THE PCS AKADEMIA
A UNIT OF THE IAS AKADEMIA

72ND BPSC PRELIMS
REVISION SERIES

NIRBHAY

90+

Complete Physics for BPSC Prelims

An exhaustive, classroom-ready reference — Lucent's breadth, NCERT's clarity, BPSC's exam intelligence, in one visual textbook.

FACULTY
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VOLUME I · PHYSICS

MATERIAL PREPARED UNDER THE GUIDANCE OF
THE IAS AKADEMIA TEAM

EXAM: 26 JULY 2026

HOW THIS BOOK IS BUILT

Reading the Signposts

Every chapter follows the same rhythm so nothing is ever hunted for. Coloured tags flag *what a block is for*; boxes carry the type of content a BPSC aspirant needs at each moment — from first intuition to the night-before recall.

- **PYQ** An authentic previously-asked question, with the exam and year labelled.
- **FORMULA** Formula with symbols, unit, condition, a solved example and the common slip.
- **MEMORY HOOK** A mnemonic or one-line recall device, tested against confusion.
- **EXPERIMENT** A demonstration Dr. Chaturvedi can perform live in class.
- **BIHAR** A Bihar-specific application — rivers, power, disaster, geography.
- **TRAP** A misconception BPSC has used to build a wrong option.
- **NOBEL** A Nobel Prize link, with year and official citation.
- **CLASSROOM NOTE** Analogy, board plan, live demo and the doubt students raise — in class.

DEFINITION BOX
Formal, exam-precise wording of every term before it is used.

RAPID RECALL
10–25 must-know facts closing every chapter for last-minute revision.

CLASSROOM NOTE
A ready classroom sequence: opener, board diagram, demo, doubts, recap.

ACCURACY CONVENTION
Where coaching books oversimplify, this book separates the **Exam Convention** (what BPSC has historically marked correct) from the **Scientifically Precise Position**. PYQs carry the source exam and year; questions written for practice are tagged `ORIGINAL` and never disguised as PYQs.

VOLUME I · PHYSICS

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THIS EDITION

All 30 chapters are now developed — Parts I & II in full depth, Parts III–VIII condensed high-yield, and the new Parts IX–X covering Modern Physics, Instruments, Discoveries and Nobel Prizes with diagram-first treatment. Chemistry ships as Volume II.

30	**500+**	**~28**	**Vis**
CHAPTERS PLANNED	PRACTICE MCQS	SCI QS / PRELIMS	DIAGRAM-FIRST

PART I · CHAPTER 1

Nature & Scope of Physics

Why the same subject explains a falling mango, a beating heart, a mobile signal and a nuclear reactor — and why BPSC treats Physics as a test of understanding, not arithmetic.

WHY BPSC ASKS THIS
Foundational framing feeds directly into definition-based and "which branch studies…" questions, and into scientist–field matching.

FREQUENCY
Low–moderate · usually via scientists & forces

PREREQUISITES
None. This is the map for everything that follows.

You will be able to — name the branches of Physics & classify a phenomenon into one.

Distinguish **classical** from **modern** physics with a date & a reason.

Rank the **four fundamental forces** and give one example of each.

1.1 The Story: One Rulebook for the Whole Universe

In 1665 a plague closed Cambridge and a young **Isaac Newton** went home to his mother's orchard. Watching an apple fall, he asked a question no one had joined together before: *is the force that pulls the apple down the same force that holds the Moon in its orbit?* When he showed it was — one law, one force, apple and Moon alike — Physics was born as we know it: the search for the smallest set of rules that explains the largest range of events.

That is the whole spirit of the subject. **Physics** (from the Greek *physis*, "nature") is the study of matter, energy and their interactions. Its ambition is compression: to explain a beating heart, a bursting dam, a mobile tower and a star with a handful of principles. For a BPSC aspirant this is good news — you are never asked to be a mathematician, only to recognise *which* rule governs a given everyday situation.

DIAGRAM 1.1 · THE BRANCHES OF PHYSICS

PHYSICS

CLASSICAL PHYSICS
- **Mechanics** motion, force
- **Thermodynamics** heat, energy
- **Optics** light
- **Acoustics** sound
- **Electromagnetism** — electricity, magnetism, EM waves

MODERN PHYSICS
- **Atomic** atoms, electrons
- **Nuclear** fission, fusion
- **Quantum** the very small
- **Relativity** very fast, gravity
- **Electronics** — semiconductors, devices

The dividing line is roughly the year 1900. Classical physics = everyday scales; modern physics = the very small, the very fast, and the atom.

1.2 Classical vs Modern Physics

Everything discovered up to about 1900 — Newton's mechanics, heat, sound, light as a wave, electricity and magnetism — is **classical physics**. It describes the world at human scale beautifully. But it broke down for three cases: objects far too small (atoms), far too fast (near light speed), and very high energies. The physics built after 1900 to handle these — quantum theory, relativity, atomic and nuclear physics — is **modern physics**.

DEFINITION · PHYSICS

The branch of science that studies **matter, energy, and the interactions between them**, seeking universal laws expressed through measurement.

DEFINITION · SCIENTIFIC METHOD

Observation → hypothesis → experiment → law/theory. A **law** states *what* happens; a **theory** explains *why*. A theory is not a "guess."

1.3 The Four Fundamental Forces

Every interaction in the universe — from your feet on the floor to the Sun shining — reduces to just four forces. BPSC loves the *ranking* (strongest → weakest) and the *range* of each.

FORCE	RELATIVE STRENGTH	RANGE	HOLDS TOGETHER / SEEN IN
Strong nuclear	1 (strongest)	~10^{-15} m (nucleus)	Binds protons & neutrons in the nucleus
Electromagnetic	~1/137	Infinite	Atoms, chemistry, light, electricity, friction
Weak nuclear	~10^{-6}	~10^{-18} m	Radioactive β-decay; powers the Sun's fusion chain
Gravitational	~10^{-39} (weakest)	Infinite	Planets, tides, orbits, the falling apple

MEMORY HOOK **S–E–W–G = "Strong Electricians Wire Gently"** (strongest → weakest: Strong, Electromagnetic, Weak, Gravity). Counter-intuitively, **gravity is the weakest** force yet it rules the cosmos, because it is always attractive and never cancels out over huge masses.

1.4 Physics in Daily Life & Governance

- **Transport & road safety** — momentum & friction fix speed limits, seat-belt & airbag design, and accident reconstruction.
- **Disaster management** — seismology (earthquakes), fluid dynamics (floods), heat transfer (heatwaves).
- **Public health** — X-rays, ultrasound, MRI and radiotherapy are all applied physics.
- **Development & power** — dams, grids, solar & nuclear energy, satellite & mobile communication.

BIHAR

Bihar's own physics: the **Kosi & Gandak** flood dynamics (fluid mechanics), **lightning casualties** among the highest in India (electrostatics), **seismic Zone V** north Bihar (wave physics), and solar-energy potential across the Gangetic plain.

DM's DAY

Physics in a District Magistrate's day: crowd barriers (centre of gravity), lightning arrestors on schools (electrostatics), flood-relief boats (buoyancy), heatwave advisories (thermal transfer), and remote-sensing flood maps (EM waves).

1.5 Physicists You Must Know

SCIENTIST	KNOWN FOR	BPSC ANGLE
Isaac Newton	Laws of motion, gravitation	"Father of classical mechanics"
Albert Einstein	Relativity; photoelectric effect	Nobel 1921 — for *photoelectric effect*, not relativity
C. V. Raman	Raman effect (scattering of light)	First Indian Nobel in science, 1930
S. Chandrasekhar	Stellar structure, "Chandrasekhar limit"	Nobel 1983; nephew of C. V. Raman
Homi J. Bhabha	Cosmic rays; India's nuclear programme	"Father of Indian nuclear programme"
A. P. J. Abdul Kalam	Missiles, SLV-3	"Missile Man"; 11th President

1.6 PYQ Zone

PYQ BPSC-style · Scientist-field · Easy

Q. The scattering of light by molecules, which explains why the daytime sky is blue, is associated with which Indian scientist?

(a) Homi Bhabha
(b) C. V. Raman
(c) S. N. Bose
(d) Vikram Sarabhai

✓ Answer (b) C. V. Raman. The Raman effect concerns the inelastic scattering of light. **Why not others:** Bhabha → nuclear programme; S. N. Bose → Bose–Einstein statistics; Sarabhai → "father of Indian space programme." *Trap:* the everyday blue-sky effect is **Rayleigh** scattering, but the scientist BPSC pairs with light-scattering in India is Raman.

1.7 Memory Lab

RECALL HOOKS

- **Forces (strong→weak):** "Strong Electricians Wire Gently."
- **Classical = before 1900; Modern = after 1900** (quantum + relativity).
- **Law tells what, Theory tells why.**

DO NOT CONFUSE

- **Gravity is weakest**, not strongest — yet dominates space.
- **Einstein's Nobel** = photoelectric effect, *not* relativity.
- **Scientific "theory"** ≠ a guess; it is a well-tested explanation.

CLASSROOM NOTE Dr. S. N. Chaturvedi · Class delivery

Open with: "If I drop this chalk, what pulls it down — and does the *same* thing hold the Moon up?" Let them argue, then reveal Newton's insight.

Board plan: a single tree with two branches — CLASSICAL and MODERN — grown live as you name each sub-branch.

Likely doubt: "If gravity is weakest, why does it hurt to fall?" — because Earth's mass is enormous and gravity never cancels.

Recap (5 min): four forces + the 1900 dividing line + Einstein's Nobel trap. **Bridge:** "To do any of this we must first *measure* — that's Chapter 2."

RAPID RECALL · CHAPTER 1

① Physics = study of matter, energy & their interactions.
② Four forces: Strong > EM > Weak > Gravity.
③ Strongest = strong nuclear; Weakest = gravity.
④ Infinite range: gravity & electromagnetism.
⑤ Classical ≈ before 1900; Modern ≈ after 1900.
⑥ Sun shines via fusion (strong + weak forces).
⑦ Newton = father of classical mechanics.
⑧ Einstein's Nobel (1921) = photoelectric effect.
⑨ C. V. Raman = first Indian science Nobel (1930).
⑩ Bhabha = father of Indian nuclear programme.

1.8 Practice Set

ORIGINAL **1.** Which force is responsible for holding the nucleus of an atom together? (a) Gravity (b) Electromagnetic (c) Strong nuclear (d) Weak nuclear

ORIGINAL **2.** Among the four fundamental forces, the weakest is: (a) Strong (b) Weak (c) Gravitational (d) Electromagnetic

STATEMENT **3.** Consider: (I) Quantum mechanics is part of classical physics. (II) Relativity belongs to modern physics. Which is/are correct? (a) I only (b) II only (c) Both (d) Neither

ASSERTION **4. A:** Einstein won the Nobel Prize for the theory of relativity. **R:** Relativity revolutionised our idea of space and time. (a) Both true, R explains A (b) Both true, R doesn't explain A (c) A false, R true (d) Both false

MATCH **5.** Match: (i) Raman (ii) Bhabha (iii) Sarabhai — with — (P) Space programme (Q) Nuclear programme (R) Light scattering.

