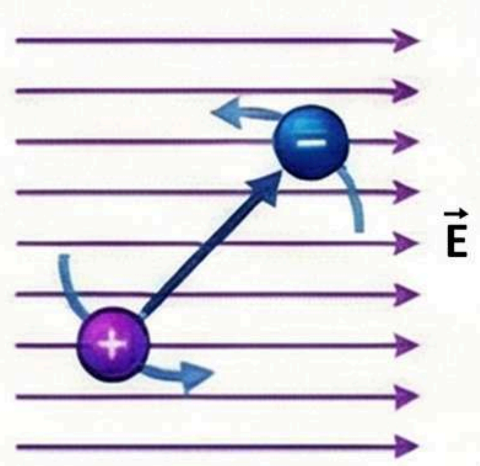


Field on the Equatorial Plane (r > a):

$$E = -\frac{1}{4\pi\varepsilon_0} \times \frac{p}{r^3}$$



$1/r^2$ dependece



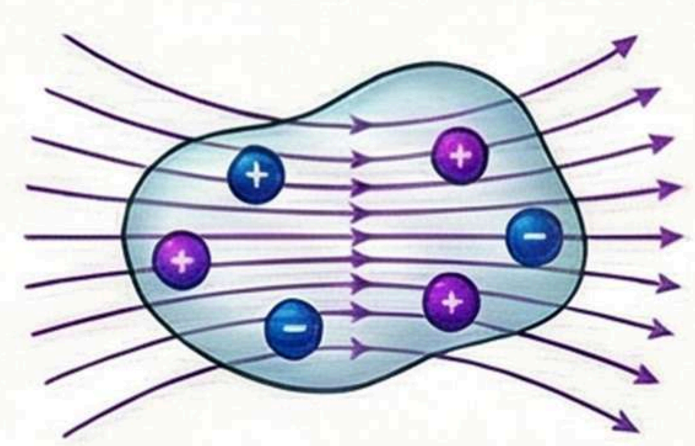
Torque on a Dipole:

$\tau = \vec{p} \times \vec{E}$

(Tends to align dipoles with E). Net force is zero.

5. Gauss's Law & Its Applications

Gauss's Law: $\Phi = \frac{q_{enclosed}}{\varepsilon_0}$

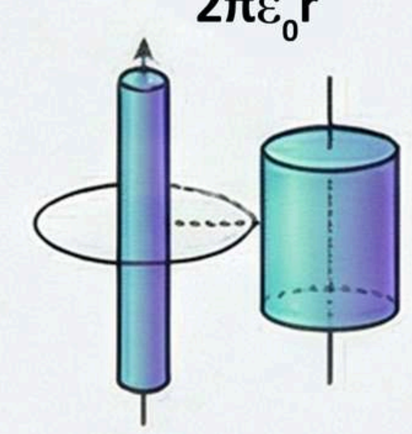


Total flux through a closed surface is proportional to enclosed charge.

Field of an Infinitely Long Straight Wire:

(Linear Charge Density λ):

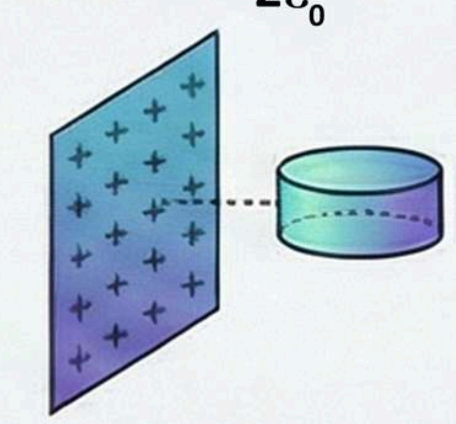
$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$



Field of a Uniformly Charged Infinite Plane Sheet:

(Surface Charge Density σ):

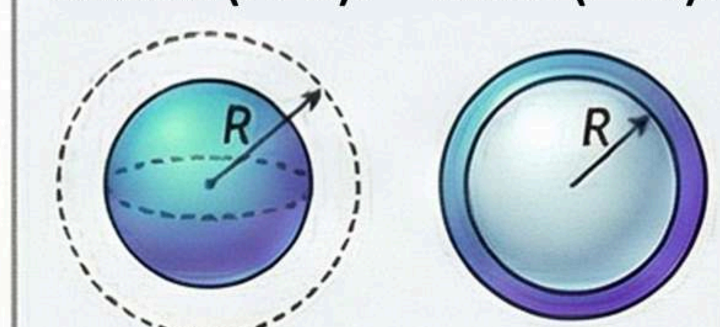
$$E = \frac{\sigma}{2\varepsilon_0}$$



Field of a Uniformly Charged Thin Spherical Shell

(Total charge q, Radius R)

Outside (r > R): Inside (r < R):

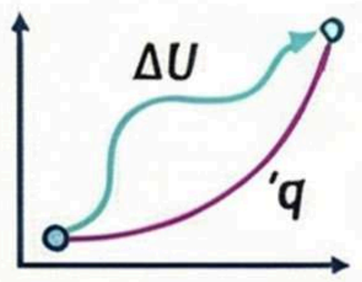


$E = \frac{q}{4\pi\varepsilon_0 r^2}$ $E = 0$

Electrostatic Potential & Capacitance

PART 1: ELECTROSTATIC POTENTIAL & ENERGY

Potential Energy Difference (ΔU)



Work done by external force to move charge 'q' against an electric field without acceleration.

Path-independent.

Electrostatic Potential (V)

The work done per unit positive charge by an external force in bringing a charge from infinity to a specific point in an electric field.

Potential due to a Point Charge (Q)

$$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$$

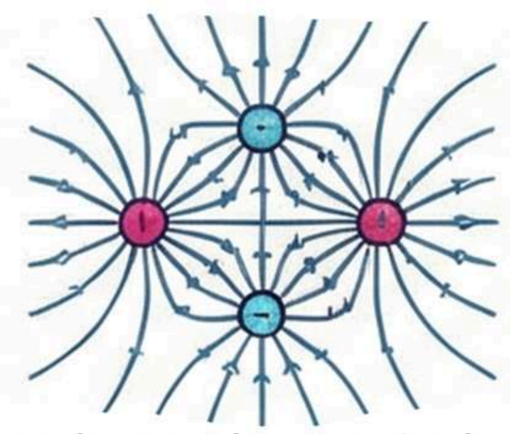
Potential decreases as 1/r

Potential due to an Electric Dipole

$$V = \frac{1}{4\pi\varepsilon_0}\frac{\vec{p}\hat{r}}{r^2}$$

Potential decreases as $1/r^2$, faster than a single charge.

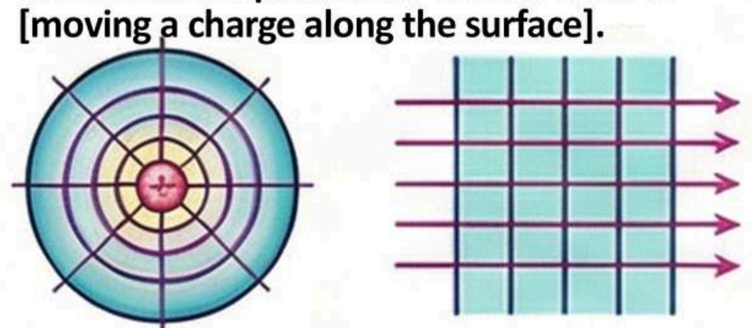
Superposition Principle



The total potential at any point due to a system of charges is the algebraic sum of the potentials due to each individual charge.

Equipotential Surfaces

A surface where the electrostatic potential is constant at all points. No work is done in [moving a charge along the surface].



Field & Equipotential Surfaces are Perpendicular

The electric field (E) is always normal (perpendicular) to the equipotential surface at every point and points in the direction of the steepest decrease in potential.

Relationship Between Field (E) & Potential (V)

$$E = -dV/dl$$

The magnitude of the electric field is the change in potential per unit displacement normal to the equipotential surface.

Potential Energy of a System of Two Charges

$$U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}}$$

q_1 q_2

Series Combination

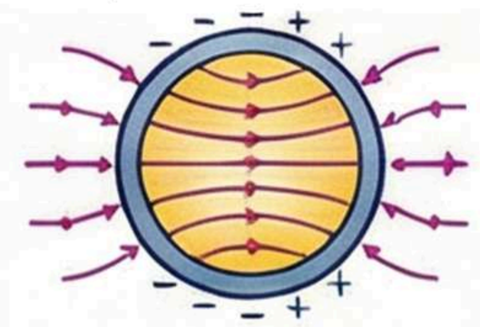
Key Characteristic: Charge (Q) is the same on each capacitor.

Total voltage is the sum

$$1/C_{eq} = 1/C_1 + 1/C_2 + \ldots$$

PART 2: CONDUCTORS, DIELECTRICS & CAPACITANCE

Properties of Conductors in Static Fields



1. The electric field inside is zero.
2. Excess charge on surface only.
3. Potential constant throughout.
4. The field at the surface is perpendicular.

Electrostatic Shielding

The cavity inside the conductor is shielded from external electric fields; the field inside is zero.

This is used to protect sensitive instruments.

Dielectrics & Polarisation

Insulators in the external field produce an internal opposing field, reducing net field inside.

Capacitor & Capacitance (C)

A system of two conductors separated by an insulator used to store charge and energy.

Capacitance is the ratio of charge (Q) to potential difference (V).

Unit: Farad (F).

Parallel Plate Capacitor (in vacuum)

$$c_0 = \frac{B_0 A}{d}$$

Parallel Combination

Key Characteristic: Voltage (V) is the same across each capacitor.

Total charge is the sum

$$C_{eq} = C_1 + C_2 + \ldots$$

Effect of a Dielectric

Inserting a dielectric with constant K between the plates increases capacitance by a factor of K:

$$C = Kc_0$$

Energy Stored in a Capacitor (U)

$$U = 1/2QV = 1/2CV^2 = Q^2/2C$$

Excellency The Experience

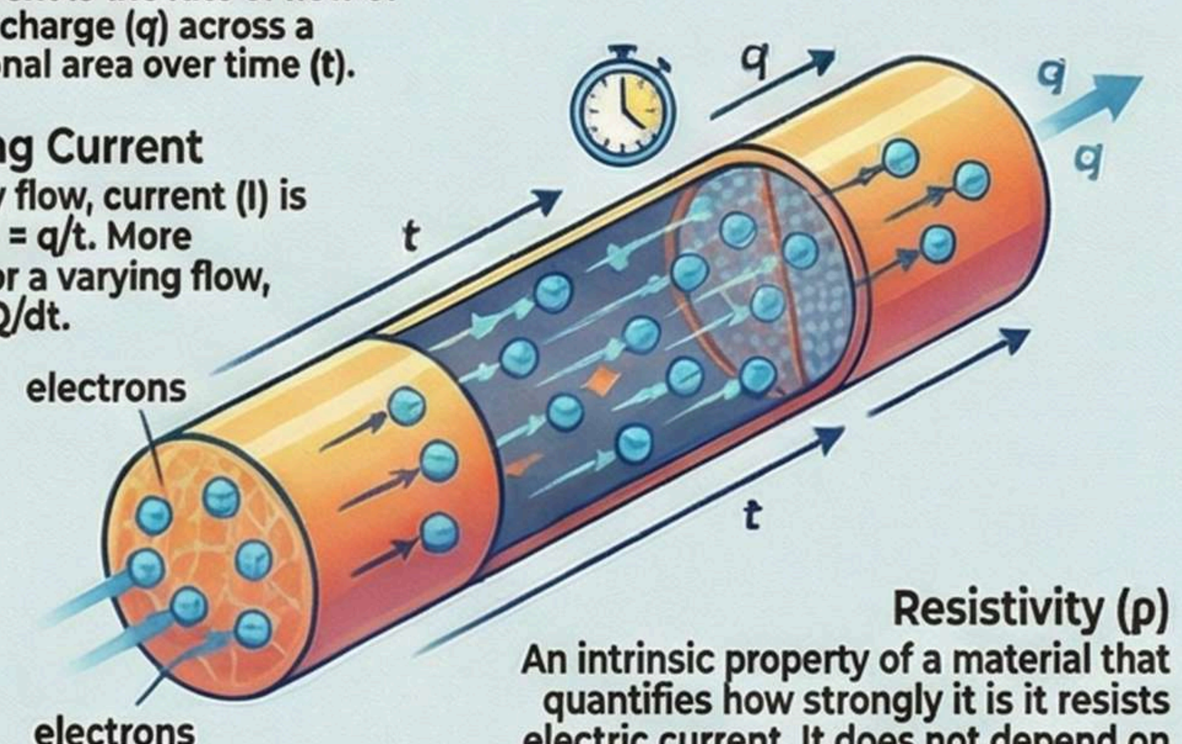
Subject Expo

Current Electricity

1. FUNDAMENTALS OF ELECTRIC CURRENT

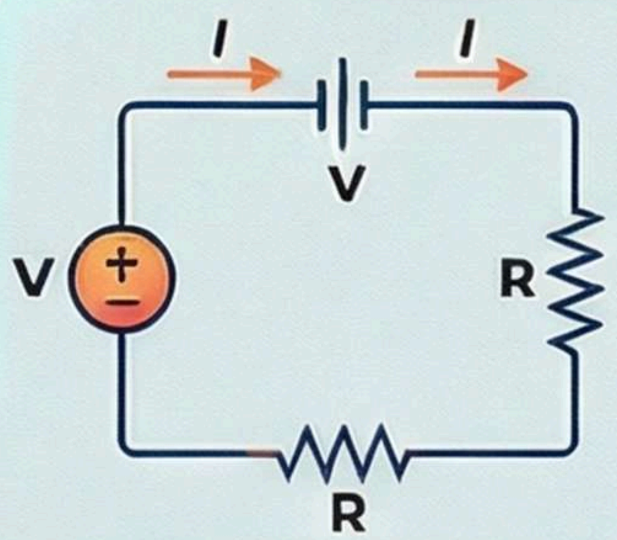
What is Electric Current?
Electric current is the rate of flow of net electric charge (q) across a cross-sectional area over time (t).

Calculating Current
For a steady flow, current (I) is defined as $I = q/t$. More generally, for a varying flow, it is $I(t) = dQ/dt$.



Resistivity (ρ)
An intrinsic property of a material that quantifies how strongly it is it resists electric current. It does not depend on the material's dimensions.