ANSWER KEY – **1(c)** strong nuclear binds protons/neutrons. **2(c)** gravity is ~10^{39} times weaker than the strong force. **3(b)** quantum mechanics is *modern*, so I is false. **4(c)** Assertion is false — the Nobel was for the photoelectric effect; the Reason is a true statement on its own. **5** i-R, ii-Q, iii-P.

PART I · CHAPTER 2

Units, Dimensions & Measurement

You cannot ask "how fast, how hot, how heavy?" without a yardstick everyone agrees on. This chapter is the single most reliable source of BPSC Physics marks.

02

WHY BPSC ASKS THIS

SI units, instruments and "which quantity is a vector" are near-guaranteed. Units named after scientists are a favourite.

FREQUENCY

High · 1–2 Qs almost every year

PREREQUISITES

Chapter 1. Basic arithmetic only.

Outcome — name the 7 SI base units & their quantities without hesitation.

Separate **scalars** from **vectors** instantly.

Match each **instrument** to the quantity it measures.

2.1 The Story: A Metre Kept in a Vault

For 130 years the world's definition of "one metre" was a platinum-iridium bar locked in a vault near Paris. Every ruler on Earth ultimately traced back to that one bar. The trouble? A bar can be scratched, can expand with heat, can be lost in a war. So in 1983 scientists replaced it with something no one can damage: **the metre is now the distance light travels in vacuum in $\frac{1}{299,792,458}$ of a second.** Measurement grew up — from an object you could steal to a law of nature you cannot.

Every measurement has two parts: a **number** and a **unit**. "5" means nothing; "5 metres" is an answer. BPSC tests whether you know the *right unit* for each quantity, the *instrument* that reads it, and whether it carries a *direction*.

DEFINITION · FUNDAMENTAL QUANTITY

A quantity that **cannot** be expressed in terms of others (length, mass, time…). There are **7**.

DEFINITION · DERIVED QUANTITY

Built from fundamentals — e.g. **speed** = length ÷ time, **force** = mass × acceleration.

2.2 The Seven SI Base Units

Quantity	Unit	Symbol
LENGTH	metre	m
MASS	kilogram	kg
TIME	second	s
ELECTRIC CURRENT	ampere	A
TEMPERATURE	kelvin	K
AMOUNT OF SUBSTANCE	mole	mol
LUMINOUS INTENSITY	candela	cd

MEMORY HOOK

"Mary Kissed Sam At King's Market Counter"

2.3 The Wall Chart — Quantity · Formula · SI Unit · Instrument

QUANTITY	FORMULA	SI UNIT	INSTRUMENT	S/V
Speed	distance/time	m/s	speedometer	S
Velocity	displacement/time	m/s	—	V
Force	mass × accel.	newton (N)	spring balance	V
Pressure	force/area	pascal (Pa)	barometer/manometer	S
Work / Energy	force × distance	joule (J)	—	S
Power	work/time	watt (W)	wattmeter	S
Frequency	1/time period	hertz (Hz)	frequency meter	S
Electric charge	current × time	coulomb (C)	—	S
Resistance	voltage/current	ohm (Ω)	ohmmeter	S

S = scalar (magnitude only) · V = vector (magnitude + direction). Note SI units written after a person's name are lower-case (newton, pascal) but their symbol is capitalised (N, Pa).

2.4 Scalars vs Vectors & the Confusing Pairs

SCALARS — MAGNITUDE ONLY

Distance, speed, mass, time, energy, work, power, temperature, electric current*, volume, density, pressure.

VECTORS — MAGNITUDE + DIRECTION

Displacement, velocity, acceleration, force, momentum, weight, torque, electric & magnetic field.

TRAP **Electric current is a scalar** despite having a direction — because it does not obey vector addition (currents add algebraically at a junction, per Kirchhoff). * A classic BPSC trick option.

MASS VS WEIGHT

	MASS	WEIGHT
Nature	amount of matter	force of gravity
Unit	kg (scalar)	N (vector)
On Moon	same	1/6 of Earth
Instrument	beam balance	spring balance

SI PREFIXES

tera T = 10^{12} · giga G = 10^{9}
mega M = 10^{6} · kilo k = 10^{3}
centi c = 10^{-2} · milli m = 10^{-3}
micro μ = 10^{-6} · nano n = 10^{-9}

1 light-year = distance (not time!) ≈ 9.46×10^{15} m.

2.5 Precision Instruments & Least Count

VERNIER CALLIPERS

Measures internal/external diameter & depth. **Least count = 0.1 mm (0.01 cm)**. LC = 1 main-scale div − 1 vernier-scale div.

SCREW GAUGE (MICROMETER)

Measures thickness of wire/sheet. **Least count = 0.01 mm**. More precise than vernier callipers (works on the screw principle).

FORMULA **Least count** = smallest value an instrument can read. Smaller LC ⇒ greater precision. *Example:* a vernier reading 0.01 cm resolves a hair's width; a metre scale (LC 1 mm) cannot.

2.6 SI Units Named After Scientists — a BPSC favourite

Newton (N) — force	**Pascal (Pa)** — pressure	**Joule (J)** — energy
Watt (W) — power	**Hertz (Hz)** — frequency	**Coulomb (C)** — charge
Volt (V) — potential	**Ampere (A)** — current	**Ohm (Ω)** — resistance
Kelvin (K) — temperature	**Tesla (T)** — magnetic field	**Farad (F)** — capacitance

2.7 PYQ Zone

PYQ SI unit · Easy

Q. The SI unit of pressure is:

(a) Newton (b) Pascal (c) Joule (d) Watt

✓ **(b) Pascal** = 1 N/m². Newton is force, Joule is energy, Watt is power.

PYQ Scalar/vector · Moderate

Q. Which of the following is a vector quantity?

(a) Speed (b) Work (c) Momentum (d) Temperature

✓ **(c) Momentum** (mass × velocity — carries direction). Speed, work & temperature are scalars.

CLASSROOM NOTE Class delivery + live demo

Open with: hold a 1-litre water bottle — "this is about 1 kg. What's its weight in newtons?" (≈ 9.8 N). Separates mass from weight in one stroke.

Board plan: two columns SCALAR | VECTOR, fill live as students call out quantities.

EXPERIMENT **Measuring a coin's thickness:** pass a screw gauge round — show LC = 0.01 mm reveals what a ruler cannot.

Likely doubt: "Is current a vector?" — No; it has direction but adds algebraically.

RAPID RECALL · CHAPTER 2

① 7 SI base units: m, kg, s, A, K, mol, cd.
② Force → newton; Pressure → pascal; Energy → joule.
③ Power → watt; Frequency → hertz; Charge → coulomb.
④ Speed is scalar; velocity is vector.
⑤ Current = scalar (adds algebraically).
⑥ Mass = kg (constant); Weight = N (varies with g).
⑦ Vernier LC = 0.01 cm; Screw gauge LC = 0.01 mm.
⑧ Light-year = unit of distance, not time.
⑨ Beam balance → mass; Spring balance → weight.
⑩ Unit named after person: lower-case name, capital symbol.

2.8 Practice Set

ORIGINAL **1.** The number of fundamental (base) units in the SI system is: (a) 5 (b) 6 (c) 7 (d) 9

ORIGINAL **2.** Light-year is the unit of: (a) time (b) distance (c) speed (d) intensity

MATCH **3.** (i) Ammeter (ii) Barometer (iii) Screw gauge — (P) pressure (Q) current (R) thickness.

STATEMENT **4.** (I) Weight is a scalar. (II) Mass is the same everywhere. Correct? (a) I (b) II (c) Both (d) Neither

ASSERTION **5. A:** The kilogram is a fundamental unit. **R:** It cannot be derived from other units. (a) Both true, R explains A (b) Both true, unrelated (c) A true R false (d) Both false

ANSWER KEY — **1(c)** seven. **2(b)** distance. **3** i-Q, ii-P, iii-R. **4(b)** weight is a vector, so I is false; mass is invariant, so II is true. **5(a)** both true and the reason correctly explains it.

PART II · CHAPTER 3

Motion

Nothing in the universe is truly at rest. This chapter gives you the vocabulary of movement — and the three equations that describe almost any journey.

WHY BPSC ASKS THIS
Graph reading, "distance vs displacement", circular motion & free fall appear as concept MCQs, rarely as heavy sums.

FREQUENCY
Moderate

PREREQUISITES
Ch 2 (scalars vs vectors).

03

3.1 The Story: Are You Moving Right Now?

You feel perfectly still reading this — yet you are spinning with the Earth at ~1,600 km/h at the equator, orbiting the Sun at ~1,08,000 km/h, and riding the galaxy through space faster still. So *are* you moving? The honest answer: **motion is relative**. A passenger is at rest relative to the train but in motion relative to the platform. There is no "absolute rest" anywhere in the universe — you must always ask, *relative to what?*

DEFINITION · DISTANCE VS DISPLACEMENT

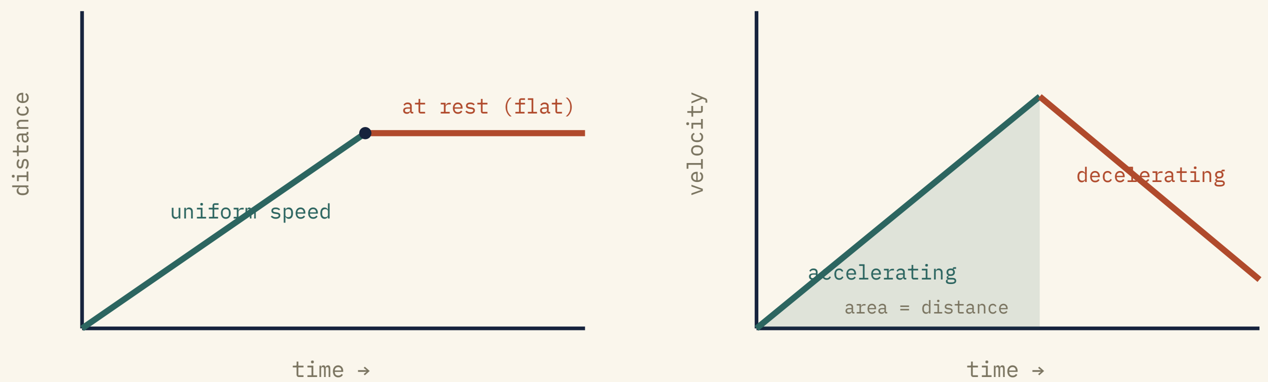
Distance = total path length (scalar, never negative). **Displacement** = shortest straight line from start to end, with direction (vector). Walk a full circle: distance = circumference, displacement = **zero**.

DEFINITION · ACCELERATION

Rate of change of **velocity** (m/s²). A body slowing down has **negative** acceleration (retardation). Uniform circular motion is accelerated even at constant speed — the *direction* changes.

3.2 Reading Motion Graphs

DIAGRAM 3.1 · DISTANCE-TIME & VELOCITY-TIME GRAPHS



*On a distance–time graph the **slope = speed** (flat line = at rest). On a velocity–time graph the **slope = acceleration** and the **area under it = distance travelled**.*

3.3 The Three Equations of Motion

FORMULA valid only for **uniform acceleration** (a = constant)

$$v = u + at$$
velocity–time

$$s = ut + \tfrac{1}{2}at^2$$
distance–time

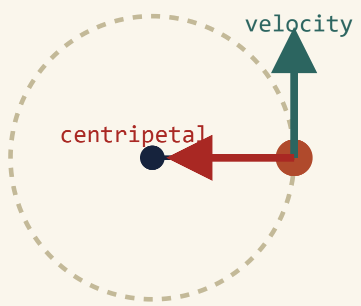
$$v^2 = u^2 + 2as$$
velocity–distance

Symbols: u = initial velocity, v = final velocity, a = acceleration, t = time, s = displacement. **Units:** all SI (m, m/s, m/s^2, s). **Solved example:** a car starts from rest (u=0), a = 2 m/s^2, after t = 5 s → v = 0 + 2×5 = **10 m/s**; s = 0 + ½×2×25 = **25 m**.

COMMON MISTAKE
Using these equations when acceleration is **not** constant (e.g. a body in circular motion or under air resistance). They fail there.

3.4 Circular Motion, Free Fall & Terminal Velocity

DIAGRAM 3.2 · CIRCULAR MOTION



*Velocity points along the tangent; a **centripetal force** pulls inward. Remove it (cut the string) and the body flies off tangentially — not outward.*

FREE FALL
Only gravity acts. All bodies fall with the **same** acceleration g ≈ 9.8 m/s^2, regardless of mass — a feather and a coin land together *in vacuum* (Apollo 15 proved it on the Moon).

TERMINAL VELOCITY
In air, drag grows with speed until it balances gravity — the body then falls at a constant **terminal velocity**. This is why a parachute (large drag) lets a skydiver land safely.

TRAP The force in circular motion is **centripetal** (centre-seeking, real). "Centrifugal force" is only an apparent (pseudo) force felt in the rotating frame — a favourite BPSC distractor.

3.5 Real-Life Applications

- **Banked roads & race tracks** tilt inward to supply centripetal force for turns.
- **Washing-machine spin** & centrifuges throw water/particles outward (inertia).
- **Parachutes & raindrops** reach terminal velocity — rain doesn't hit like a bullet.
- **Speedometer & odometer** read speed & distance; over-speeding fines use these.

3.6 PYQ Zone

PYQ Concept · Moderate

Q. A body moving in a circle at constant speed is said to be accelerating because:

(a) its speed changes
(b) its direction changes
(c) it covers unequal distances
(d) it is not accelerating

✓ **(b).** Velocity is a vector; even at constant speed, a continuously changing direction means changing velocity — hence acceleration (centripetal, directed to the centre).

MEMORY HOOKS

- d–t graph slope = **speed**; v–t graph slope = **acceleration**, area = **distance**.
- Circular motion → force is **centri-PET-al** (pets pull toward you).
- Free fall: mass doesn't matter (in vacuum).

CLASSROOM NOTE + DEMO

Demo: swing a stone tied to a string overhead, then release — it flies off *tangentially*, not radially. **Doubt:** "Does a heavier body fall faster?" Drop a book and a flat sheet on top of it together — they land together (sheet shielded from air).

RAPID RECALL · CHAPTER 3

① Motion is relative — always ask "relative to what?"
② Distance = scalar; displacement = vector (can be 0).
③ $v=u+at$, $s=ut+\frac{1}{2}at^2$, $v^2=u^2+2as$ (constant a only).
④ d–t slope = speed; v–t slope = acceleration.
⑤ v–t area = distance travelled.
⑥ Uniform circular motion is accelerated (dir. changes).
⑦ Centripetal force = real, inward; centrifugal = apparent.
⑧ Free fall $g \approx 9.8\ m/s^2$; mass-independent in vacuum.
⑨ Terminal velocity: drag balances gravity.
⑩ Cut the string → body flies off tangentially.

3.7 Practice Set

ORIGINAL **1.** Which can be zero for a moving body? (a) distance (b) displacement (c) speed (d) time

ORIGINAL **2.** Slope of a velocity–time graph gives: (a) distance (b) speed (c) acceleration (d) displacement

STATEMENT **3.** (I) In free fall, heavier bodies accelerate faster. (II) Terminal velocity is constant. (a) I (b) II (c) Both (d) Neither

ASSERTION **4. A:** A stone whirled in a circle has acceleration. **R:** Its direction of motion keeps changing. (a) Both true, R explains A (b) Both true, unrelated (c) A true R false (d) Both false

ANSWER KEY — **1(b)** displacement is zero on returning to start. **2(c)** acceleration. **3(b)** free-fall acceleration is mass-independent, so I is false; terminal velocity is indeed constant. **4(a)** both true, reason explains it.

PART II · CHAPTER 4

Newton's Laws, Force & Momentum

Three laws written in 1687 still explain seat belts, rockets, walking and the recoil of a gun. This is the beating heart of BPSC mechanics.

04

WHY BPSC ASKS THIS
"Which law explains…" statements, inertia examples, rocket & recoil, and friction types are perennial.

FREQUENCY
High

PREREQUISITES
Ch 3 (velocity, acceleration).

4.1 The Story: Why a Coin Drops into the Glass

Place a coin on a stiff card over a glass, then flick the card sharply sideways. The card shoots away — but the coin drops straight into the glass. Why? The coin's **inertia**: it "wants" to stay at rest, and the flick is too quick to drag it along. That single stubbornness of matter is Newton's First Law. Newton didn't invent forces; he found the exact rules they obey — and those rules have not needed a correction for everyday life in over 300 years.

4.2 The Three Laws

FIRST LAW · INERTIA
A body stays at rest or in uniform motion unless a **net external force** acts. *"Law of inertia."*
Seat belts, coin-card, sudden bus jerk.

SECOND LAW · F = ma
Force = rate of change of momentum. **F = ma.** The *quantitative* law — defines the newton.
Catching a ball, airbags, hitting a six.

THIRD LAW · ACTION–REACTION
Every action has an **equal & opposite reaction**, on *different* bodies.
Rockets, gun recoil, walking, swimming.

MEMORY HOOK **"In-Fa-Re"** — **In**ertia (1st), **Fa** = ma (2nd, Force), **Re**action (3rd). Or: *"Lazy · Push · Kick-back."*

4.3 Momentum, Impulse & Conservation

FORMULA

$$p = m \times v$$
momentum · unit kg·m/s (vector)

$$\text{Impulse} = F \times t = \Delta p$$
unit N·s

Conservation of momentum: in the absence of external force, total momentum before = after. A gun (mass M) firing a bullet (mass m) recoils so that M·V = m·v — the reason a rifle kicks your shoulder. **Solved:** bullet 0.01 kg at 400 m/s from a 4 kg gun → recoil V = (0.01×400)/4 = **1 m/s** backward.

WHY IMPULSE MATTERS
Airbags & cricketers "give" with the ball to **increase t**, which **lowers F** for the same Δp — less injury.

4.4 Friction — Friend and Foe

TYPE	WHEN	RELATIVE SIZE
Static	before motion starts	largest (self-adjusting)
Sliding (kinetic)	surfaces sliding	less than static
Rolling	wheel/ball rolling	**smallest** — why wheels win
Fluid (drag)	moving through air/liquid	grows with speed

FRICTION AS FRIEND

Walking, gripping, brakes, writing, striking a match, nails holding wood.

FRICTION AS FOE

Wear & tear, heat, wasted engine energy — reduced by lubricants, ball-bearings, streamlining.

4.5 Everyday Applications — Which Law?

EVERYDAY EVENT	LAW	EXPLANATION
Passenger lurches forward when bus brakes	**1st**	Body's inertia keeps it moving
Cricketer pulls hands back to catch a ball	**2nd**	More time → smaller force
Rocket / jet moves forward	**3rd**	Gas pushed back → rocket pushed forward
Gun recoils on firing	**3rd**	Momentum conserved
Swimmer pushes water back	**3rd**	Water pushes swimmer forward

DM's DAY

Road-accident momentum: a truck at low speed carries more momentum ($p = mv$) than a fast bike — heavy-vehicle speed limits, crash barriers and helmet mandates all follow directly from $F = \Delta p/t$. Slowing the impact over more time (crumple zones, airbags) is the physics behind every road-safety order.

4.6 PYQ Zone

PYQ Concept · Easy

Q. A rocket works on the principle of conservation of:

(a) mass (b) energy (c) momentum (d) velocity

✓ **(c) momentum.** Hot gas ejected backward gives the rocket forward momentum (3rd law + conservation).

PYQ Friction · Moderate

Q. Ball-bearings are used in machines to convert:

(a) sliding into rolling friction (b) rolling into sliding (c) static into fluid (d) reduce mass

✓ **(a).** Rolling friction is the smallest, so replacing sliding with rolling saves energy & wear.

CLASSROOM NOTE

EXPERIMENT **Coin & card (inertia):** flick the card, coin drops in the glass. **Balloon rocket:** release an inflated balloon — 3rd law in flight.

Open with: "Why do we fall forward when a bus stops suddenly?"

Likely doubt: "If action = reaction, how does anything move?" — because they act on *different* bodies, so they never cancel on the same object.

Bridge: "Force can move things — but doing so takes *work*. That's Chapter 5."

RAPID RECALL · CHAPTER 4

① 1st law = inertia; 2nd law = F=ma; 3rd = action–reaction.
② Inertia ∝ mass; heavier = harder to move/stop.
③ Momentum p = mv (vector, kg·m/s), conserved.
④ Impulse = F×t = change in momentum.
⑤ Airbags/catching: increase t → reduce force.
⑥ Rocket, gun recoil, walking → 3rd law.
⑦ Rolling friction smallest; static largest.
⑧ Ball-bearings: sliding → rolling friction.
⑨ Action & reaction act on different bodies.
⑩ Newton (N) = kg·m/s² = force to accel. 1 kg by 1 m/s².