2. OHM'S LAW AND RESISTANCE



Ohm's Law
The voltage (V) across a conductor is directly proportional to the current (I) flowing through it, provided physical conditions like temperature remain constant.

$$V = IR$$

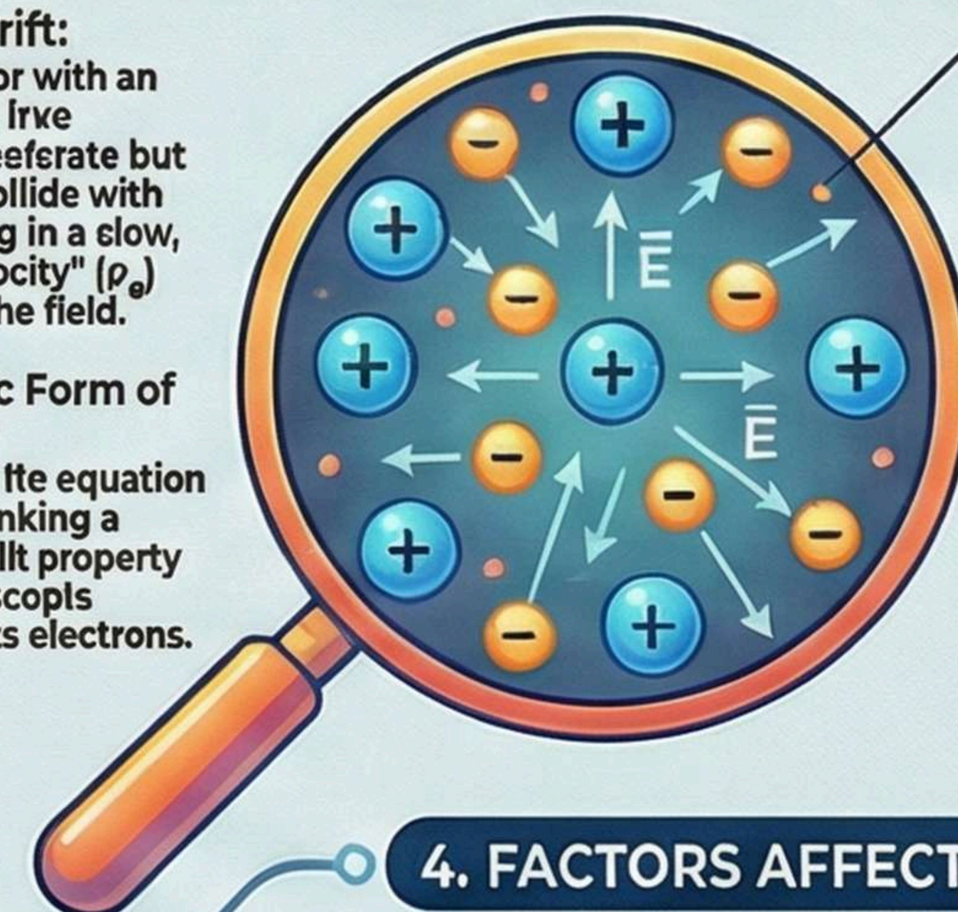
V = potential difference (Volte), I = current (Atpperes), and B = resistance (Ohms, Ω).

Resistance and its Dimensions:
$R = \rho(t)$,
$R = \rho(l/A)$, where ρ is resistivity, l is the length, and A is the cross-sectional area.

3. THE MICROSCOPIC ORIGIN OF RESISTANCE

Electron Drift:
In a conductor with an electric field, lrxe electrons aceeferate but repeatedly collide with lans, resulting in a slow, not "drift velocity" (ρ_e) opposite to the field.

Microscopic Form of Ohm's Law
Resistoed by Ite equation p = m w, linking a material a built property to the microscopls behavior of its electrons.



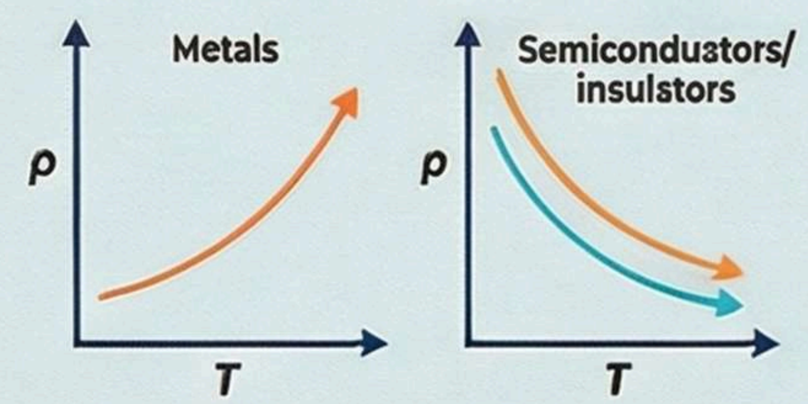
Drift Velocity (v_e):
The average velocity of charge corrlers is given by $v_e = (eE/m)\tau$, where τ is the relaxation time (overage time between collisions).

4. FACTORS AFFECTING RESISTIVITY

Material Classification by Resistivity

Conductors	Semiconductors	Insulators
(e.g., mateial: very low ρ (10^{-8} to 10^{-6} Om)	(e.g., silicon): in between	(e.g., rubber): very high ρ

Temperature's Effect on Materials



For metals, resistivity increases with temperature. For eemiconductors and risulators, resistivity decreases with temperature.

Temperature Dependence of Resistivity:
For matals ever a limited range,
$\rho T = \rho_c[1 + \alpha[T - T_0]]$,
where α is the temperature coefficient of resistivity.

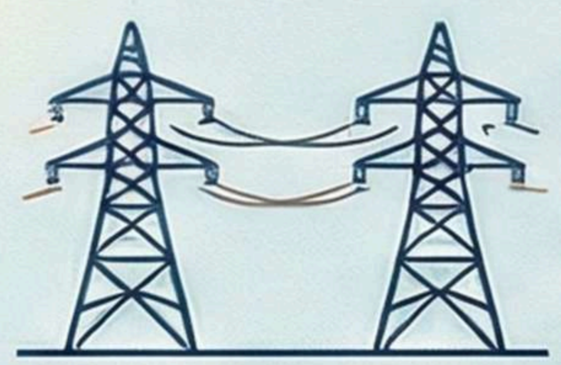
Key Physical Quantities & Formulas Reference

Electric Current	I	Ampore (A)	$I = dQ/dt$
Resistance	R	Glun (D)	$R = V/I$
Resistivity	ρ	Ohm-meter (Rm)	$R = \rho(l/A)$
Electromotive Force (EMP)	ε	Velt (V)	Work/Charge (spae cheult)
Power	P	Welt (W)	$P = VI = I^2R$
Current Density	j	A/m³	$J = I/A$
Difft Velocity	v_d	m/s	$I = noA(v_d)$
Conductivity	σ	Siemons/meter (S/m)	$\sigma = 1/\rho$

5. ELECTRICAL ENERGY AND POWER

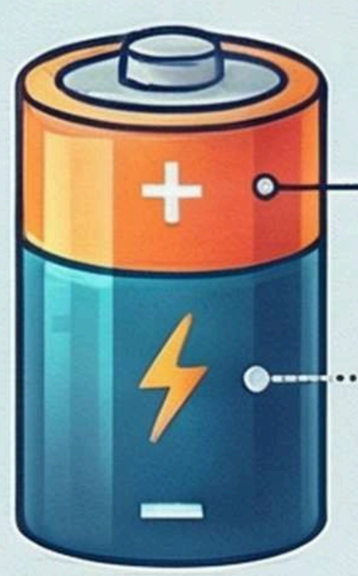
Electric Power: Power (P) is the rate at which electrical energy is dissipated in a circuit component, typically as heet. The SI unit is the Watt (W).

Calculating Power Dissipation:
$$P = VI, \quad P = I^2R, \text{ and } P = \frac{V^2}{R}.$$



Power Transmission:
Power less in transmission cables ($P_c = I^2Rc$) is minimized by transmitting electricity at very high voltages, which reduces the current (I) for a given power ($P = VI$).

6. CELLS, EMF, AND CIRCUIT ANALYSIS

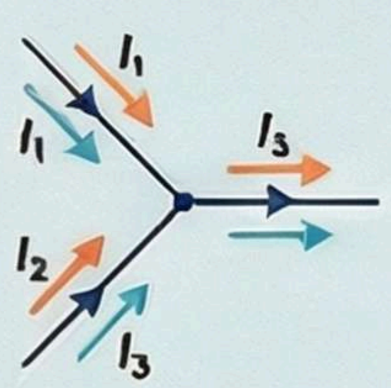


Electromotive Force (EMF or ε):
The potential difference between the terminals of a cell when no current is flowing jupen circuit), it represents the total energy per unit charge supplied by the source.

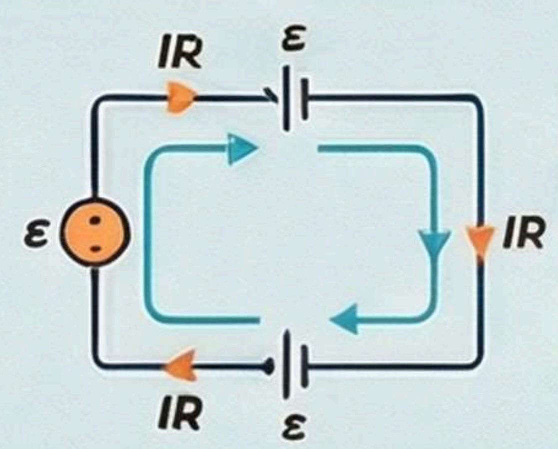
The actual voltage across a cell's terminals when it supplies a current (I) is
$V = \varepsilon - Ir$

Internal Resistance (r)
The resistance offered by the electrolyte and electrodes within a cell, which causes a voltage drop when current flows.

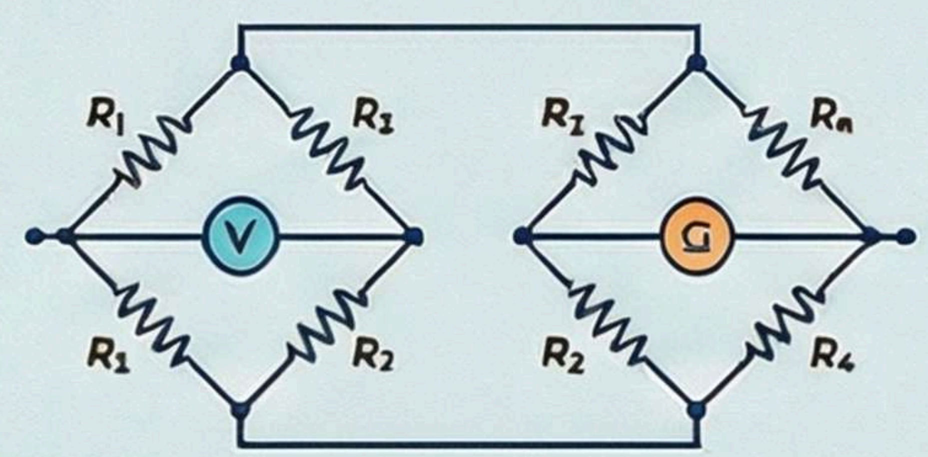
7. KIRCHHOFF'S RULES FOR COMPLEX CIRCUITS



Rule 1:
Junction Rule
The sum of currents entering any junction is equal to the sum of currents leaving that junction. This is based on the conservation of charge.



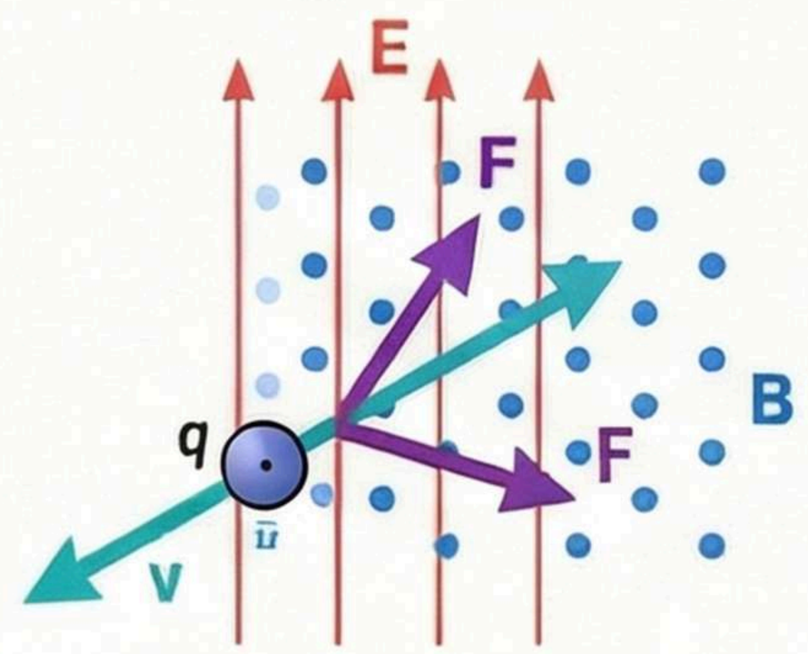
Rule 2:
Loop Rule
The algebraic sum of the changes in potential around any stosed circuit loop is zero. This is based on the conservation of energy.



Wheatstone Bridge
A chcuit used to measure an unknown resistance. The bridge is "balanced" (no current through the gaivcnometer) when the condition $\frac{R_c}{R_1} = \frac{R_c}{R_2}$ is met.

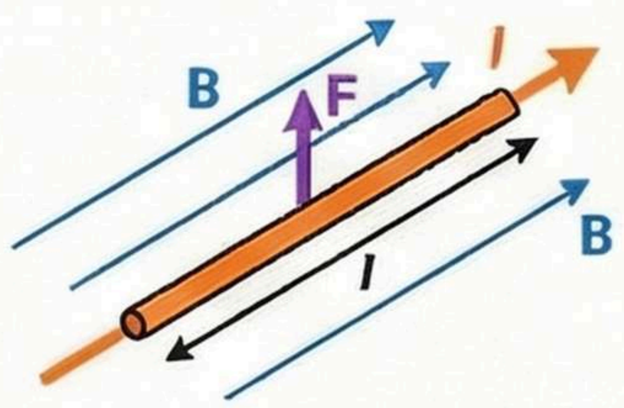
Moving Charges and Magnetism

1. The Magnetic Force



Lorents Force:
The Total Electromagnetic Force.
$F = q[\vec{E} + (\vec{v} \times \vec{B})]$

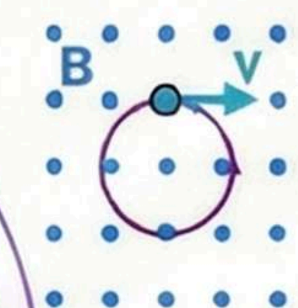
Nature of Magnetic Force:
The magnetic force $F = q|\vec{v} \times \vec{B}|$ is always perpendicular to both the velocity (v) and the magnetic field (B). Consequently, it does no work and cannot change the kinetic energy of the charge.



Force on a Current-Carrying Wire.
$\vec{F} = I(\vec{l} \times \vec{B})$

The Tesla: Unit of Magnetic Field (T).
$1\ G = 10^{-4}\ T$

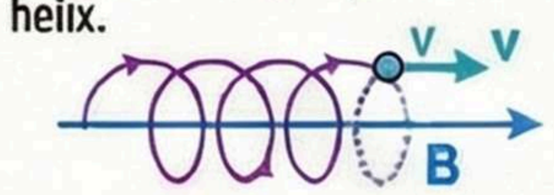
2. Motion of a Charged Particle in a Magnetic Field



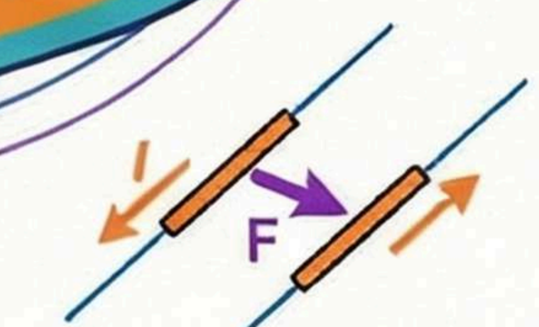
Circular Motion in a Perpendicular Field: Magnetic force acts as a centripetal force, causing the particle to move in a circle.

Radius of Circular Path:
$r = \frac{mv}{qB}$

Helical Motion: If the velocity has a component parallel to the magnetic field, its path will be a heilx.