4.7 Practice Set

ORIGINAL **1.** The property by which a body resists change in its state of motion is: (a) force (b) inertia (c) momentum (d) impulse

ORIGINAL **2.** SI unit of momentum is: (a) N (b) kg·m/s (c) N·m (d) J

STATEMENT **3.** (I) Action & reaction act on the same body. (II) They are equal in magnitude. (a) I (b) II (c) Both (d) Neither

MATCH **4.** (i) Seat belt (ii) Rocket (iii) Ball-bearing — (P) 3rd law (Q) reduce friction (R) inertia.

ANSWER KEY – **1(b)** inertia. **2(b)** kg·m/s. **3(b)** they act on *different* bodies (I false); equal in magnitude (II true). **4** i-R, ii-P, iii-Q.

PART II · CHAPTER 5

Work, Energy & Power

Energy can never be created or destroyed — only changed in form. On that one sentence rest power plants, food, fuels and your electricity bill.

05

WHY BPSC ASKS THIS

Energy forms & conversions, "commercial unit of electricity" (kWh), and the three classes of levers are recurring.

FREQUENCY

Moderate

PREREQUISITES

Ch 4 (force).

5.1 The Story: Carrying Bricks Is Not "Work"

A labourer stands all day holding a heavy load on his head. He is exhausted — yet in physics he has done **zero work**, because the load did not move in the direction of the force. Work has a precise meaning: force must produce *displacement along its own direction*. This is the single most counter-intuitive idea BPSC exploits.

POSITIVE WORK

Force & motion same direction — lifting, pushing a cart forward.

NEGATIVE WORK

Force opposes motion — friction, brakes, gravity on a rising ball.

ZERO WORK

Force ⊥ motion — carrying a bag horizontally; Moon orbiting Earth.

FORMULA

$W = F \times d$
Work · joule (J)

$KE = ½mv^2$
Kinetic energy · J

$PE = mgh$
Potential energy · J

Power = work/time = W/t, unit **watt (W)**. 1 horsepower ≈ **746 W**. **Solved:** lifting 10 kg by 2 m in 4 s → W = mgh = 10×9.8×2 = 196 J; Power = 196/4 = **49 W**.

COMMON MISTAKE

Confusing energy (J) with power (W). Power is the **rate** of doing work — a fast worker has more power, not more work.

5.2 Forms & Conservation of Energy

Energy appears as mechanical, heat, light, sound, electrical, chemical, nuclear & magnetic — and constantly converts: a dam turns *PE→KE→electrical*; a torch turns *chemical→electrical→light+heat*; photosynthesis turns *light→chemical*. The total, however, is always conserved.

BIHAR

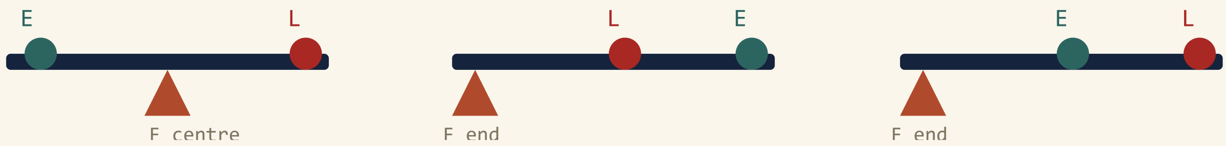
Bihar's **hydropower & barrages** (Gandak, Kosi, Sone) convert water's potential energy to electricity; thermal stations (Barauni, Kahalgaon nearby) convert chemical→heat→electrical.

COMMERCIAL UNIT OF ELECTRICITY

1 unit = 1 kilowatt-hour (kWh) = 3.6 × 10^6 J. Your bill counts kWh, not joules. A 1000 W heater run 1 hour = 1 unit.

5.3 Simple Machines — The Three Classes of Levers

DIAGRAM 5.1 · LEVER CLASSES (E = EFFORT, L = LOAD, F = FULCRUM)



Class I
F between E & L
see-saw, scissors, pliers, crowbar

Class II
L between F & E
wheelbarrow, nutcracker, bottle-opener

Class III
E between F & L
tongs, forearm, fishing rod, broom

The human forearm is a Class-III lever (elbow = fulcrum, biceps = effort). Mechanical advantage = load ÷ effort = effort-arm ÷ load-arm.

MEMORY HOOK **"F-L-E" order tells the class:** whatever is in the *middle* names it — **F**ulcrum-middle = I, **L**oad-middle = II, **E**ffort-middle = III. (1-2-3 → F-L-E.)

Pulley lifts loads, changes direction	**Inclined plane** ramp — less effort, more distance	**Screw** inclined plane wrapped round	**Wedge** axe, knife — two inclined planes	**Wheel & axle** steering, doorknob, screwdriver

5.4 PYQ Zone

PYQ Units · Easy

Q. The commercial unit of electrical energy is:
(a) watt (b) joule (c) kilowatt-hour (d) volt

✓ **(c) kWh** = 1 "unit" = 3.6×10^6 J. Joule is the SI unit but too small for billing.

PYQ Levers · Moderate

Q. A wheelbarrow is an example of a lever of:
(a) first class (b) second class (c) third class (d) none

✓ **(b).** Load lies between fulcrum (wheel) and effort (hands) — Class II.

CLASSROOM NOTE

Open with: "If I hold this bag still for an hour, how much work have I done?" (Zero!). EXPERIMENT flex the forearm to show a Class-III lever live.

Doubt: "Do machines reduce work?" — No; they reduce *effort* by increasing distance. Work in ≈ work out (minus friction). **Bridge:** "The biggest force of all — gravity — is Chapter 6."

RAPID RECALL · CHAPTER 5

① Work W = F×d (joule); zero if F ⊥ motion.
② KE = ½mv²; PE = mgh.
③ Power = work/time (watt); 1 HP ≈ 746 W.
④ Energy is conserved — only converts form.
⑤ 1 unit electricity = 1 sc-camel-k-wh = 3.6×10^6 J.
⑥ Lever middle element names class: F-L-E → I-II-III.
⑦ Wheelbarrow = II; forearm/tongs = III.
⑧ Machines cut effort, not total work.
⑨ Mechanical advantage = load ÷ effort.
⑩ Dam: PE → KE → electrical energy.

5.5 Practice Set

ORIGINAL **1.** Energy of a body due to its motion is: (a) potential (b) kinetic (c) chemical (d) nuclear

ORIGINAL **2.** Work done is zero when the angle between force and displacement is: (a) 0° (b) 45° (c) 90° (d) 180°

STATEMENT **3.** (I) A see-saw is a Class-I lever. (II) Power is measured in joules. (a) I (b) II (c) Both (d) Neither

MATCH **4.** (i) Hydroelectric (ii) Photosynthesis (iii) Torch — (P) chem→elec→light (Q) PE→electrical (R) light→chemical.

ANSWER KEY – **1(b)** kinetic. **2(c)** 90° (cos 90° = 0). **3(a)** see-saw is Class-I (true); power is in watts, not joules (II false). **4** i-Q, ii-R, iii-P.

PART II · CHAPTER 6

Gravitation

The weakest force in nature holds the Moon, launches ISRO's satellites and decides your weight on every planet. Space & satellites make this a high-value chapter.

06

WHY BPSC ASKS THIS

Escape velocity, geostationary vs polar satellites, weightlessness & g-variation connect directly to ISRO current affairs.

FREQUENCY

High · with space current affairs

PREREQUISITES

Ch 4–5 (force, energy).

6.1 The Story: The Moon Is Always Falling

Here is Newton's most beautiful idea. Fire a cannonball fast enough from a mountain and it won't land — the Earth curves away beneath it just as fast as it falls, so it circles the planet forever. That is exactly what the Moon does: it is **perpetually falling toward Earth but always missing.** An orbit is simply endless free-fall. The same gravity that drops an apple keeps the Moon, and every ISRO satellite, in the sky.

FORMULA Newton's Universal Law of Gravitation

$$F = G \cdot m_1 m_2 / r^2$$

every mass attracts every other

$$g = 9.8\ m/s^2\ (\text{Earth})$$

accel. due to gravity

Symbols: G = universal gravitational constant (6.67×10^{-11} $N{\cdot}m^2/kg^2$, same everywhere); r = distance between centres. Force **weakens as $1/r^2$** — double the distance, quarter the force. **Note:** G is universal & constant; **g varies** with location.

g VARIES

g is **maximum at poles**, minimum at the equator; decreases with altitude & depth; g on Moon = 1/6 of Earth.

6.2 Escape Velocity, Orbital Velocity & Satellites

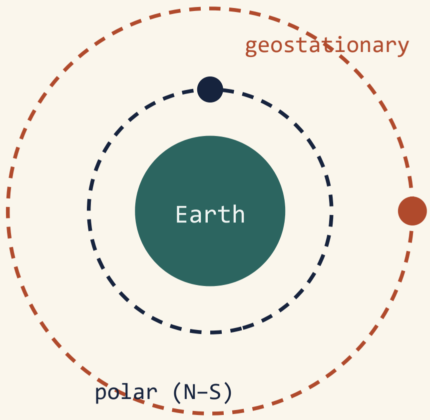
ESCAPE VELOCITY

Minimum speed to break free of Earth's gravity forever = **11.2 km/s** (≈ 40,000 km/h). Independent of the object's mass. On the Moon it is only 2.4 km/s.

ORBITAL VELOCITY

Speed to stay in a circular orbit ≈ **7.9 km/s** for a low orbit. Escape velocity = √2 × orbital velocity.

DIAGRAM 6.1 · GEOSTATIONARY VS POLAR ORBIT



Geostationary: orbits at **~36,000 km** above the equator with a 24-hour period, so it appears *fixed* over one spot. Used for **communication, TV & weather** (e.g. INSAT, GSAT).

Polar (Sun-synchronous): low orbit (~700–800 km) crossing the poles; scans the whole Earth strip-by-strip. Used for **remote sensing, mapping, resource & disaster survey** (e.g. Cartosat, RISAT).

APPLICATION · ISRO

PSLV (Polar Satellite Launch Vehicle) typically places remote-sensing satellites in **polar** orbit; **GSLV** places heavy communication satellites in **geostationary transfer** orbit. Polar-orbit remote sensing directly supports **flood & drought mapping** — of direct use to Bihar's disaster management.

6.3 Why Astronauts Float — and Other Effects

WEIGHTLESSNESS

Astronauts float *not* because there's no gravity (there's ~90% of it at the ISS!) but because they are in continuous **free fall** with their spacecraft — apparent weight is zero. Same feeling as a lift whose cable snaps.

TIDES & KEPLER

Tides arise mainly from the Moon's gravity (Sun adds ~half). **Kepler's laws:** orbits are ellipses; planets sweep equal areas in equal times (faster when nearer the Sun).

TRAP "No gravity in space" is **false**. Weightlessness = free fall, not absence of gravity. Also: your **mass** is unchanged on the Moon; only your **weight** becomes 1/6.