Cyclotron Frequency:
$\nu_c = \frac{qB}{2\pi m}$
(independent of speed or energy)



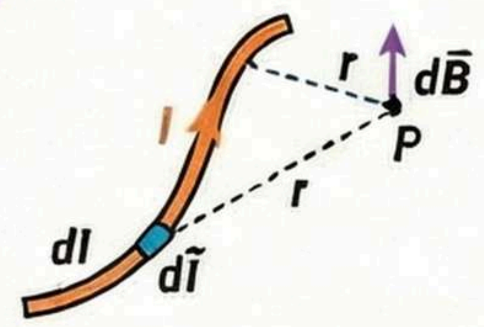
Force Between Parallel Currents:
Parallel currents attract, anti-parallel repel.

Force per unit length: $f = \frac{\mu_0 I_a I_e}{2\pi d}$

The Ampere (SI Unit): Defined by force between parallel conductors. 1 Ampere produces 2×10^{-7} N/m between wires 1m apart.

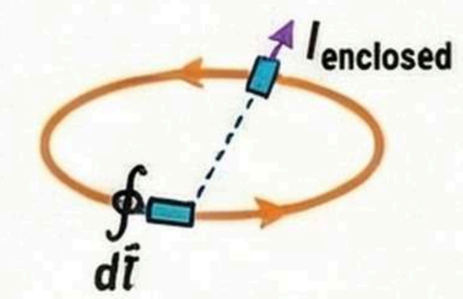
3. Sources of Magnetic Field

Oersted's Discovery:
Moving charges/currents produce a magnetic field.



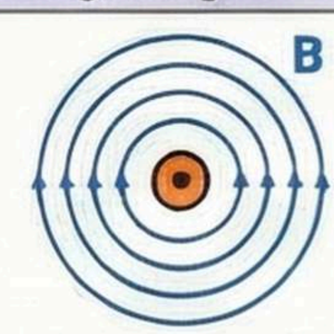
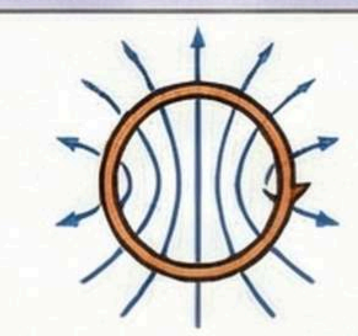
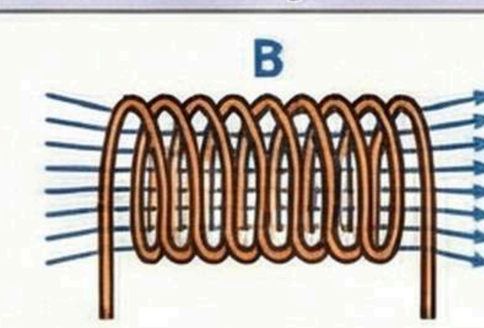
Biot-Savart Law:
Calculates magnetic field $d\vec{B}$ from current element $I\,dl$.

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{(I\, d\vec{l} \times \hat{r})}{r^2}$$

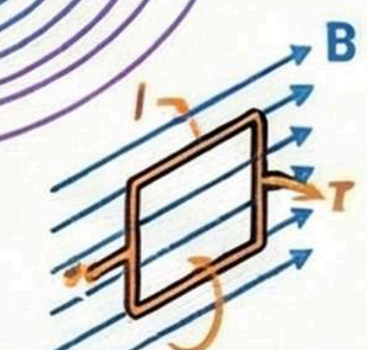


Ampere's Circuital Law:
Relates the integrated magnetic field to oncloope curface.

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{enclosed}$$

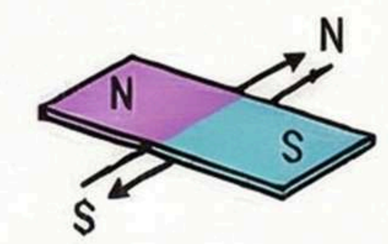
	Long Straight Wire	Center of a Circular Loop	Inside a Long Selenoid
B Field	 B		 B
Note	$B = \frac{\mu_0 I}{2\pi r}$ Field lines are concentric circles around the wire.	$B = \frac{\mu_0 I}{2R}$ R is the radius of the loop.	$B = \mu_0 n I$ n is turns per unit length. Field is strong and uniform inside.

4. Forces, Torques, and Dipoles &
5. The Moving Coil Galvanometer (MCG)



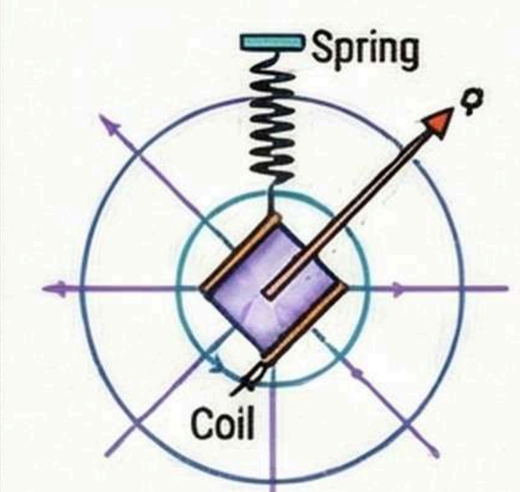
Torque on a Current Loop:
A current loop in a uniform magnetic field experiences zero net force, but a torque acts to align it with the field.

$\tau = IABxinB$

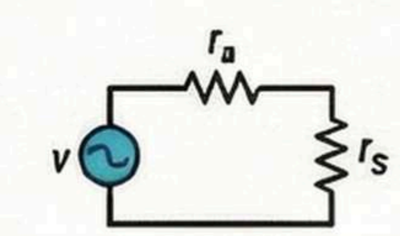


Magnetic Dipole Moment (m):
A current loop behaves like a magnetic dipole.

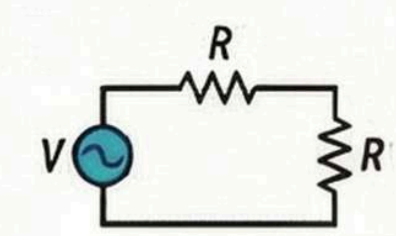
$m = NIA$. Torque: $\tau = m \times \vec{B}$



Operating Principle of the MCG:
To measure current, a low-resistance "shunt" (r_s) is connected in parallel with the galvanometer to limit the current drawn from the circuit.



Conversion to an Ammeter: Connect low-resistance "shunt" in parallel

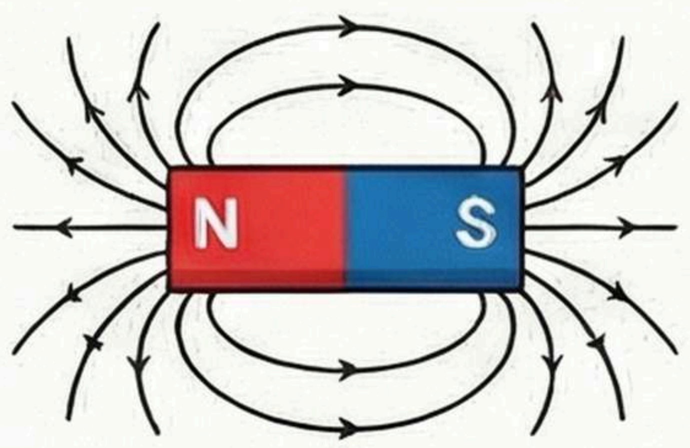


Conversion to a Voltmeter: Connect high-resistance resistor in series

Sensitivity: Current sensitivity = $\frac{\phi}{I}$, Voltage sensitivity = $\frac{\phi}{V}$

Magnetism and Electromagnetic Induction

PART 1: Magnetism and Matter

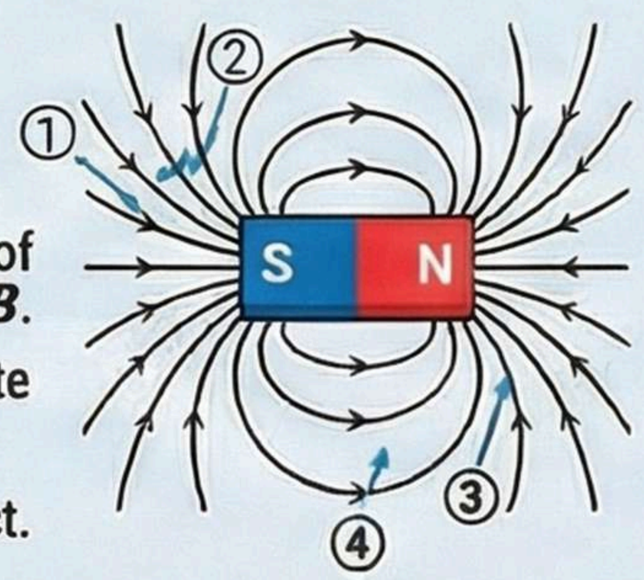


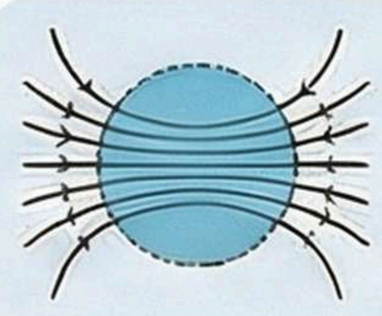
Magnets are Dipoles

Every magnet has a North and South pole.
Unlike electric charges, Isolated magnetic poles (monopoles) are not known to exist.
Cutting a magnet creates two smaller magnets.

Properties of Magnetic Field Lines

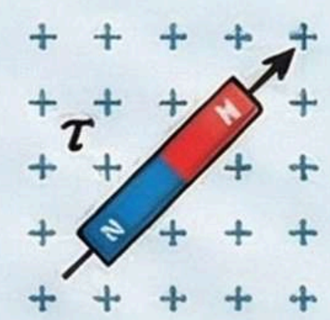
(1) Form continuous closed loops.
(2) Tangent to the line gives the direction of the magnetic field $\boldsymbol{B}$.
(3) Denser lines indicate a stronger field.
(4) They never intersect.





Gauss's Law for Magnetism

The net magnetic flux through any closed surface is always zero. This is a consequence of magnetic monopoles not existing.



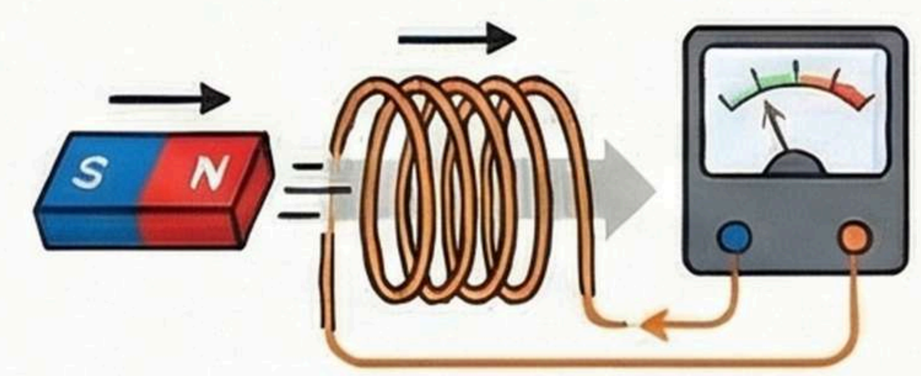
Torque & Energy in a Uniform Field

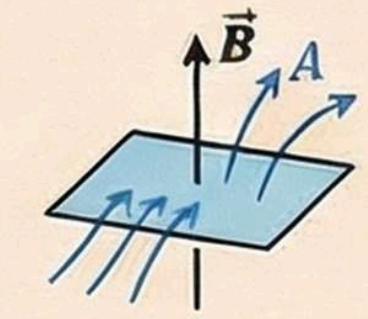
Torque $\tau = m \times B$
Potential energy $U = -m \cdot B$

Magnetic Materials Comparison

	Diamagnetic	Paramagnetic	Ferromagnetic
Behavior in Field	Weakly repelled	Weakly attracted	Strongly attracted
Magnetic Susceptibility (χ)	Small, negative ($-1 \le \chi < 0$)	Small, positive ($0 < \chi < \varepsilon$)	Large, positive ($\chi \gg 1$)
Relative Permeability (μ_r)	Slightly less than 1 ($0 \le \mu_r < 1$)	Slightly greater than 1 ($1 < \mu_r < 1+\varepsilon$)	Much greater than 1 ($\mu_r \gg 1$)
Atomic Moment	No permanent dipole moment	Permanent dipole moments, randomly oriented	Moments aligned in domains
Examples	Biemuth, Copper, Water, Superconductors	Aluminum, Calcium, Oxygen	Iron, Cobalt, Nickel, Alnico

PART 2: Electromagnetic Induction



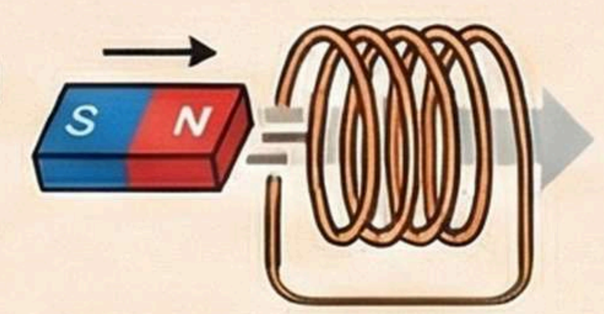


What is Magnetic Flux (Φ_B)?

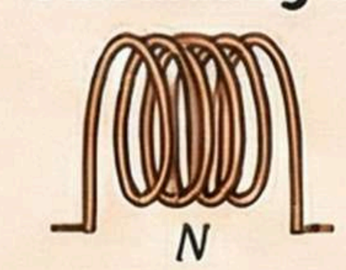
A measure of the total magnetic field lines passing through a given area. The SI unit is the weber (Wb).
Formula: $\Phi_B = \boldsymbol{B} \cdot \boldsymbol{A} = BA\cos\theta$.

Faraday's Law of Induction

An electromotive force (emf) is induced in a coil whenever the magnetic flux through it changes over time. The magnitude of the emf is proportional to the rate of this change.



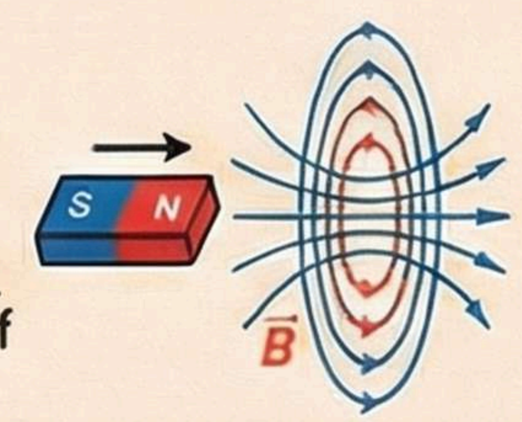
Calculating Induced EMF (ε)

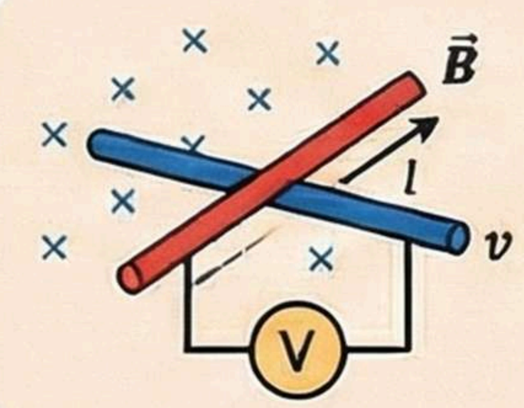


$$\varepsilon = -N\frac{d\Phi_B}{dt}$$

Lenz's Law

The direction of the induced current is always such that it opposes the change in magnetic flux that caused it. This law is a consequence of the conservation of energy.

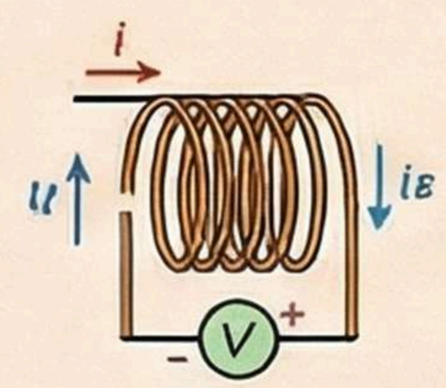




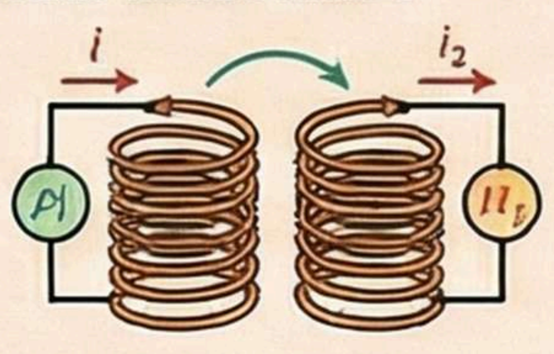
Motional EMF

An emf induced when a conductor moves through a magnetic field.
For a rod of length 'l' moving at velocity 'v' perpendicular to field 'B', the emf is $\varepsilon = Blv$.

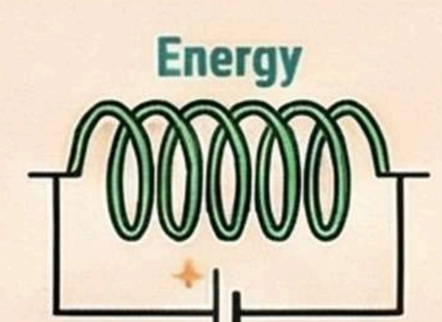
Self & Mutual Inductance



Self-Inductance (L):
A changing current in a coil induces a "back emf" in itself $\left(\varepsilon = -L\frac{dI}{dt}\right)$

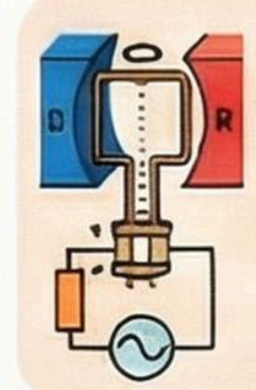


Mutual Inductance (M):
A changing current in one coil induces an emf in a neighboring coil
$\left(\varepsilon_1 = -M\frac{dI_2}{dt}\right)$



Energy Stored in an Inductor

Work done to establish a current in an inductor is stored as magnetic potential energy.
Formula: $U = \frac{1}{2}LI^2$.



The AC Generator

Converts mechanical energy into electrical energy by rotating a coil in a magnetic field, which continuously changes the magnetic flux and induces a sinusoidal alternating current.
Formula: $\varepsilon = NBA\omega\sin(\omega t)$.

Alternating Current and EM Waves

Chapter 1: Alternating Current (AC)

AC

What is Alternating Current (AC)?
Varies sinusoidally with time, changing direction periodically.
Primary form of electricity for homes and offices.

Measuring AC: RMS Values

$V_{rms} = \frac{V_{peak}}{\sqrt{2}} = 0.707 \cdot V_{peak}$

$I_{rms} = \frac{I_{peak}}{\sqrt{2}} = 0.707 \cdot I_{peak}$

DC

RMS Value (Effective)

AC

Peak Value

Why AC is Preferred Over DC
Easily stopped up/down by transformers for efficient long-distance transmission.

Visualizing AC: Phasors
θ

Rotating vector representing a sinusoidal quantity.
Length = amplitude, angle = phase.

AC in LCR Circuits

Component	Resistance/Reactance	Phase Relationship & Power
Resistor (R)	Resistance (R)	Voltage and Current are in phase. P = PR (Maximum Power)
Inductor (L)	Inductive Reactance ($X_L = \omega L$)	Current lags Voltage by 90° (π/2). Zero (over a full cycle)
Capacitor (C)	Capacitive Reactance ($X_C = 1/\omega C$)	Current leads Voltage by 90° (π/2). Zero (over a full cycle)

Series LCR Circuits & Impedance
R L R C C

Impedance $(Z) = \sqrt{R^2 + (X_L - X_C)^2}$

The Phenomenon of Resonance
ω_0

Resonance occurs at ω_0 where $X_L = X_C$.
Minimum Impedance (Z=R), Maximum Current.

Transformers: Changing AC Voltage
Iron

Step-Up: $N_s > N_p$
Voltage increases
Current decreases.

Step-Down: $N_s < N_p$
Voltage decreases
Current increases.

Application:
Tuning circuits in radios and TVs.

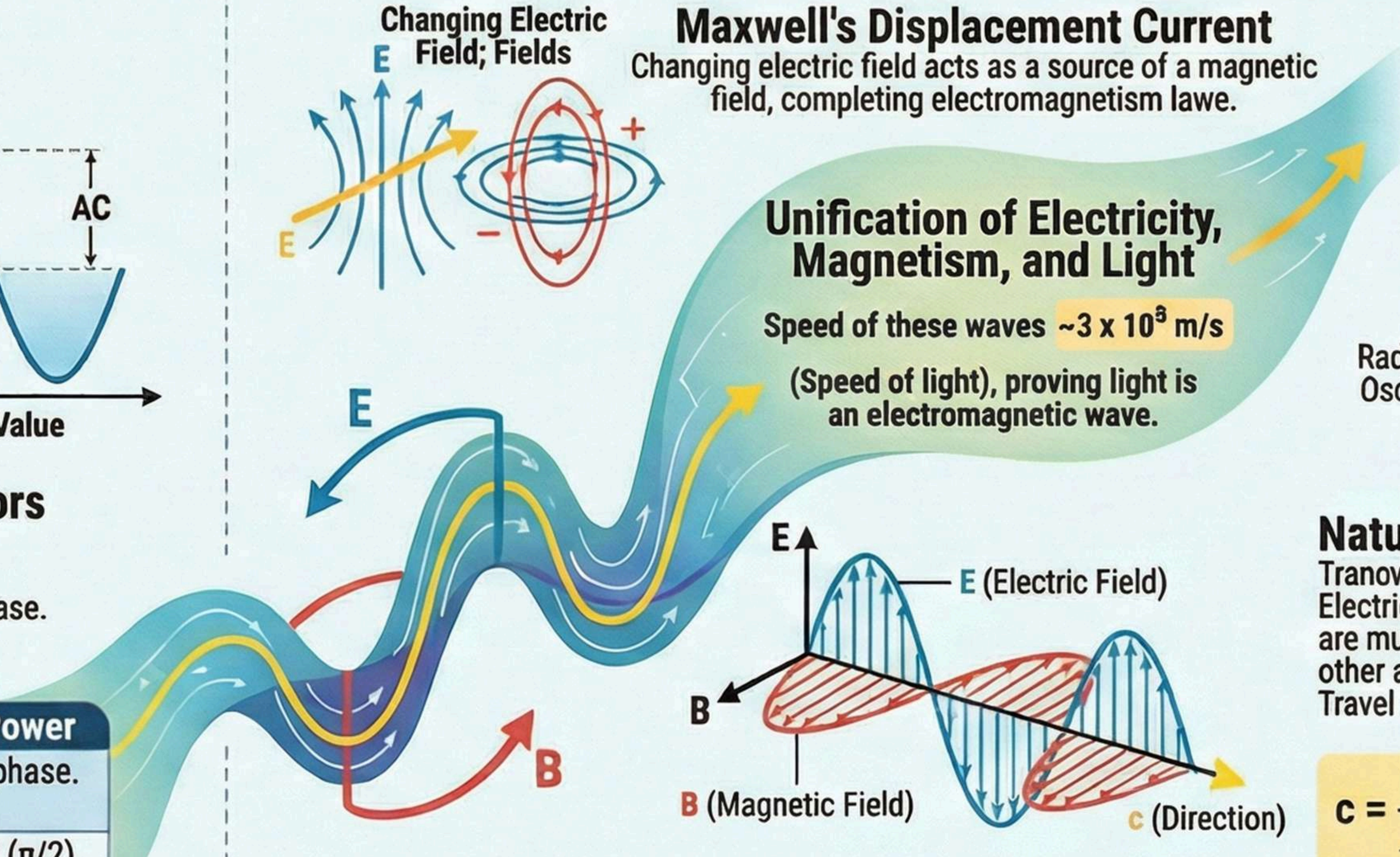
Chapter 2: Electromagnetic (EM) Waves

Changing Electric Field; Fields

E E + −

Maxwell's Displacement Current
Changing electric field acts as a source of a magnetic field, completing electromagnetism lawe.

Unification of Electricity, Magnetism, and Light
Speed of these waves ~3 x 10^3 m/s
(Speed of light), proving light is an electromagnetic wave.



Oscillating Charge

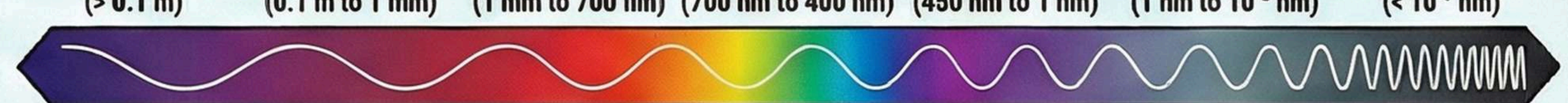
How EM Waves are Produced
Radiated by accelerated charges. Oscillating electric and magnetic fields regenerate and propagate.

Nature of EM Waves
Tranoverze waves,
Electric (E) and magnetic (B) fields are mutually perpeddicular to each other and propagation direction.
Travel at speed of light, c, in vacuum.

$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ $\frac{E_0}{B_0} = c$

Electromagnetic Spectrum (Ordered by Decreasing Wavelength)

Radio Waves (> 0.1 m)
Microwaves (0.1 m to 1 mm)
Infrared (1 mm to 700 nm)
Visible Light (700 nm to 400 nm)
Ultraviolet (UV) (450 nm to 1 nm)
X-rays (1 nm to 10^{-5} nm)
Gamma Bays (< 10^{-3} nm)



Antennas
Radio/TV breadcast
Gellatar Phones

Klystrons
Magnetrons
Radar
Microwave ovens

Hot bodies
Remote controls
Physical therapy

Electrons moving in stoms
Human vision
Photography

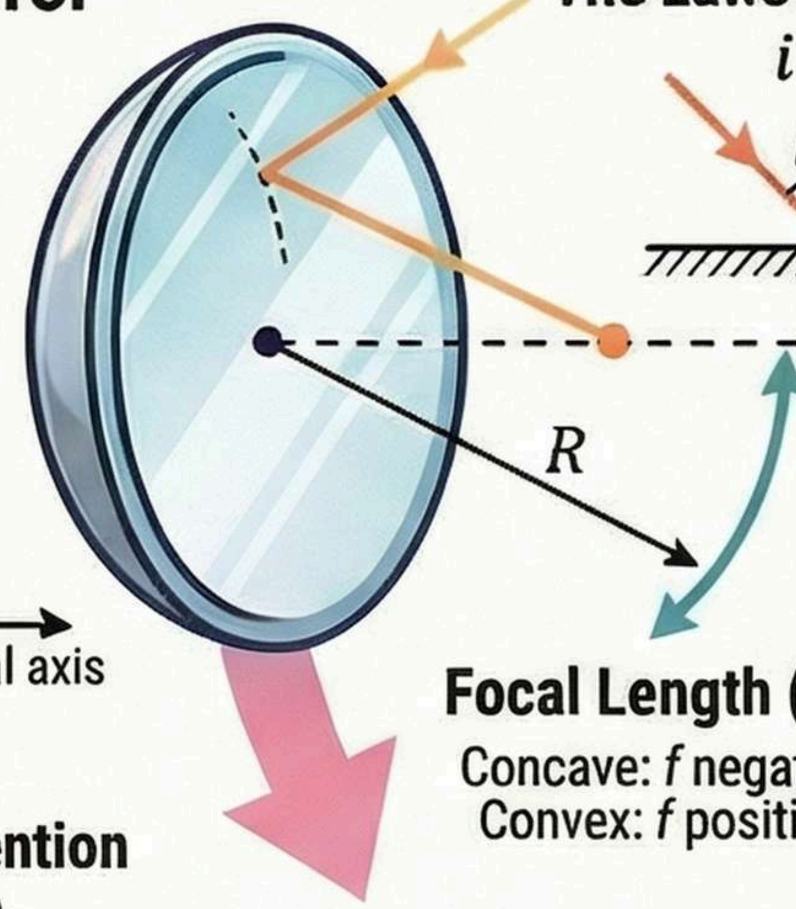
Special lamps
Sun
Water purifiers
LASIK eye surgery

Bombarding metal
Medical imaging
Cancer treatment

Nuclear reactions
Radioactive decay
Cancer treatment
(radiotherapy)

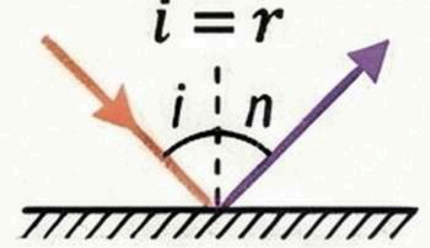
Ray Optics

1. Spherical Mirror



The Laws of Reflection

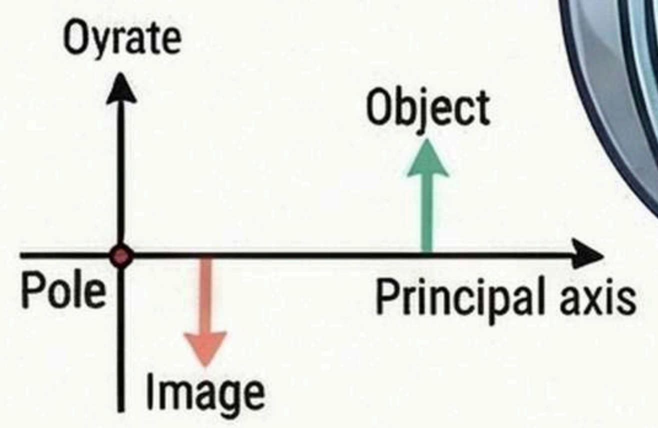
$i = r$



The incident ray, reflected ray, and the normal all lie in the same plane.

Focal Length (f) = $\frac{R}{2}$

Concave: f negative;
Convex: f positive.



Cartesian Sign Convention

Distances from pole.
+ direction of light, - opposite.
+ above axis, - below.