6.4 Your Weight Across the Solar System

BODY	g (m/s²)	A 60 kg PERSON WEIGHS…
Earth	9.8	≈ 588 N (baseline)
Moon	1.6	≈ 1/6 of Earth
Jupiter	24.8	≈ 2.5× Earth (heaviest)
Mars	3.7	≈ 0.38× Earth

6.5 PYQ Zone

PYQ Value · Moderate

Q. The escape velocity from the Earth's surface is approximately:

(a) 7.9 km/s (b) 9.8 km/s (c) 11.2 km/s (d) 3.0×10^8 m/s

✓ **(c) 11.2 km/s.** 7.9 km/s is orbital velocity; 3×10^8 m/s is the speed of light.

PYQ Satellites · Moderate

Q. A geostationary satellite has an orbital period of:

(a) 1 hour (b) 12 hours (c) 24 hours (d) 1 month

✓ **(c) 24 hours** — matching Earth's rotation, so it stays over one point (used for communication).

CLASSROOM NOTE

Open with: "Is there gravity on the space station?" (Yes — ~90%!). Then unpack why astronauts still float. **Board:** Newton's cannonball on a mountain.

Doubt: "Why do we weigh less on the Moon?" — smaller mass & radius → smaller g. **Bridge:** "Now we leave forces behind and study matter itself — Part III."

RAPID RECALL · CHAPTER 6

① $F = Gm_1m_2/r^2$; $G = 6.67 \times 10^{-11}$ (universal, constant).

② $g \approx 9.8$ m/s²; max at poles, min at equator.

③ g on Moon = 1/6 of Earth.

④ Escape velocity (Earth) = 11.2 km/s.

⑤ Orbital velocity ≈ 7.9 km/s; escape = $\sqrt{2}$ × orbital.

⑥ Geostationary: 36,000 km, 24 h, equatorial — comms.

⑦ Polar: ~700 km, Sun-synchronous — remote sensing.

⑧ Weightlessness = free fall, not zero gravity.

⑨ Tides mainly due to the Moon.

⑩ Mass constant everywhere; weight varies with g.

6.6 Practice Set

ORIGINAL **1.** Acceleration due to gravity is maximum at the: (a) equator (b) poles (c) centre (d) top of Everest

ORIGINAL **2.** Remote-sensing satellites are usually placed in which orbit? (a) geostationary (b) polar (c) elliptical high (d) none

STATEMENT **3.** (I) There is no gravity in space. (II) Escape velocity depends on the object's mass. (a) I (b) II (c) Both (d) Neither

ASSERTION **4. A:** Astronauts feel weightless in orbit. **R:** They and the spacecraft are in continuous free fall. (a) Both true, R explains A (b) Both true, unrelated (c) A true R false (d) Both false

ANSWER KEY – **1(b)** poles (Earth is flattened there, so closer to centre). **2(b)** polar. **3(d)** both false — gravity exists in space, and escape velocity is independent of the object's mass. **4(a)** both true, reason explains it.

PART III · CHAPTER 7

Matter, Density & Elasticity

Why ice floats, why pipes burst in winter, and why a steel spring returns to shape — the everyday behaviour of solids, liquids and gases.

07

WHY BPSC ASKS THIS

Anomalous expansion of water, density/relative density, states of matter and elasticity appear as concept MCQs.

FREQUENCY

Moderate

PREREQUISITES

Ch 2 (units).

7.1 The Story: The Lake That Freezes Top-Down

Fish survive a frozen winter because of one strange fact: water is **densest at 4 °C**, not at 0 °C. As a pond cools, the coldest water (near 0 °C) is *lighter*, so it rises and freezes at the surface, while 4 °C water sinks to the bottom — keeping fish alive under the ice. This "anomalous expansion of water" is a BPSC favourite, and the same expansion-on-freezing is why water pipes and engine blocks burst in the cold.

DEFINITION · DENSITY

Density = mass ÷ volume (kg/m³). Relative density (specific gravity) = density of substance ÷ density of water; it has **no unit**. Water = 1000 kg/m³.

DEFINITION · ELASTICITY

The property of a body to **return to its original shape** after the deforming force is removed. Beyond the **elastic limit** it deforms permanently (plasticity).

7.2 States of Matter & Stress–Strain

STATE	SHAPE	VOLUME
Solid	fixed	fixed
Liquid	of container	fixed
Gas	of container	fills fully
Plasma	ionised gas	stars, Sun

HOOKE'S LAW

Within the elastic limit, **stress ∝ strain**. **Stress** = force/area; **strain** = change in dimension/original. Their ratio = modulus of elasticity (e.g. Young's modulus). Steel is **more elastic than rubber** — a classic trap.

TRAP **Steel is more elastic than rubber.** "Elastic" in physics means *resistance to deformation & quick return* — not "stretchy". Steel resists and returns better, so it is the more elastic material.

7.3 Everyday Consequences

- **Ice floats** because it is *less dense* than water (expands ~9% on freezing).
- **Winter pipe-burst** — water expands as it freezes, cracking the pipe.
- **Gaps in railway tracks & bridges** allow for thermal expansion of metal.
- **Lactometer** checks milk purity via density; **hydrometer** checks liquids.

7.4 PYQ Zone

PYQ Concept · Moderate

Q. Water has maximum density at:

(a) 0 °C
(b) 4 °C
(c) 100 °C
(d) −4 °C

✓ **(b) 4 °C.** Below 4 °C water expands again (anomalous expansion), so ice at 0 °C is less dense and floats — the reason ponds freeze top-down.

MEMORY HOOKS

- Water densest at **4 °C**; expands both on heating past 4° and on freezing.
- Relative density = **no unit**.
- Steel > rubber in elasticity.

DO NOT CONFUSE

- Density (kg/m³) vs relative density (no unit).
- Elastic ≠ stretchy.
- Stress (cause) vs strain (effect).

RAPID RECALL · CHAPTER 7

① Density = mass/volume (kg/m³).
② Water = 1000 kg/m³; densest at 4 °C.
③ Relative density has no unit.
④ Ice floats — less dense than water.
⑤ Water expands ~9% on freezing → pipes burst.
⑥ Hooke's law: stress ∝ strain (elastic limit).
⑦ Steel more elastic than rubber.
⑧ 4th state = plasma (Sun, stars).
⑨ Lactometer → milk; hydrometer → liquids.
⑩ Expansion gaps in rails & bridges.

7.5 Practice Set

ORIGINAL **1.** Which has no unit? (a) density (b) relative density (c) pressure (d) stress

ORIGINAL **2.** The most elastic among these is: (a) rubber (b) steel (c) glass (d) copper

STATEMENT **3.** (I) Ice is denser than water. (II) Water expands on freezing. (a) I (b) II (c) Both (d) Neither

ANSWER KEY – **1(b)** relative density. **2(b)** steel. **3(b)** ice is *less* dense (I false); water does expand on freezing (II true).

PART III · CHAPTER 8

Pressure & Fluid Mechanics

How a tiny push lifts a car, why ships float and aircraft fly, and why a cricket ball swings — the physics of pressure and moving fluids.

WHY BPSC ASKS THIS

Pascal's law, Archimedes' principle, Bernoulli & capillarity are asked as application MCQs almost every year.

FREQUENCY

High

PREREQUISITES

Ch 7 (density).

8.1 The Story: Lifting a Car With One Finger

At a service station a mechanic raises a whole car with barely any effort. The secret is **Pascal's law**: pressure applied to an enclosed fluid is transmitted *equally* in all directions. Push a small piston hard over a small area; the same pressure acts on a large piston and produces a huge force. A small input force becomes a large output force — the hydraulic lift, brake and jack all live on this one idea.

FORMULA

$$\text{Pressure} = \text{Force} \div \text{Area}$$

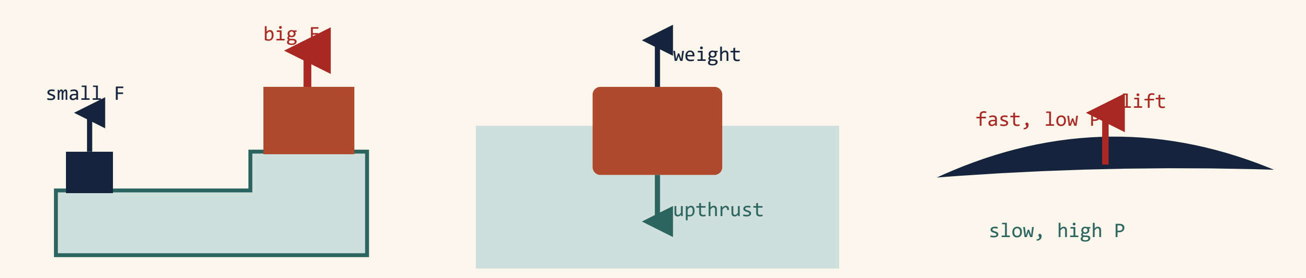
unit: pascal (Pa) = N/m²

Small area → high pressure (sharp knife, nail, camel's broad feet reduce it). Atmospheric pressure ≈ **1.013×10^5 Pa**, measured by a **barometer** (mercury).

ARCHIMEDES' PRINCIPLE

A body in a fluid experiences an **upthrust equal to the weight of fluid displaced**. If upthrust ≥ weight, it floats. This is why a heavy steel ship floats (it displaces a lot of water) but a small nail sinks.

DIAGRAM 8.1 · HYDRAULIC LIFT · FLOATING BODY · AIRCRAFT WING



Hydraulic lift — Pascal's law

Floating — Archimedes

Wing lift — Bernoulli

Bernoulli: where a fluid flows faster, its pressure is lower. Fast air over the curved top of a wing → low pressure above → net upward lift.

8.2 Surface Tension, Capillarity & Viscosity

SURFACE TENSION

Liquid surface acts like a stretched film — droplets are spherical, insects walk on water, a needle floats.

CAPILLARITY

Liquid rises in a thin tube — oil in a wick, water up plant stems & soil, ink in blotting paper.

VISCOSITY

A fluid's internal friction — honey is more viscous than water. Falls with temperature for liquids.

APPLICATION

Bernoulli explains the **swing of a cricket ball** (one side rougher → different air speeds), **atomisers & sprayers**, and why a fast train can pull you toward it. Submarines dive by flooding ballast tanks (increasing weight above upthrust).

8.3 PYQ Zone

PYQ Principle · Easy

Q. A hydraulic lift works on:

(a) Archimedes' (b) Pascal's (c) Bernoulli's (d) Newton's

✓ **(b) Pascal's law** — equal transmission of pressure in an enclosed fluid.

PYQ Application · Moderate

Q. An aircraft wing generates lift because of:

(a) surface tension (b) capillarity (c) Bernoulli's principle (d) viscosity

✓ **(c).** Faster air over the curved top lowers pressure there → net upward lift.