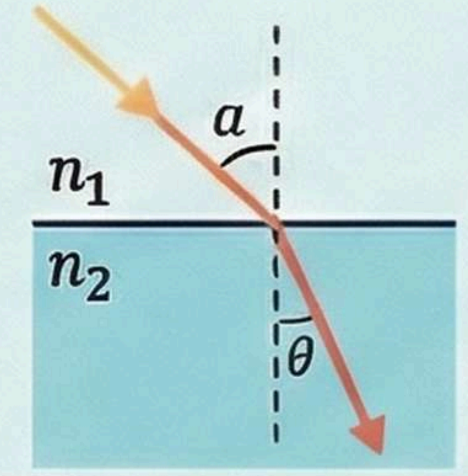
The Mirror Equation:

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

Linear Magnification (m) $= -\frac{v}{u}$

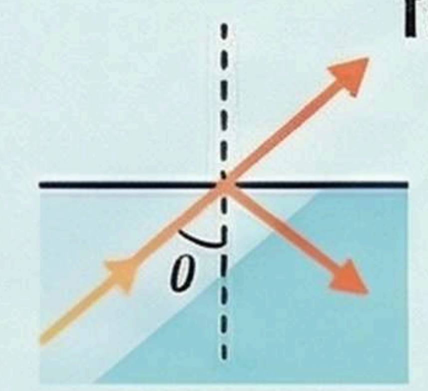
Negative "m" indicates a real, inverted image.

2. Refraction & Total Internal Reflection



Snell's Law of Refraction

$$\frac{\sin i}{\sin r} = n_{21}$$



Total Internal Reflection (TIR)

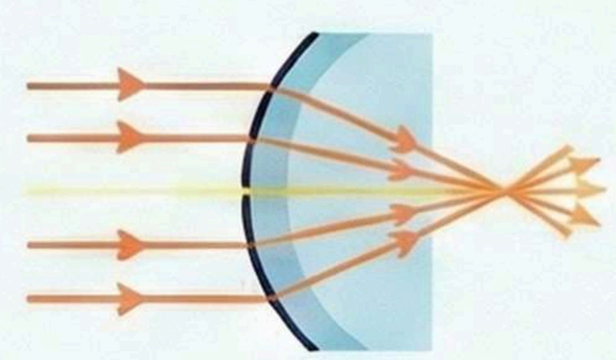
Occurs from denser to rarer medium when $i >$ critical angle, all light reflected back.

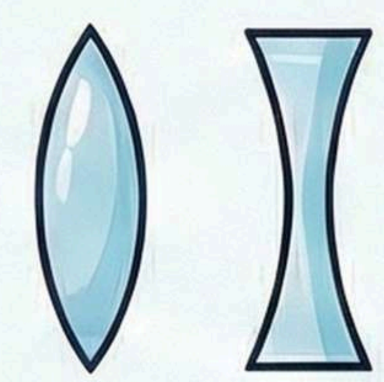
Critical Angle (i_c):

$$\sin(i_c) = n_{21}$$

Applications of TIR

3. Lenses & Refraction at Spherical Surfaces





Refraction at a Spherical Surface:

$$\left(\frac{n_2}{v}\right) - \left(\frac{n_1}{u}\right) = \frac{n_2 - n_1}{R}$$

Lens Maker's Formula

$$\frac{1}{f} = \underbrace{(n_{21} - 1)}_{\text{Refractive index}} * \underbrace{\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}_{\text{Radii}}$$

Thin Lens Formula:

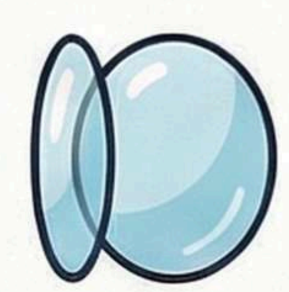
$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

Power of a Lens (P) = $1/f$

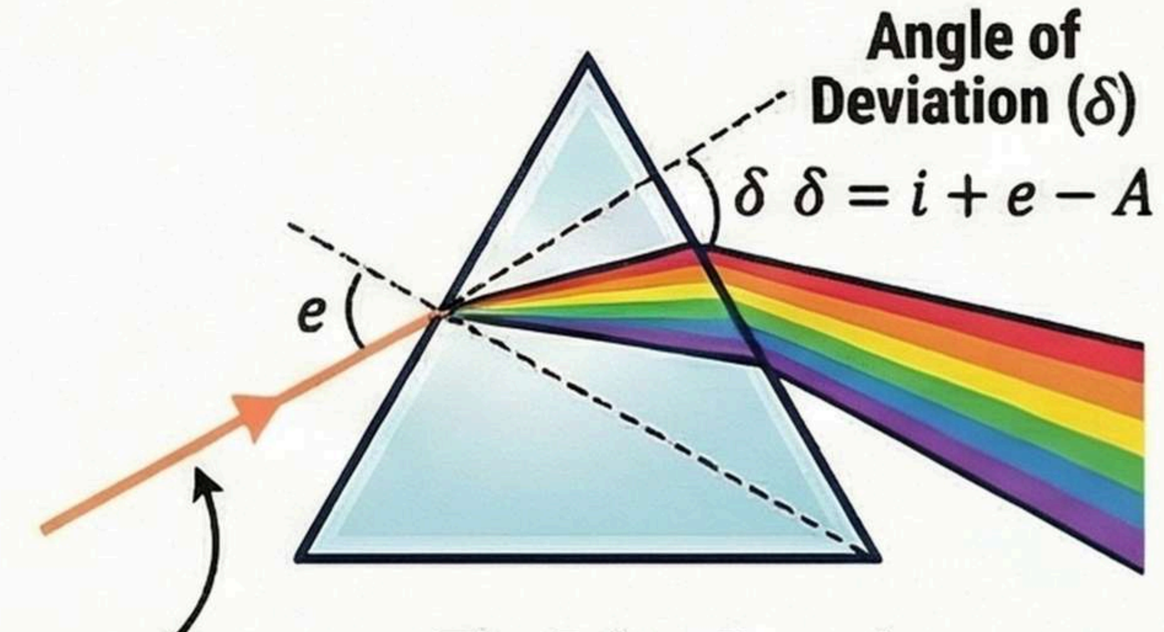
SI unit: dioptre (D), f in meters.
+ for convex, - for concave.

Combination of Lenses

Total power $P = P_1 + P_2 + \cdots$
Total magnification $m = m_1 \times m_2 \times \cdots$



4. Refraction Through a Prism



Minimum Deviation (δ_m) occurs when i=e; ray inside is parallel to base

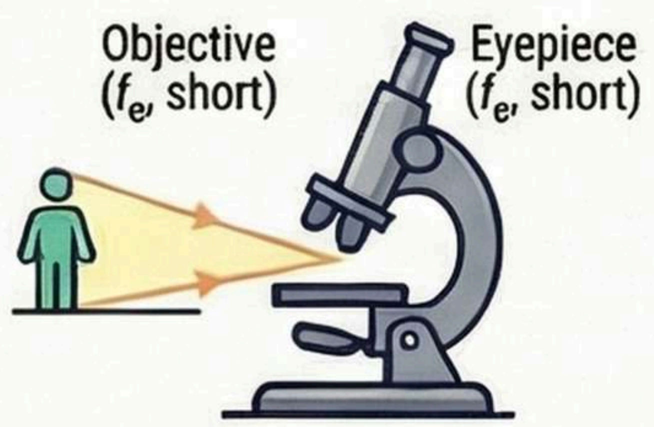
The Prism Formula

$$n_{21} = \frac{\sin((A + \delta_m)/2)}{\sin(A/2)}$$

This formula is used to determine the refractive index of the prism's material.

5. Optical Instruments

The Compound Microscope

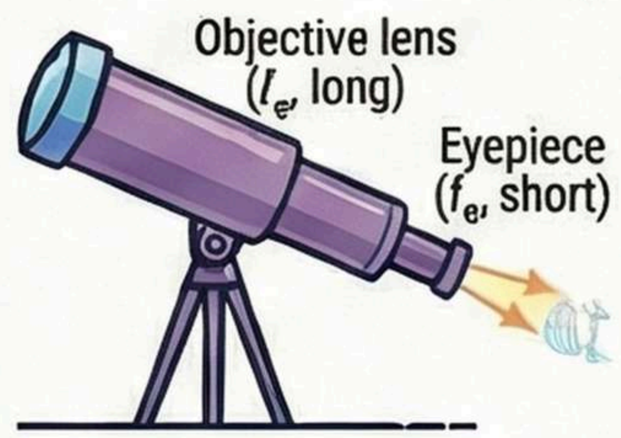


Magnification of a Microscope

$$m \approx (L/f_0) \times (D/f_e)$$

L = tube length
D = near point (~25 cm)

The Astronomical Telescope



Magnifying Power of a Telescope

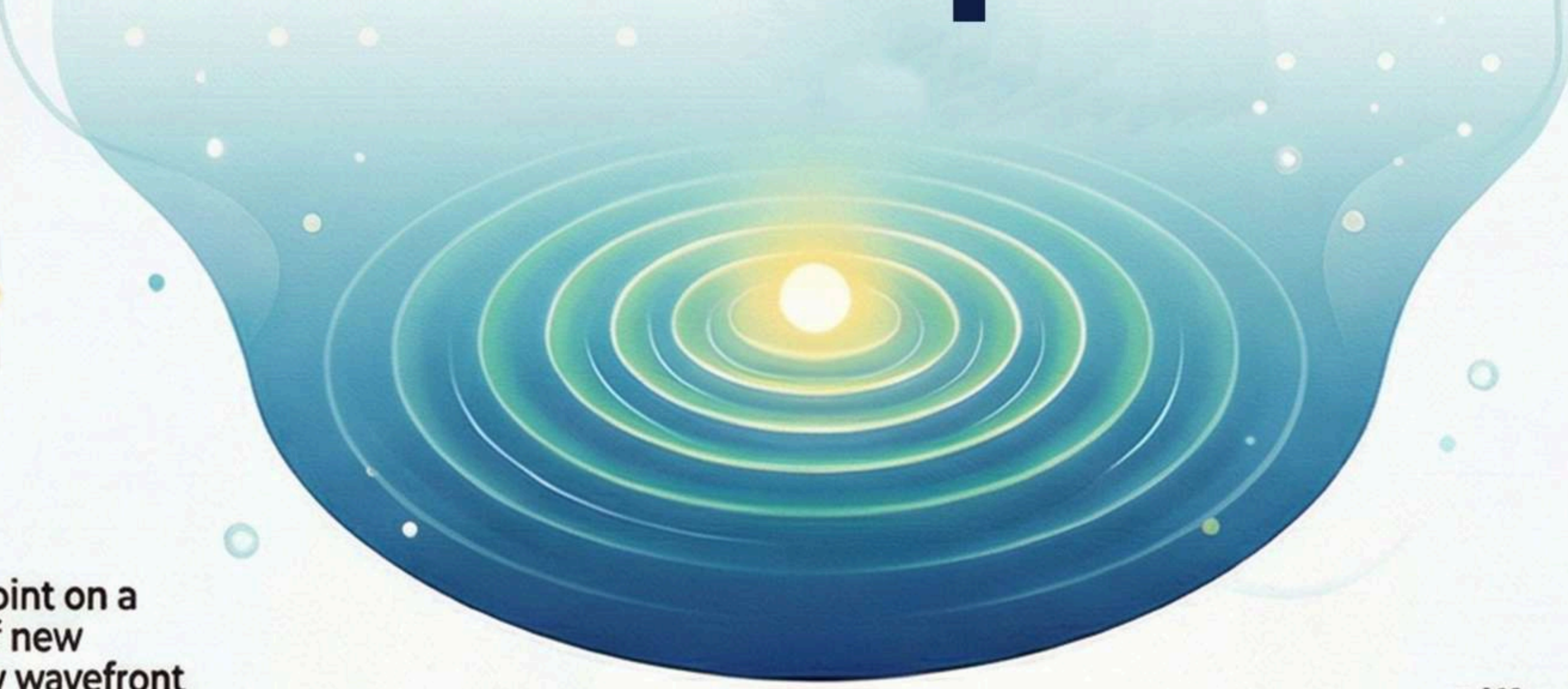
$$m = \frac{f_o}{f_e}$$

For normal adjustment

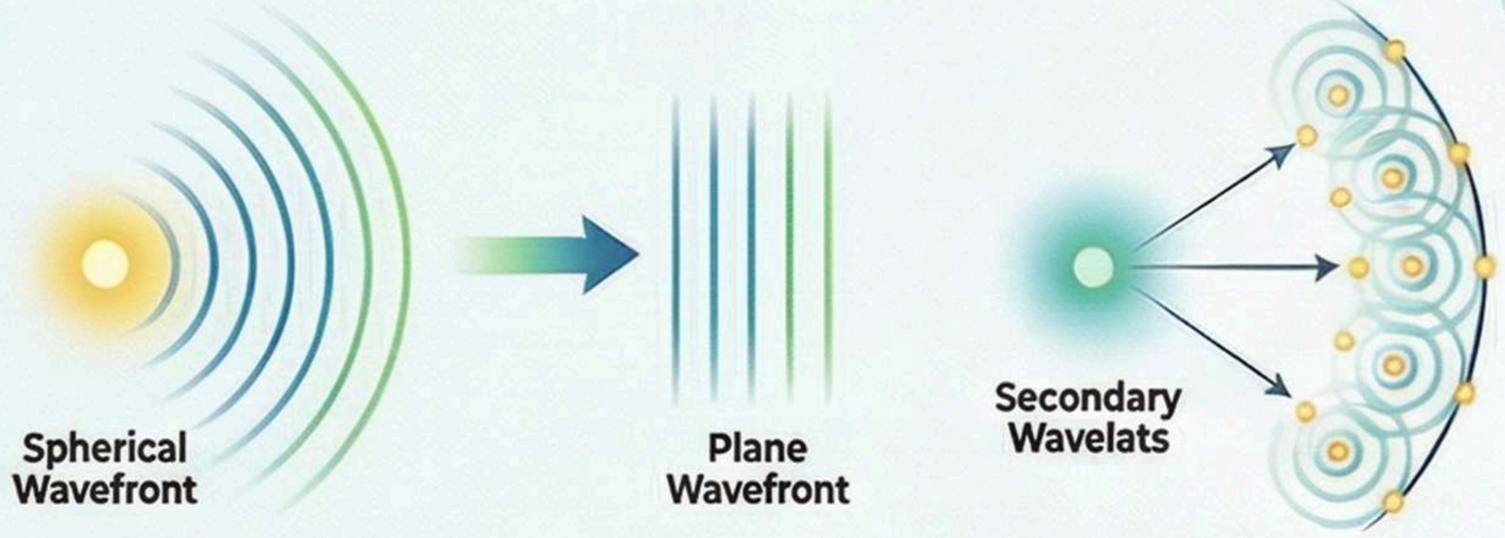
Reflecting vs. Refracting Telescopes

Modern telescopes use mirrors to eliminate chromatic aberration, reduce weight, and make large objectives easier.

Wave Optics



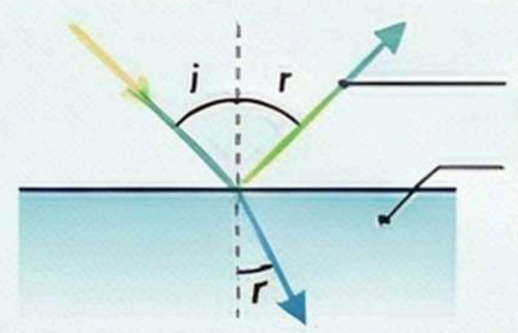
Chapter 1:
Huygens' Principle & Wavefronts



Wavefront: Locus of all points in a medium oscillating in the same phase. E.g.. Ripples on water. At a large distance is considered a plane wavefront.

Huygens' Principle: Every point on a wavefront acts as a source of new secondary wavelets. The new wavefront is the common tangent to these wavelets.

Explaining Reflection & Refraction



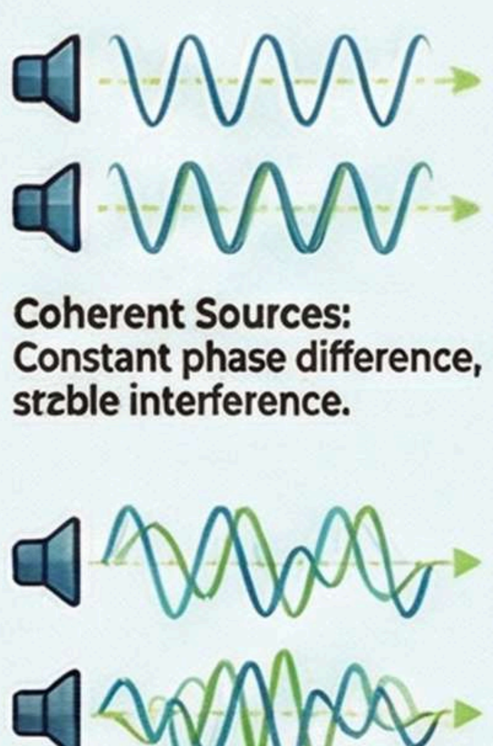
Angle of Incidence = Angle of Reflection

Shell's Law ($n_1 \sin i = n_2 \sin r$)

Wave Theory's Correct Prediction: Light slows down in denser media (e.g., air to water), confirming wave nature.

Chapter 2:
Interference & Young's Experiment

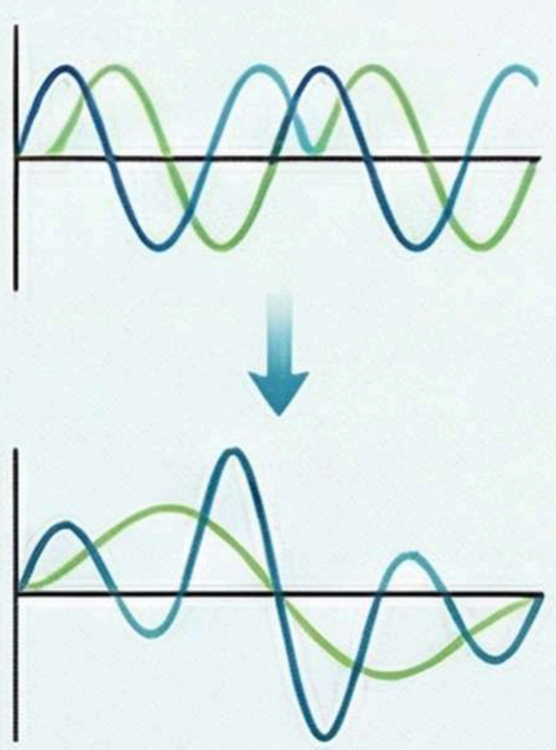
Coherent vs. Incoherent Sources



Coherent Sources: Constant phase difference, stzble interference.

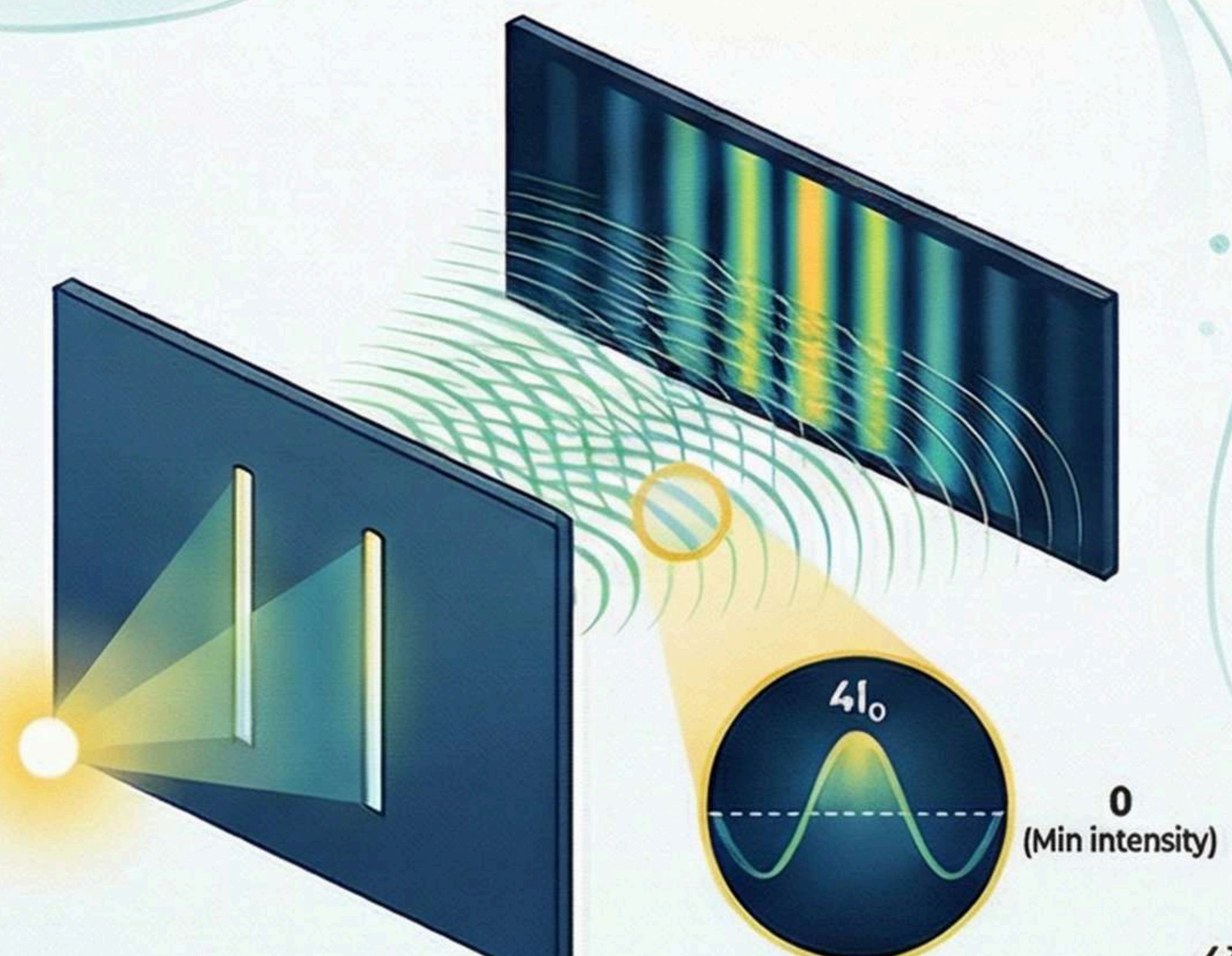
Incoherent Sources: Rapidly changing phase difference.

The Superposition Principle



Resultant displacement is the vector sum of individual displacements.

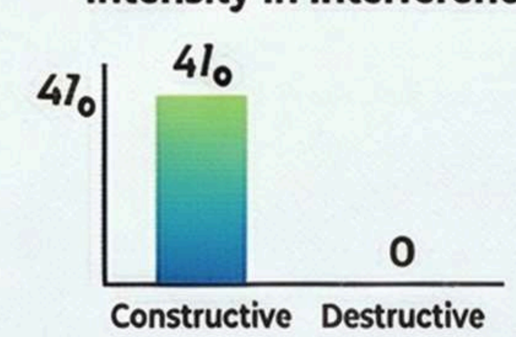
Young's Double-Slit Experiment



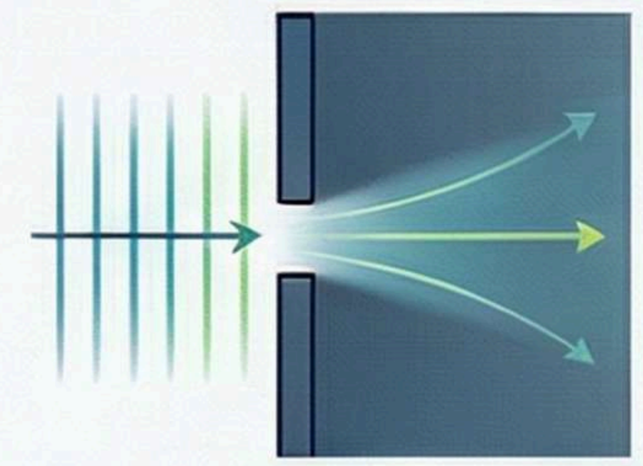
Young's Experiment (1801): Two coherent sources produce a superposition pattern of bright and dark fringes, proving light's wave nature.

Destructive Interference (Dark Spots): Path difference is $(n+1/\lambda)\lambda$ (hall-integer multiples).

Intensity in Interference

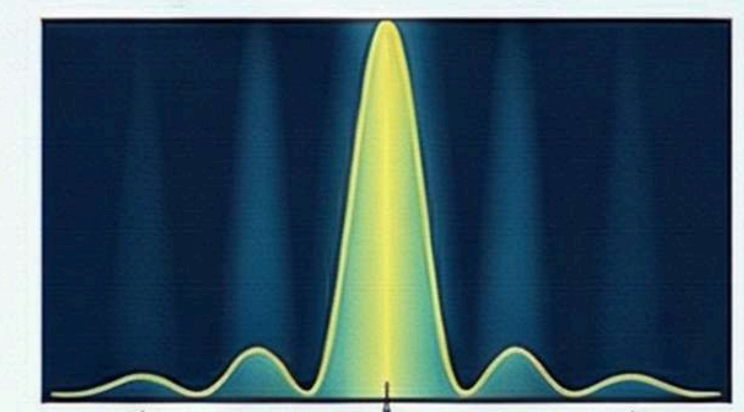


Chapter 3:
Diffraction



Diffraction: Bending or spreading of waves around an obstacle or through an aperture.

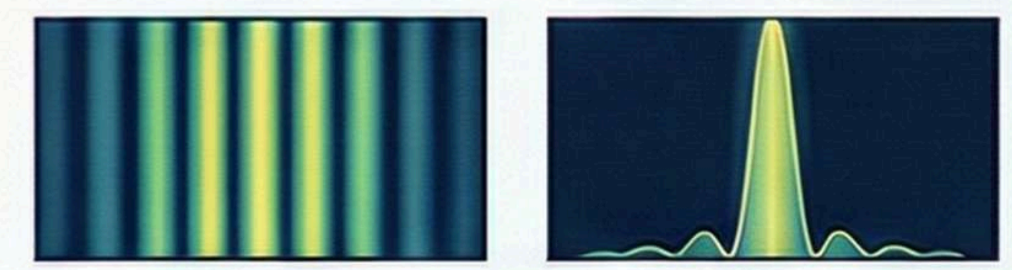
Single-Slit Diffraction Pattern



Contral Maximum (≀s width, very bright)

Secondary Maxima (weaker, decreasing intensity)

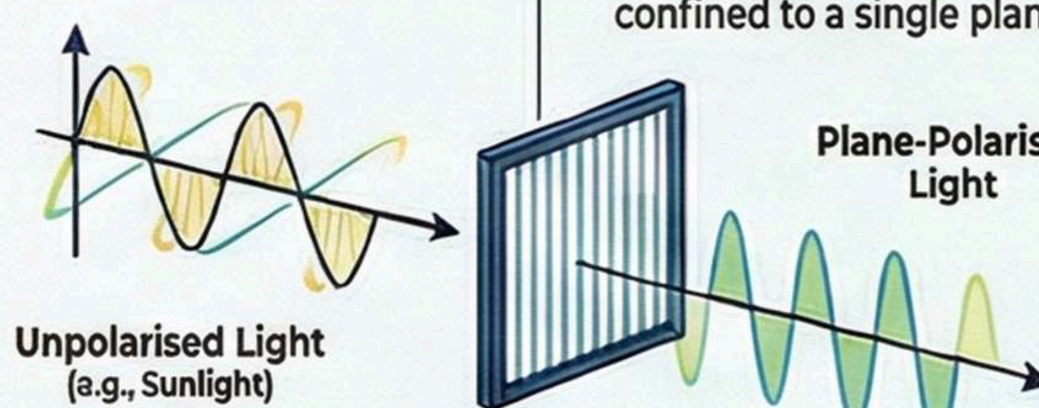
Diffraction vs. Interference Fringes



Interference fringes are typically of equal intensity and spacing. In diffraction, the central fringe is twice as wide and much brighter, and the intensity of fringes decreases rapidly away from the center.

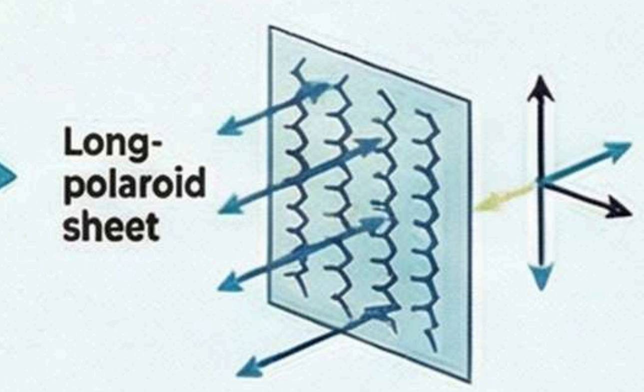
Chapter 4:
Polarisation

Unpolarised light (like sunlight) has electric field oscillations in all random directions. Plane-polarised light has oscillations confined to a single plane.



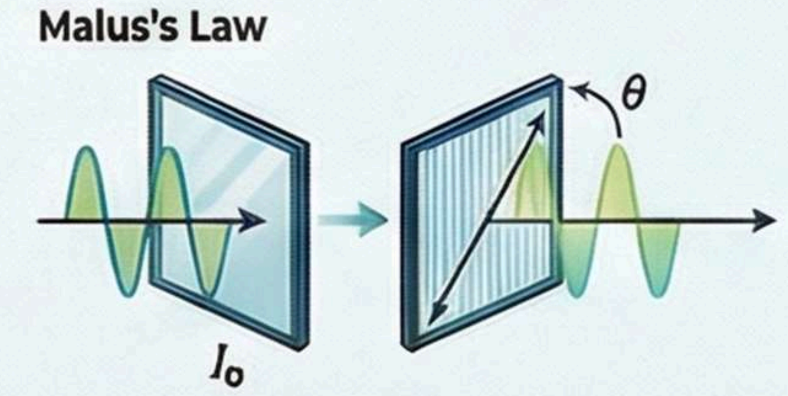
Proof that Light is a Transverse Wave: Polarisation is exclusive to transverse waves, where oscillations are perpendicular to energy transfer. Since light can be

How a Polaroid Filter Works



Absorbs vectors patallel to long-chain melecules, transmits vectors perpendicular via pass-axis.

Malus's Law



$$I = I_0 \cos^2\theta$$

Transmitted intensity (I) through an analyser is proportional to the spuare of the cosine of the angle (6) between pass-axes.