RAPID RECALL · CHAPTER 8

① Pressure = force/area (pascal); small area → high P.
② Pascal's law → hydraulic lift, brakes, jack.
③ Archimedes: upthrust = weight of fluid displaced.
④ Ships float by displacing much water.
⑤ Bernoulli: faster flow → lower pressure.
⑥ Wing lift, ball swing, atomiser → Bernoulli.
⑦ Surface tension → spherical drops, needle floats.
⑧ Capillarity → oil in wick, water in soil/plants.
⑨ Viscosity → honey > water; barometer → atm. pressure.
⑩ Atmospheric P ≈ 1.013×10^5 Pa.

8.4 Practice Set

ORIGINAL **1.** The upward force on a body immersed in a fluid is called: (a) thrust (b) buoyancy (c) viscosity (d) tension

ORIGINAL **2.** A sharp knife cuts better because it has: (a) more area (b) less area → more pressure (c) more mass (d) less mass

MATCH **3.** (i) Hydraulic brake (ii) Ship floating (iii) Insect on water — (P) surface tension (Q) Pascal (R) Archimedes.

ANSWER KEY — **1(b)** buoyancy (upthrust). **2(b)** smaller area → higher pressure. **3** i-Q, ii-R, iii-P.

PART IV · CHAPTER 9

Heat & Temperature

Heat is energy in transit; temperature is how hot something is. Confusing the two is the single most common science error — and BPSC knows it.

09

WHY BPSC ASKS THIS
Temperature-scale conversion, latent heat, evaporation vs boiling and specific heat of water recur.

FREQUENCY
Moderate

PREREQUISITES
Ch 5 (energy).

9.1 The Story: A Spark vs a Bathtub

A spark from a grinder is at ~1000 °C but won't hurt you; a bathtub of water at 50 °C will scald. The spark has high **temperature** but almost no **heat** (tiny mass); the tub has lower temperature but enormous heat energy. Heat flows from hot to cold until both reach the same temperature (thermal equilibrium). Water's unusually high specific heat is why it is used as a coolant and why coastal areas have mild climates.

DEFINITION · SPECIFIC HEAT
Heat to raise 1 kg by 1 °C. Water's is very high (4200 J/kg·°C) — it heats/cools slowly, moderating climate.

DEFINITION · LATENT HEAT
Heat absorbed/released during a **change of state** at constant temperature — why steam burns worse than boiling water.

DIAGRAM 9.1 · TEMPERATURE SCALES

Celsius °C	Fahrenheit °F	Kelvin K
water: 0 → 100	water: 32 → 212	water: 273 → 373

°F = (9/5)·°C + 32 · K = °C + 273 · −40 °C = −40 °F (they meet!)

Kelvin is the SI unit; 0 K (absolute zero) = −273.15 °C is the lowest possible temperature. Normal body temp = 37 °C = 98.6 °F.

EVAPORATION vs BOILING

Evaporation happens at any temperature, only at the surface, and causes cooling (sweating, earthen pots, wet clothes on a line). **Boiling** is at a fixed temperature throughout the liquid. Evaporation increases with heat, surface area, wind and dryness.

9.2 PYQ Zone

PYQ Concept · Easy

Q. A burn from steam is more severe than from boiling water at 100 °C because:

(a) steam is hotter
(b) steam carries latent heat
(c) steam moves faster
(d) steam is lighter

✓ **(b).** Both are at 100 °C, but steam also releases its **latent heat of vaporisation** (~2260 kJ/kg) when it condenses on the skin — a much bigger energy dump.

RAPID RECALL · CHAPTER 9

① Heat = energy in transit (J); temperature = degree of hotness.
② SI temp unit = kelvin; 0 K = −273.15 °C.
③ °F = (9/5)°C + 32; K = °C + 273.
④ −40 °C = −40 °F.
⑤ Water's specific heat is very high → coolant, mild climate.
⑥ Latent heat: state change at constant temperature.
⑦ Steam burns worse (latent heat of vaporisation).
⑧ Evaporation: any temp, surface, causes cooling.
⑨ Boiling: fixed temp, whole liquid.
⑩ Body temp 37 °C = 98.6 °F.

9.3 Practice Set

ORIGINAL **1.** The SI unit of temperature is: (a) °C (b) °F (c) kelvin (d) joule

ORIGINAL **2.** Earthen pots keep water cool due to: (a) conduction (b) evaporation (c) radiation (d) reflection

STATEMENT **3.** (I) 100 °C = 373 K. (II) Water has low specific heat. (a) I (b) II (c) Both (d) Neither

ANSWER KEY – **1(c)** kelvin. **2(b)** evaporation through pores cools the water. **3(a)** 100 °C = 373 K (true); water has *high* specific heat (II false).

PART IV · CHAPTER 10

Transfer of Heat

Three ways heat travels — and why a thermos, a sea breeze, a solar cooker and woollen clothes all exploit them.

WHY BPSC ASKS THIS

"Which mode of transfer" MCQs, sea/land breeze, greenhouse effect and thermos flask are staple questions.

FREQUENCY

Moderate

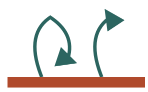
PREREQUISITES

Ch 9.

DIAGRAM 10.1 · CONDUCTION VS CONVECTION VS RADIATION

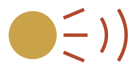
Conduction

Through solids, no matter moves. Metals = good conductors.



Convection

In fluids, hot fluid rises & carries heat. Sea breeze, boiling.



Radiation

No medium needed — Sun's heat, fire's warmth reach us.

Only radiation can cross a vacuum — which is how the Sun's heat reaches Earth. A thermos flask blocks all three: vacuum stops conduction/convection, silvering stops radiation.

10.1 Everyday Applications

- **Sea breeze (day)** & land breeze (night) — land heats/cools faster than sea → convection.
- **Woollen clothes** trap air (poor conductor) → keep body heat in.
- **Black surfaces** absorb & radiate heat best; white/shiny reflect — solar cookers use black.
- **Greenhouse effect** — CO_2 traps outgoing infrared, warming the planet.

DM's DAY · BIHAR

Heatwave management: Bihar's summer heatwaves are a thermal-transfer problem — advisories on light-coloured clothing, shaded shelters, hydration and cool roofs (white paint reflects radiation) are physics turned into public health orders.

10.2 PYQ Zone

PYQ Concept · Easy

Q. Heat from the Sun reaches the Earth mainly by:

(a) conduction (b) convection (c) radiation (d) all three

✓ **(c) radiation** — the only mode that crosses the vacuum of space (no medium needed).

RAPID RECALL · CHAPTER 10

① Conduction (solids), convection (fluids), radiation (any/vacuum).
② Only radiation crosses a vacuum → Sun's heat.
③ Metals = good conductors; air/wood = poor.
④ Sea & land breeze = convection.
⑤ Thermos blocks all three (vacuum + silvering).
⑥ Black absorbs/radiates; white reflects.
⑦ Woollens trap air (insulation).
⑧ Greenhouse effect traps infrared (CO_2).
⑨ Solar cooker: black pot + glass lid + mirror.
⑩ Land heats/cools faster than water.

10.3 Practice Set

ORIGINAL **1.** Which mode needs no material medium? (a) conduction (b) convection (c) radiation (d) all

ORIGINAL **2.** A thermos flask is silvered to reduce heat loss by: (a) conduction (b) convection (c) radiation (d) evaporation

MATCH **3.** (i) Sea breeze (ii) Metal spoon hot (iii) Sun's heat — (P) radiation (Q) conduction (R) convection.

ANSWER KEY – **1(c)** radiation. **2(c)** silvering reflects radiation. **3** i-R, ii-Q, iii-P.

PART IV · CHAPTER 11

Thermodynamics

The four laws that govern heat engines, refrigerators — and rule out the perpetual-motion machine forever.

WHY BPSC ASKS THIS
Laws of thermodynamics (esp. first = energy conservation) and "perpetual motion is impossible" are recurring statements.

FREQUENCY
Low–moderate

PREREQUISITES
Ch 5, 9.

11.1 The Four Laws — Plainly Stated

ZEROTH LAW
If A and B are each in thermal equilibrium with C, then A and B are too. This defines **temperature** and is why thermometers work.

FIRST LAW
Energy is conserved: heat added = increase in internal energy + work done. Rules out a machine that creates energy from nothing.

SECOND LAW
Heat flows spontaneously only from hot to cold; **no engine is 100% efficient**. Entropy (disorder) of an isolated system always increases.

THIRD LAW
Absolute zero (0 K) can be approached but **never fully reached**; at it, entropy of a perfect crystal is zero.

MEMORY HOOK **"You can't win, you can't break even, you can't quit."** 1st: you can't win (energy conserved). 2nd: you can't break even (some heat always wasted). 3rd: you can't leave the game (can't reach absolute zero).

11.2 Heat Engines, Fridges & Perpetual Motion

HEAT ENGINE
Converts heat into work (car, thermal plant). Always loses some heat to the surroundings — the **Carnot engine** sets the theoretical maximum efficiency, never reached in practice.

REFRIGERATOR
A heat engine in reverse — uses work to pump heat from cold to hot. A fridge **cannot cool a room** with its door open (it dumps more heat out the back).

TRAP A **perpetual-motion machine is impossible** — one that runs forever violates the 1st law; one that is 100% efficient violates the 2nd. BPSC often frames this as a "which is impossible?" statement.

11.3 PYQ Zone

PYQ Concept · Moderate

Q. The first law of thermodynamics is essentially the law of:

(a) conservation of energy
(b) conservation of momentum
(c) increasing entropy
(d) absolute zero

✓ **(a).** The first law is the conservation of energy applied to heat & work. Entropy belongs to the second law; absolute zero to the third.

RAPID RECALL · CHAPTER 11

① Zeroth law → defines temperature.
② First law → conservation of energy.
③ Second law → heat flows hot→cold; entropy rises.
④ Third law → can't reach 0 K.
⑤ No engine is 100% efficient (2nd law).
⑥ Carnot = ideal max efficiency.
⑦ Fridge = reverse heat engine.
⑧ Open-door fridge can't cool a room.
⑨ Perpetual-motion machine is impossible.
⑩ Entropy = measure of disorder.

11.4 Practice Set

ORIGINAL **1.** Which is impossible as per thermodynamics? (a) heat engine (b) refrigerator (c) 100%-efficient engine (d) Carnot cycle

ORIGINAL **2.** Entropy of an isolated system: (a) decreases (b) stays constant (c) increases (d) becomes zero

ASSERTION **3. A:** A fridge cannot cool a closed room with its door open. **R:** It dumps more heat from its back than it removes. (a) Both true, R explains A (b) Both true, unrelated (c) A true R false (d) Both false

ANSWER KEY – **1(c)** a 100%-efficient engine violates the 2nd law. **2(c)** increases. **3(a)** both true, reason explains it.

PART V · CHAPTER 12

Wave Motion

*Drop a stone in a pond: the ripples travel, the water does not. A wave carries **energy** without carrying matter — the idea behind sound, light and every mobile signal.*

WHY BPSC ASKS THIS

Transverse vs longitudinal, v = fλ, and "which wave needs no medium" are standard one-liners feeding into Sound and Light.

FREQUENCY

Moderate

PREREQUISITES

Ch 3 (motion), Ch 5 (energy).

12.1 The Vocabulary of a Wave

DEFINITION · WAVELENGTH & FREQUENCY

Wavelength (λ) = distance between two consecutive crests (metre). **Frequency (f)** = vibrations per second (hertz). **Time period T = 1/f**.

MASTER EQUATION · V = FΛ

Wave speed = frequency × wavelength. Works for every wave — sound, light, water. One equation, many MCQs.

DIAGRAM 12.1 · TRANSVERSE VS LONGITUDINAL

Transverse

Vibration ⊥ to travel. Crests & troughs. Light, ripples on water.

Longitudinal

Vibration ∥ to travel. Compressions & rarefactions. Sound in air.

Earthquakes send both: P-waves (longitudinal, faster, arrive first) and S-waves (transverse, cannot cross liquids — how we know Earth's outer core is liquid).

MECHANICAL vs ELECTROMAGNETIC

Mechanical waves (sound, water, seismic) need a material medium — sound cannot cross a vacuum. **Electromagnetic waves** (light, radio, X-rays) need none — all travel at 3×10^8 m/s in vacuum. An astronaut sees an explosion before... hearing nothing at all.

12.2 PYQ Zone

PYQ Concept · Easy

Q. Sound waves in air are:

(a) transverse
(b) longitudinal
(c) electromagnetic
(d) stationary

✓ **(b) longitudinal** — air particles vibrate along the direction of travel, forming compressions and rarefactions.

RAPID RECALL · CHAPTER 12

① Waves carry energy, not matter.
② $v = f\lambda$; $T = 1/f$; frequency in hertz.
③ Transverse: vibration ⊥ travel (light, water surface).
④ Longitudinal: vibration // travel (sound in air).
⑤ Mechanical waves need a medium; EM waves don't.
⑥ Sound cannot travel in vacuum.
⑦ All EM waves: 3×10^8 m/s in vacuum.
⑧ P-waves longitudinal & faster; S-waves transverse.
⑨ S-waves can't cross liquids → outer core is liquid.
⑩ Frequency doesn't change when a wave changes medium.

12.3 Practice Set

ORIGINAL **1.** A wave has f = 50 Hz and λ = 4 m. Its speed is: (a) 12.5 m/s (b) 54 m/s (c) 200 m/s (d) 400 m/s

ORIGINAL **2.** Which cannot travel in vacuum? (a) light (b) radio waves (c) X-rays (d) sound

STATEMENT **3.** (I) Light is a transverse wave. (II) Earthquake P-waves arrive before S-waves. (a) I (b) II (c) Both (d) Neither

ANSWER KEY — **1(c)** v = fλ = 50×4 = 200 m/s. **2(d)** sound is mechanical. **3(c)** both true.

PART V · CHAPTER 13

Sound

You see lightning, then hear thunder — light outruns sound a million times over. From that gap comes SONAR, echoes, ultrasound scans and the bat's night vision.

WHY BPSC ASKS THIS

Speed of sound in media, audible range, ultrasonic uses (SONAR, bats, sonography) and echo are among the most repeated science questions.

FREQUENCY

High

PREREQUISITES

Ch 12.

13

13.1 Speed, Range & the Sound Spectrum

DIAGRAM 13.1 · SPEED OF SOUND & THE FREQUENCY SPECTRUM

Air ~343 m/s	Water ~1480 m/s	Steel ~5000 m/s
at 20 °C; rises with temperature & humidity	~4× faster than air	solids fastest — ear on the rail

Infrasonic < 20 Hz · Audible 20 Hz – 20,000 Hz · Ultrasonic > 20,000 Hz

Solid > liquid > gas — the opposite of what most people guess. Elephants use infrasound; bats and dolphins use ultrasound.

- **SONAR** — ships map the seabed & find submarines by timing ultrasonic echoes.
- **Sonography** — ultrasound images a foetus safely (no ionising radiation, unlike X-rays).
- **Echo** — needs ≥ 1/10 s gap → reflector at least ~17 m away in air.
- **Doppler effect** — pitch rises as a siren approaches, falls as it recedes; also used in speed guns & astronomy (red shift).

PITCH · LOUDNESS · QUALITY

Pitch depends on frequency (woman's voice > man's, typically). **Loudness** depends on amplitude, measured in **decibels** — above ~85 dB sustained is harmful. **Quality (timbre)** is why a sitar and flute playing the same note sound different.

13.2 PYQ Zone

PYQ Concept · Easy

Q. Bats can fly in complete darkness because they navigate using:

(a) infrared light
(b) ultrasonic waves
(c) infrasonic waves
(d) sharp eyesight

✓ **(b).** Bats emit ultrasonic clicks (>20 kHz) and read the echoes — **echolocation**, the same principle as SONAR.

RAPID RECALL · CHAPTER 13

① Speed in air ~343 m/s; solid > liquid > gas.
② Audible range: 20 Hz – 20 kHz.
③ Ultrasonic >20 kHz: bats, SONAR, sonography, cleaning.
④ Infrasonic <20 Hz: elephants, earthquakes.
⑤ Echo needs ≥17 m in air (1/10 s gap).
⑥ Pitch ↔ frequency; loudness ↔ amplitude (dB).
⑦ Quality/timbre distinguishes instruments.
⑧ Doppler: pitch rises on approach, falls on recede.
⑨ Sound speed rises with temperature & humidity.
⑩ Lightning seen before thunder — light ≫ sound speed.

13.3 Practice Set

ORIGINAL **1.** Sound travels fastest in: (a) vacuum (b) air (c) water (d) steel

ORIGINAL **2.** Loudness of sound depends on: (a) frequency (b) amplitude (c) wavelength (d) speed

MATCH **3.** (i) SONAR (ii) red shift (iii) foetal scan — (P) Doppler (Q) sonography (R) seabed mapping.

ANSWER KEY — **1(d)** steel. **2(b)** amplitude. **3** i-R, ii-P, iii-Q.

PART VI · CHAPTER 14

Light: Nature & Reflection

Sunlight is 8 minutes 20 seconds old when it touches your skin; moonlight, 1.28 seconds. Nothing in the universe travels faster.

WHY BPSC ASKS THIS
Speed of light, mirror uses (convex rear-view, concave shaving/headlight) and eclipse geometry are perennial favourites.

FREQUENCY
High

PREREQUISITES
Ch 12 (waves).

14

14.1 Light Travels in Straight Lines

Light is a **transverse electromagnetic wave** needing no medium, moving at **3×10^8 m/s in vacuum**. Its **rectilinear propagation** (straight-line travel) explains shadows, pinhole cameras and eclipses: a **solar eclipse** when the Moon blocks the Sun (new moon day), a **lunar eclipse** when Earth's shadow falls on the Moon (full moon day). Never watch a solar eclipse directly.

14.2 Mirrors — Who Uses Which

PLANE
Image: virtual, erect, same size, **laterally inverted**, as far behind as object is in front. To see your full height you need a mirror **half your height**.

CONCAVE (converging)
Magnifies when close → **shaving & dentist mirrors**; parallel beam from focus → **torch, headlight, solar cooker** reflectors.

CONVEX (diverging)
Always small, erect image with a **wide field of view** → vehicle **rear-view mirrors**, road-corner mirrors. "Objects are closer than they appear."

TRAP A concave mirror gives an erect, magnified image **only when the object is within its focus** — beyond the focus the image is inverted. BPSC loves swapping concave and convex in options.

14.3 PYQ Zone

PYQ Application · Easy

Q. The mirror used as a rear-view mirror in vehicles is:

(a) plane
(b) concave
(c) convex
(d) parabolic

✓ **(c) convex** — it always forms an erect, diminished image and covers a much wider field of view than a plane mirror.

RAPID RECALL · CHAPTER 14

① Light = transverse EM wave; 3×10^8 m/s in vacuum.
② Sunlight takes 8 min 20 s; moonlight 1.28 s.
③ Straight-line travel → shadows, pinhole, eclipses.
④ Solar eclipse: new moon; lunar: full moon.
⑤ Plane mirror: virtual, erect, laterally inverted.
⑥ Full-height view needs mirror = half your height.
⑦ Concave: shaving, dentist, headlights, solar cooker.
⑧ Convex: rear-view — small, erect, wide view.
⑨ Concave magnifies erect only within focus.
⑩ Angle of incidence = angle of reflection.

14.4 Practice Set

ORIGINAL **1.** Doctors examining teeth use: (a) plane mirror (b) concave mirror (c) convex mirror (d) convex lens only

ORIGINAL **2.** A solar eclipse can occur only on: (a) full moon (b) new moon (c) any day (d) equinox

STATEMENT **3.** (I) Light needs a medium to travel. (II) A plane mirror image is laterally inverted. (a) I (b) II (c) Both (d) Neither

ANSWER KEY — **1(b)** concave (magnified erect image up close). **2(b)** new moon. **3(b)** only II — light crosses vacuum.

PART VI · CHAPTER 15

Refraction, Lenses & Total Internal Reflection

A pencil "bends" in a glass of water, a pool looks shallower than it is, a diamond blazes, and the internet rides on light trapped in glass — all one phenomenon.

WHY BPSC ASKS THIS
"Why does a pool look shallow / a star twinkle / a diamond sparkle / a mirage appear" — refraction & TIR explain a whole family of PYQs.

FREQUENCY
High

PREREQUISITES
Ch 14.

15

15.1 Bending Light

Light **slows down** entering a denser medium and bends **toward the normal**; leaving it, it speeds up and bends away. The **refractive index** (n = c/v) measures this — glass ~1.5, water ~1.33, diamond ~2.42. Refraction is why a pool looks **shallower**, a pencil looks bent, stars **twinkle** (turbulent atmospheric layers), and the Sun is visible ~2 minutes before actual sunrise and after actual sunset.

DEFINITION · TOTAL INTERNAL REFLECTION
When light in a denser medium hits the boundary beyond the **critical angle**, it reflects entirely back — no refraction at all. A perfect mirror made of nothing.

TIR IN THE WILD
Mirage on hot roads, **diamond's** brilliance (tiny critical angle ~24°), **optical fibre** (internet, endoscopy), glittering air bubbles in water.

DIAGRAM 15.1 · TOTAL INTERNAL REFLECTION AT WORK

Optical fibre
Light zig-zags down glass — internet & cable TV

Diamond cut
Critical angle ~24° traps light — the sparkle

Mirage
Sky light bends off hot air — "water" on the road

Endoscope
Fibre bundle carries light & image inside the body

One rule — light trapped beyond the critical angle — behind the internet, jewellery and keyhole surgery.