Dual Nature and Atomic Structure

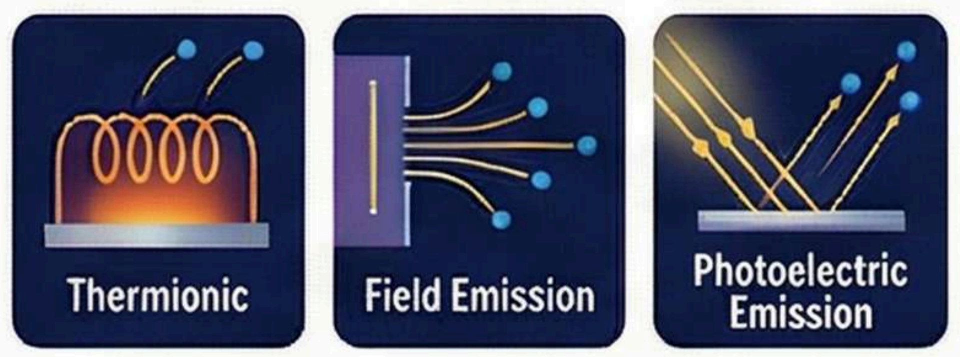
THE DUAL NATURE OF RADIATION & MATTER

Particle

ELECTRON EMISSION & WORK FUNCTION (φ_0)

For an electron to escape a metal surface, it must be given a minimum amount of energy, known as the work function, which is specific to the metal.

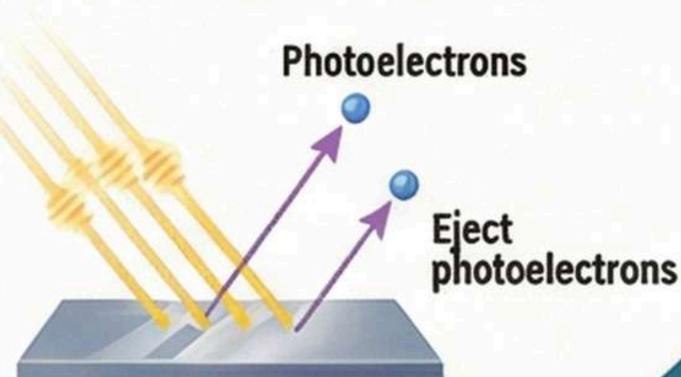
THREE METHODS OF ELECTRON EMISSION



THE PHOTOELECTRIC EFFECT: EXPERIMENTAL FACTS

When light shines on a photosensitive metal: It can eject electrons (photoelectrons).

Four key experimental observations defied classical physics.

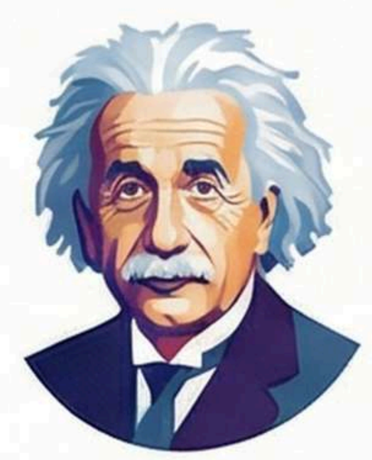


WAVE THEORY FAILS VS. EXPERIMENTAL REALITY

	WAVE THEORY PREDICTION	EXPERIMENTAL OBSERVATION
Electron Energy	Depends on light intensity.	Depends on light frequency, not intensity.
Emission Condition	Decurs at any frequency if intensity is high enangh.	Occurs only if frequency is above a 'threshold frequency' (e_c).
Time Delay	A time lag is expected for low-intensity light.	Emission is instantaneous (≠10 * 6), regardless of intensity.
Photocurrent	Proportional to light intensity.	Proportional to fight intensity (number of pholoslectreus ∝ intensity)

EINSTEIN'S SOLUTION: THE PHOTON

In 1985. Elactoin proposed that light consists of discrete energy packets called photons. The energy of a single photon is given by $E = h\nu$.



EINSTEIN'S PHOTOELECTRIC EQUATION:

$$K_{max} = h\nu - \varphi_0$$

The maximum kinstic energy (K_{max}) of an emitted electron is the photon's energy ($h\nu$) nonus the motal's work function (φ_0). This perfectly explains all experimental results.

DE BROGLIE'S HYPOTHESIS: MATTER HAS WAVES

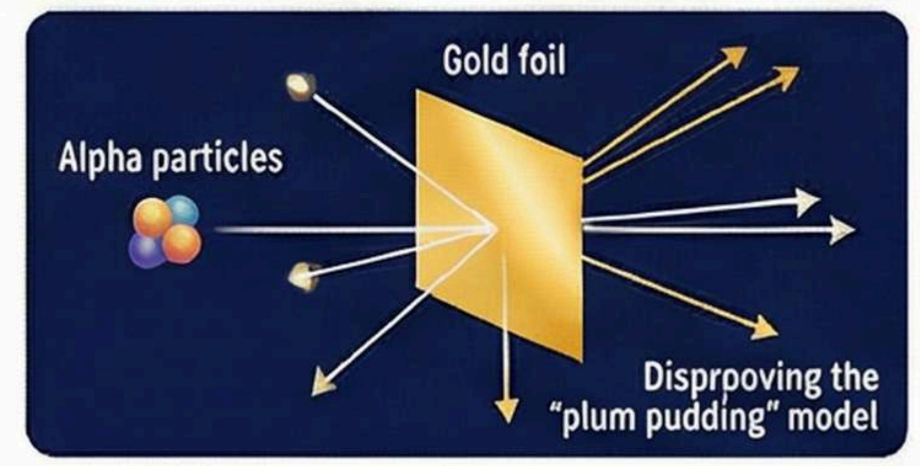
In 1924, Louis de Broglie proposed symmetry in nature: it waves can act like particles, then moving particles (like electrons) should exhibit wave-like properties.

DE BROGLIE WAVELENGTH: $\lambda = \frac{h}{p} = \frac{h}{mv}$

The wavelength (λ) of a particle is inversely proportional to its momentum (p). This is significant for subolomic particles but immeasurably small for macroscople objects.

THE STRUCTURE OF THE ATOM

1911: RUTHERFORD'S ALPHA-SCATTERING EXPERIMENT



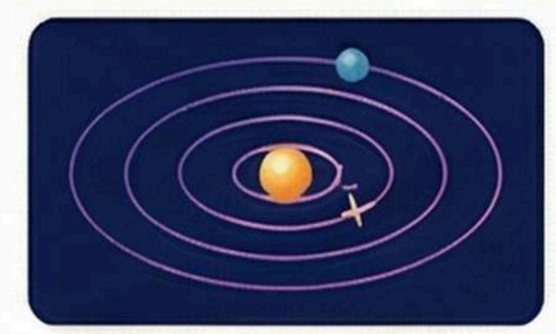
DISCOVERY OF THE NUCLEUS

The experiment showed the stom is mostly empty spece with a tiny, danse, pesitrvely-charged nucleus containing most of the mass. This led to the Rutherford "pianetary" model.

FAILURES OF THE RUTHERFORD MODEL

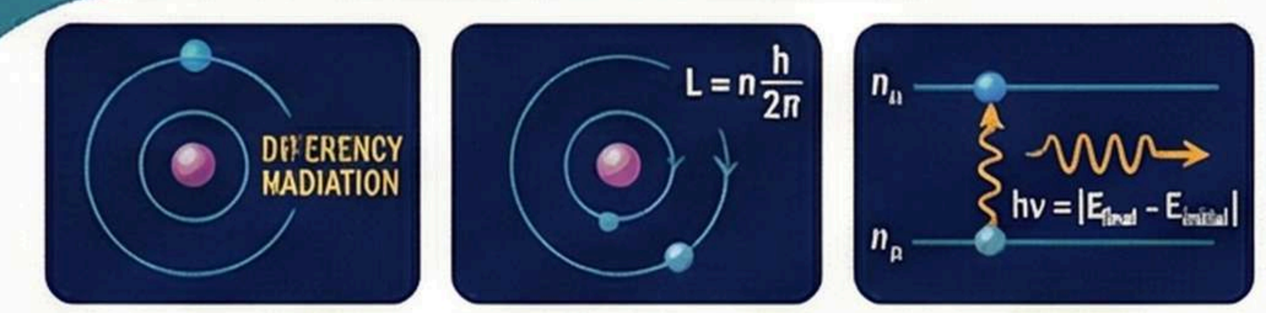
According to elessical physics, an orbiting electron is accelerating and should radiate energy, asusing it to spiral into the nuclaus. The model could not explain atomic stability or discrete line spectrs.

BOHR'S MODEL OF THE HYDROGEN ATOM (1913)



Niels Bohr proposed three postulates that combined classical and quantum ideas to fix the flaws of the Rutherford model for hydrogen.

BOHR'S THREE POSTULATES



1. Stationary Orbits: Electrons exist in stable orbits without radiating energy.
2. Quantized Angular Idomontum: Angular momentum is quantized.
3. Photon Emission: A photon is emrried or absorbed when an electron jumps between orbits.

QUANTIZED ENERGY LEVELS IN HYDROGEN:

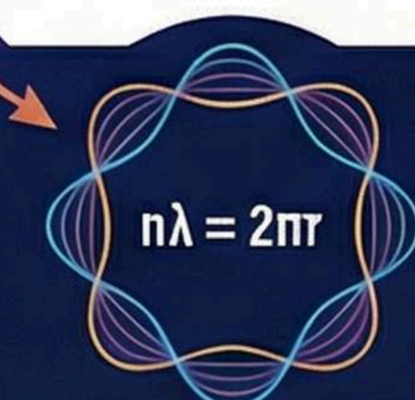
$$E_e = -13.6/n^2 eV$$

The lowest energy state (n=1) is the ground state.

ATOMIC SPECTRA EXPLAINED

The distinct lines in an element's emission or absorption spectrum correspond to the energy of photons released or absorbed during electron transitions between specific, allowed energy levels.

DE BROGLIE ESPLAINS BOHR'S 2ND POSTULATE



An electron's orbit is stable only if its circumference is an integer multiple of its de Broglie wavelength, forming a standing wave. This condition mathematically derives Bohr's quantization of angular momentum.

LIMITATIONS OF THE BOHR MODEL

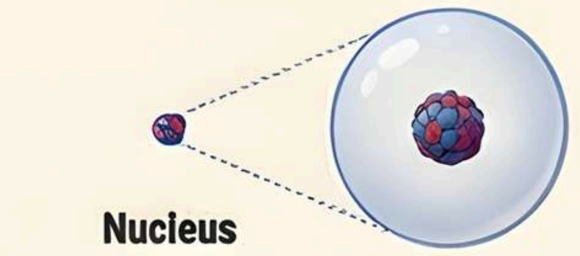
The model works only for single-electron atoms (like hydrogen) and cannot explain the varying intensities of spectral lines or the structure of more complex atoms.

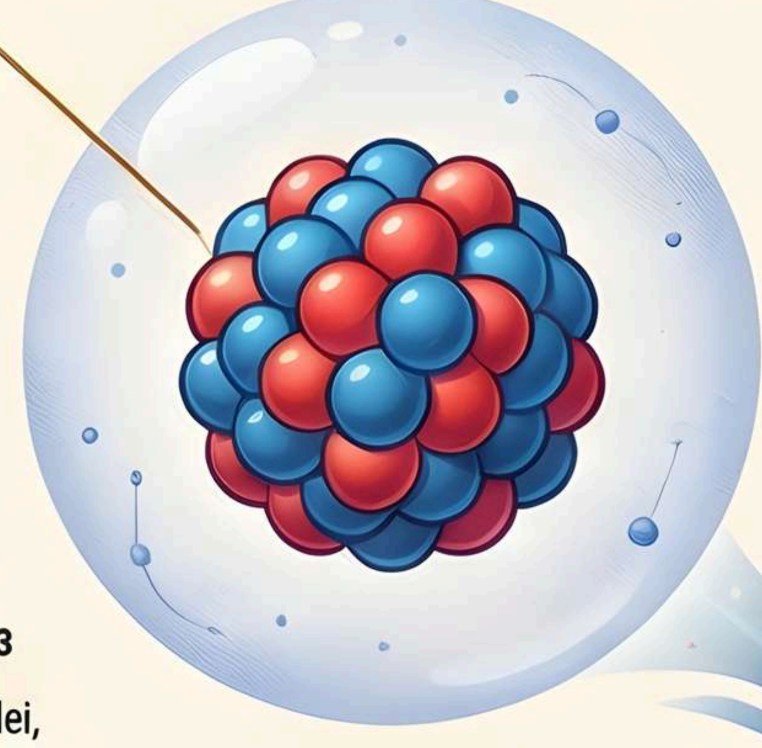
Semiconductor Electronics

Chapter 13: Inside the Atom's Core - Nuclei

The Atomic Nucleus: Dense & Massive

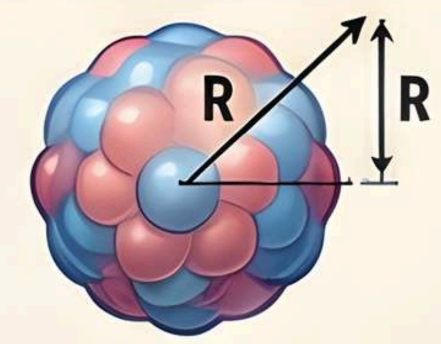
Over 99.9% of an atom's mass, radius.
Contains over 99.9% of an atom's mass

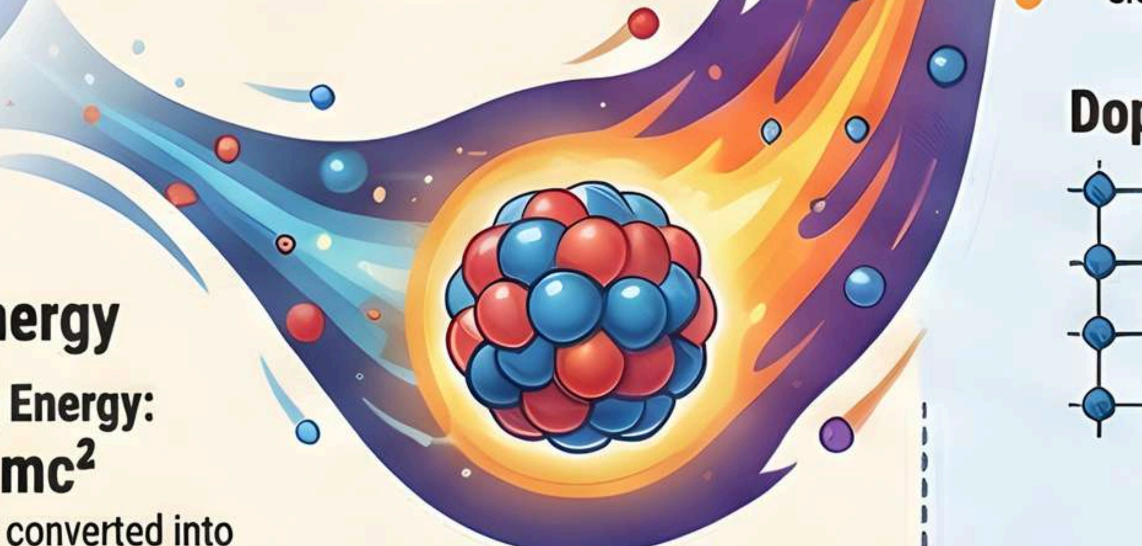




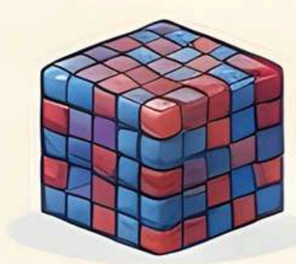
Calculating Nuclear Size

$R = R_0A^{1/3}$, where $R_0 = 1.2$ fm



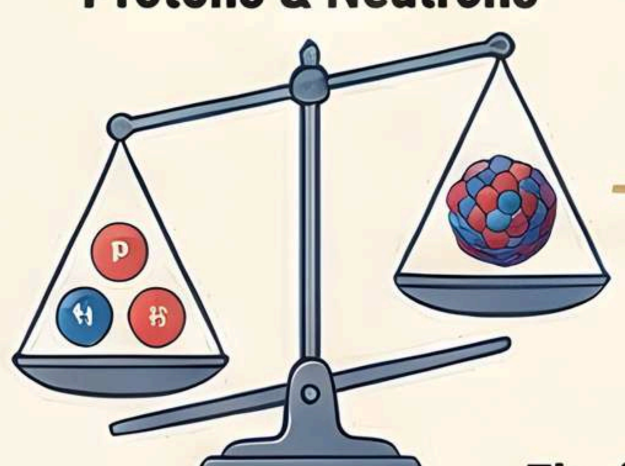


Constant Nuclear Density



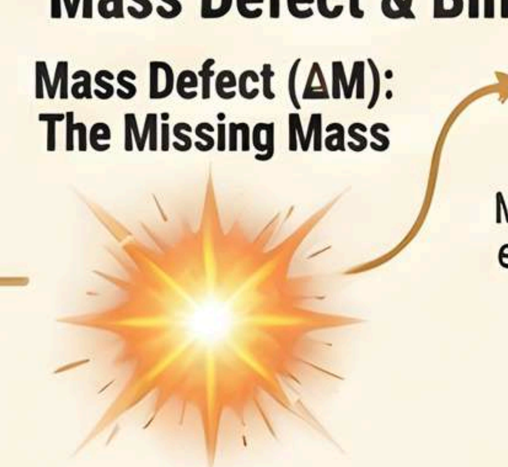
$\rho = 2.3 \times 10^{17}\ kg/m^3$
Constant value for all nuclei, independent of size.

Protons & Neutrons



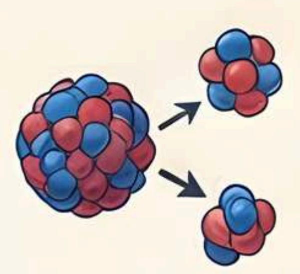
Mass Defect & Binding Energy

Mass Defect (ΔM): The Missing Mass

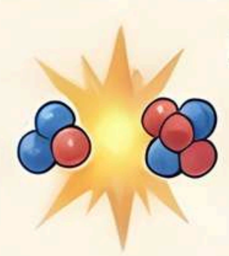


Binding Energy: $E = mc^2$
Mass defect converted into energy binding the nucleus ($E_b = \Delta M * c^2$).

Fission vs. Fusion



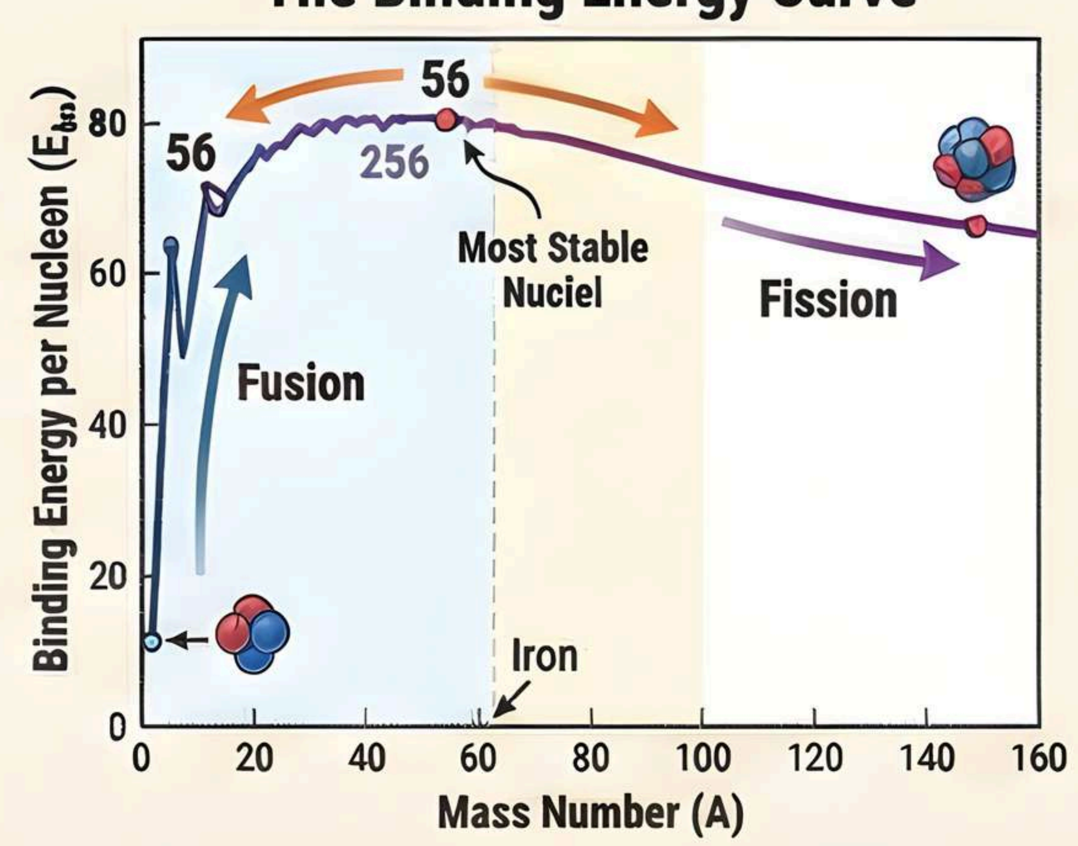
Fission: Splitting heavy nucleus (e.g., U 325) → amaiiar fragments ↓ ~200 MeV



Fusion: Combining light nuclei (e.g., Hydrogen) → heavier ona, powers the son.

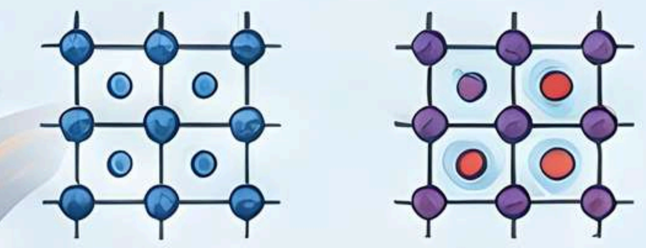
Term	Definition	Example
Isotopes	Same protons (Z), different neutrons (N)	$^1H, ^2H, ^5H$
Isobars	Same mass number (A), different protons (Z)	$^8H, ^3He$
Isotones	Same neutrons (N), different protons (Z)	$^{198}Hg, ^{197}Au$

The Binding Energy Curve



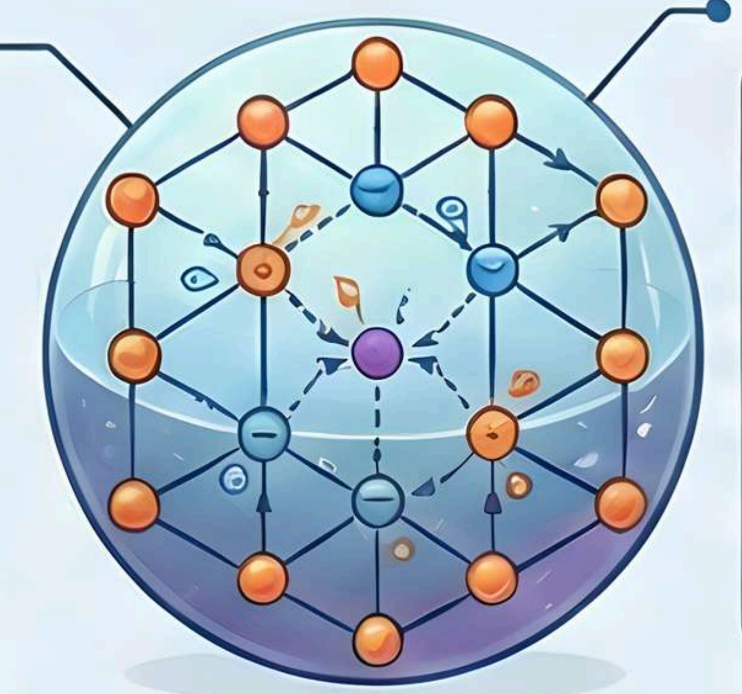
Chapter 14: The Heart of Electronics - Semiconductors

Intrinsic vs. Extrinsic Semiconductors



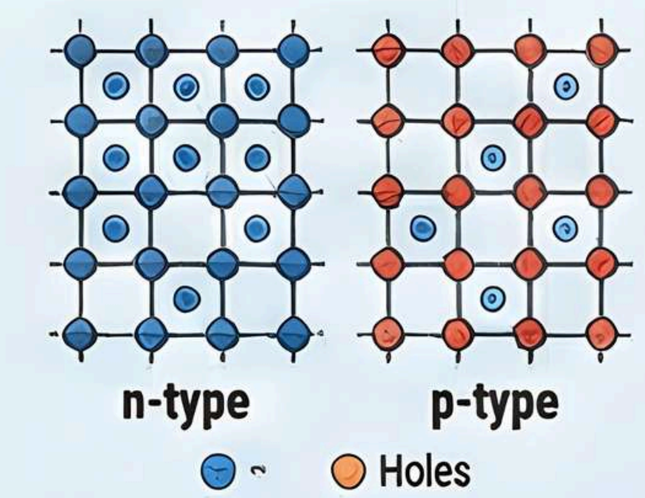
Intrinsic: Conductivity from thermally generated electron-hole pairs.

Extrinsic: Doped with impurities to increase conductivity.

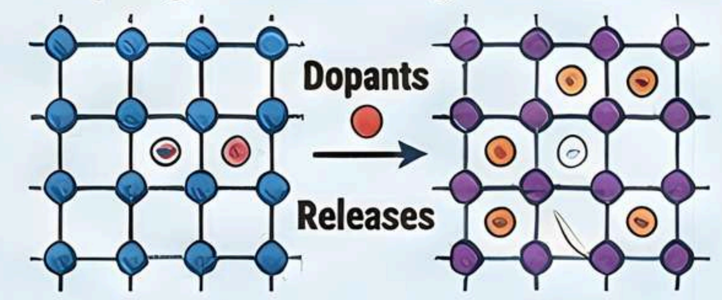


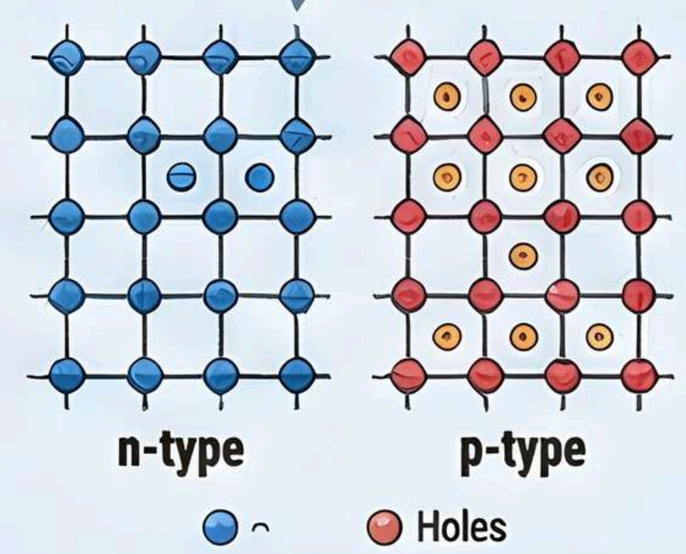
n-type vs. p-type Semiconductors

Property	n-type Semiconductor	p-type Semiconductor
Donant Type	Peotovalent (Valency S)	Trivelent (Valency S)
Examples	Arsenic (As), Phosphorus (P)	Phosphorus (P), Arsenic (As)
Majority Carriers	Electrons (negative)	Holes (positive)
Minority Corriers	Holes	Electrons
Bonant Role	Donates extra electron	Accepte electron, creates hole

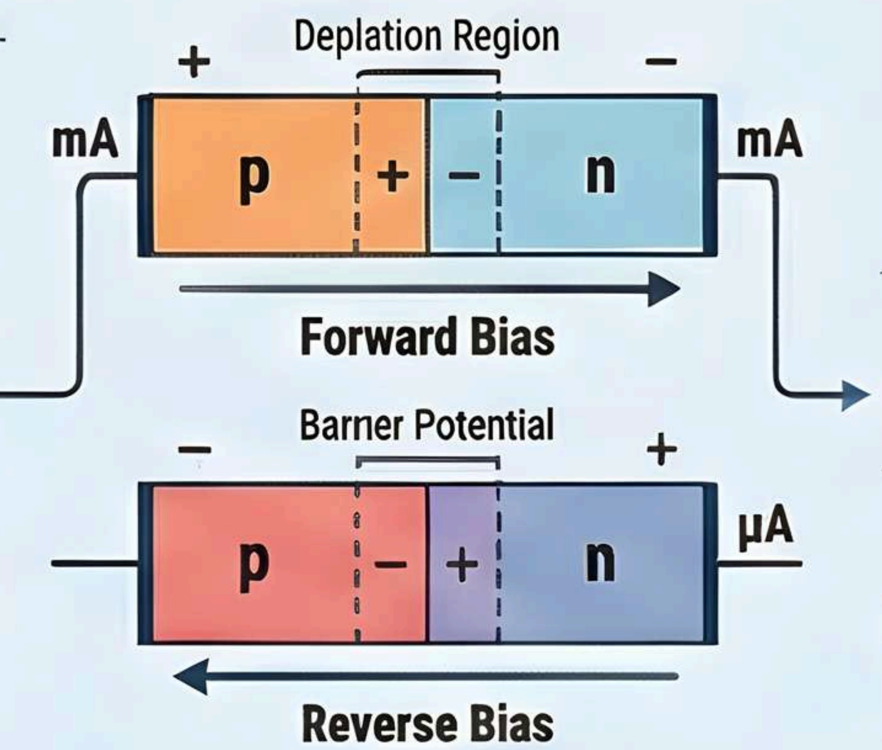


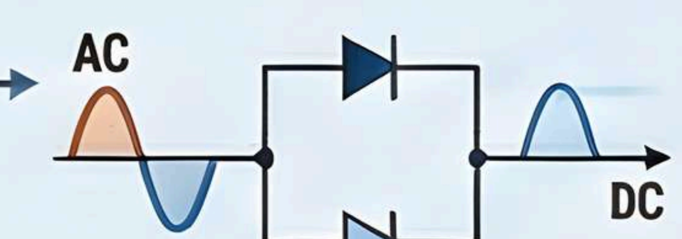
Doping: Enhancing Conductivity





The P-N Junction & Diode





Rectification: Converting AC to DC
Diodes allow current in one direction, used as rectifiers.

Material Type	Material Properties Comparison			
	Definition	Resistivity (μ)	Energy Gap (E_z)	Conduction Mechanism
Metals	Very Low 0 (10^{-2} - 10^{-8} Om)	Very Low (10^{-2} - 10^{-8} Om)	$E_g = 0$	Overlapping bands, free electrons
Semiconductors	Intermediate (10V) $\cdot 10^{-5}$ - 10^{-6} Om)	Intermediate (10^{-5} - 10^{8} Om)	Small (E_g < 3 eV)	Thermal excitation across gap
Insulators	Very High (10^{11} o - 10^{15} Om)	Very High (10^{11} - 10^{19} Om)	Large (E_g > 3 eV)	Large gap prevents movement