15.2 Lenses in One Table

CONVEX (converging)
Thicker at centre; brings rays together. **Magnifying glass, camera, projector, hypermetropia correction.** Power positive.

CONCAVE (diverging)
Thinner at centre; spreads rays apart. Always virtual, erect, diminished image. **Myopia correction, peepholes.** Power negative.

MEMORY HOOK **Power of a lens P = 1/f (in metres), unit dioptre (D).** Shorter focal length = stronger lens. Lenses in contact simply add powers: $P = P_1 + P_2$.

15.3 PYQ Zone

PYQ Concept · Moderate

Q. A mirage in a desert is caused by:

(a) reflection from sand
(b) dispersion of light
(c) total internal reflection
(d) diffraction

✓ **(c).** Hot air near the ground is rarer; light from the sky bends progressively and undergoes **total internal reflection**, looking like a pool of water.

RAPID RECALL · CHAPTER 15

① Denser medium → light slows, bends toward normal.
② n = c/v; diamond 2.42, glass 1.5, water 1.33.
③ Pool looks shallow; pencil looks bent — refraction.
④ Stars twinkle; planets don't (extended source).
⑤ Early sunrise / late sunset by ~2 min each — refraction.
⑥ TIR: beyond critical angle in denser medium.
⑦ Mirage, diamond sparkle, optical fibre = TIR.
⑧ Convex lens converges; concave diverges.
⑨ P = 1/f (dioptre); convex +, concave −.
⑩ Magnifying glass = convex lens, object within focus.

15.4 Practice Set

ORIGINAL **1.** Optical fibres work on: (a) refraction (b) total internal reflection (c) dispersion (d) polarisation

ORIGINAL **2.** The unit of power of a lens is: (a) watt (b) dioptre (c) lumen (d) candela

ASSERTION **3. A:** A diamond sparkles more than a glass replica. **R:** Diamond's refractive index is very high, so its critical angle is very small. (a) Both true, R explains A (b) Both true, unrelated (c) A true R false (d) Both false

ANSWER KEY – **1(b)** TIR. **2(b)** dioptre. **3(a)** small critical angle → light reflects internally many times before exiting.

PART VI · CHAPTER 16

Human Eye & Optical Instruments

A living convex lens that refocuses itself thousands of times a day — and the spectacles, microscopes and telescopes we built when it falls short.

WHY BPSC ASKS THIS
"Which lens corrects myopia?" is close to guaranteed. Eye defects + corrections is a must-memorise table.

FREQUENCY
Moderate

PREREQUISITES
Ch 15 (lenses).

16

16.1 The Eye as an Instrument

The cornea + convex **eye lens** focus light onto the **retina**, forming a real, **inverted** image the brain flips upright. The **iris** adjusts the pupil like a camera aperture; **ciliary muscles** change the lens's focal length — **accommodation.** Near point of a normal eye: **25 cm**; far point: infinity. **Persistence of vision** (~1/16 s) is why 24 frames per second looks like smooth motion in cinema. Rods sense dim light; cones sense colour — night blindness is vitamin-A deficiency; a fully clouded lens is a **cataract**.

16.2 Defects & Corrections — The Must-Know Table

MYOPIA (near-sightedness)
Distant objects blur — image forms **before** the retina (eyeball too long). Correct with a **concave lens** (−).

HYPERMETROPIA (far-sightedness)
Near objects blur — image forms **behind** the retina. Correct with a **convex lens** (+).

PRESBYOPIA (old age)
Ciliary muscles weaken with age; accommodation fails. Correct with **bifocal lenses** (concave top + convex bottom).

ASTIGMATISM
Uneven cornea curvature — blurred in one direction. Correct with **cylindrical lenses**.

INSTRUMENTS IN ONE LINE

Simple microscope = one convex lens. **Compound microscope** = two convex lenses (objective + eyepiece). **Telescope** = large objective for distant objects. **Periscope** = two plane mirrors at 45° (submarines, trenches). **Kaleidoscope** = mirrors at 60°.

16.3 PYQ Zone

PYQ Concept · Easy

Q. Myopia (short-sightedness) is corrected using a:

(a) convex lens
(b) concave lens
(c) cylindrical lens
(d) bifocal lens

✓ **(b) concave lens** — it diverges incoming rays so the image moves back onto the retina.

RAPID RECALL · CHAPTER 16

① Retina image: real & inverted; brain flips it.
② Near point 25 cm; far point infinity.
③ Accommodation = ciliary muscles change focal length.
④ Myopia → concave lens; hypermetropia → convex.
⑤ Presbyopia → bifocals; astigmatism → cylindrical.
⑥ Persistence of vision ~1/16 s → cinema.
⑦ Rods = dim light; cones = colour.
⑧ Night blindness = vitamin A deficiency.
⑨ Periscope: two plane mirrors at 45°.
⑩ Compound microscope: two convex lenses.

16.4 Practice Set

ORIGINAL **1.** The image formed on the retina is: (a) virtual, erect (b) real, erect (c) real, inverted (d) virtual, inverted

ORIGINAL **2.** A periscope uses: (a) convex lenses (b) plane mirrors at 45° (c) concave mirrors (d) prisms only

MATCH **3.** (i) Myopia (ii) Presbyopia (iii) Astigmatism — (P) cylindrical (Q) concave (R) bifocal.

ANSWER KEY – **1(c)** real, inverted. **2(b)** plane mirrors at 45°. **3** i-Q, ii-R, iii-P.

PART VI · CHAPTER 17

Dispersion, Scattering & Optical Phenomena

Why the sky is blue, the sunset red, the rainbow seven-coloured and the danger signal always red — the sky is one big physics demonstration.

WHY BPSC ASKS THIS
"Why is the sky blue?" and "why is danger red?" are the most asked optics questions across all PCS exams — plus Raman effect for the India connection.

FREQUENCY
High

PREREQUISITES
Ch 15.

17

17.1 Dispersion — White Light Unpacked

A prism splits white light into **VIBGYOR** because each colour travels at a slightly different speed in glass — **violet bends most, red least.** A **rainbow** is dispersion + total internal reflection inside millions of raindrops, always seen with the Sun **behind** you. Newton showed a second inverted prism recombines the colours into white — dispersion, not "colouring" by the glass.

17.2 Scattering — The Sky's Colour Code

- **Sky is blue** — air molecules scatter short (blue) wavelengths most (Rayleigh scattering $\propto 1/\lambda^4$).
- **Sunrise/sunset is red** — sunlight crosses more atmosphere; blue scatters away, red survives.
- **Danger signals are red** — red scatters least, so it stays visible farthest through fog and dust.
- **Space looks black** — no atmosphere, no scattering; astronauts see a dark sky even in daylight.

INDIA CONNECT

Raman effect (1928): C. V. Raman showed scattered light can change wavelength — earning Asia's first science Nobel (1930). **National Science Day, 28 February**, marks the discovery. The **Tyndall effect** — a light beam visible in mist or a dusty room — is scattering by larger colloidal particles.

17.3 PYQ Zone

PYQ Concept · Easy

Q. The sky appears blue due to:

(a) reflection by the sea
(b) scattering of light
(c) dispersion by clouds
(d) refraction by ozone

✓ **(b) scattering** — air molecules scatter shorter (blue) wavelengths far more strongly than red (Rayleigh scattering).

RAPID RECALL · CHAPTER 17

① Prism splits white light: VIBGYOR (dispersion).
② Violet bends most; red least.
③ Rainbow = dispersion + TIR in raindrops; Sun behind you.
④ Sky blue = Rayleigh scattering ($\propto 1/\lambda^4$).
⑤ Red sunrise/sunset: longer air path scatters blue away.
⑥ Danger signals red: scatters least, seen farthest.
⑦ Space/sky from Moon looks black — no atmosphere.
⑧ Tyndall effect: beam visible in mist/dust (colloids).
⑨ Raman effect (1928) → Nobel 1930, Asia's first in science.
⑩ National Science Day = 28 February.

17.4 Practice Set

ORIGINAL **1.** In the spectrum of white light, the colour that deviates least is: (a) violet (b) green (c) yellow (d) red

ORIGINAL **2.** National Science Day commemorates: (a) Chandrayaan (b) Raman effect (c) Pokhran test (d) Aryabhata launch

STATEMENT **3.** (I) A rainbow forms opposite the Sun. (II) The sky on the Moon appears blue. (a) I (b) II (c) Both (d) Neither

ANSWER KEY – **1(d)** red. **2(b)** Raman effect (28 Feb 1928). **3(a)** only I — the Moon has no atmosphere, so its sky is black.

PART VII · CHAPTER 18

Electric Charge & Electrostatics

A comb rubbed on dry hair lifts paper bits; a monsoon cloud rubbed on air throws a 30,000-ampere spark at the ground. Same physics, different scale.

WHY BPSC ASKS THIS

Lightning & the lightning conductor, "gains or loses electrons", and conductor–insulator sorting are steady one-mark questions.

FREQUENCY

Moderate

PREREQUISITES

Ch 1 (forces), Ch 7 (matter).

18.1 Charge: The Two-Sign Currency

Matter carries two kinds of charge. Rubbing transfers **electrons only** — protons never move in friction. A body that **gains electrons becomes negative**; one that loses them becomes positive. Like charges repel, unlike attract; the SI unit is the **coulomb (C)**, and one electron carries 1.6×10^{-19} C. **Conductors** (metals, human body, moist air, graphite) let charge flow; **insulators** (dry wood, glass, rubber, pure water) do not — which is why linemen wear rubber gloves and why *salty* tap water, not pure water, is the real conductor.

DEFINITION · COULOMB'S LAW

The force between two charges ∝ product of charges, ∝ $1/(\text{distance})^2$ — the exact same inverse-square shape as gravity, but 10^{36} times stronger and with both attraction *and* repulsion.

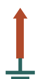
DEFINITION · EARTHING

Connecting a charged body to the ground by a conductor so excess charge drains safely into the Earth — the principle behind the lightning conductor and the third pin of a plug.

18.2 Lightning — Electrostatics at Full Volume

Inside a thundercloud, rising air currents rub water droplets and ice crystals together; the cloud base turns strongly negative. When the electric field grows large enough, air itself breaks down and conducts — the flash. A **lightning conductor** (Benjamin Franklin, 1752) is a pointed copper strip running from above the roof to a plate buried in the earth: it gives the discharge an easy, harmless path. During a storm, a car is safe not because of its rubber tyres but because its **metal body carries the charge around the passengers** — the Faraday-cage effect.

DIAGRAM 18.1 · STATIC ELECTRICITY AT WORK



Lightning conductor
Pointed copper strip, earthed

Photocopier & laser printer
Charged drum attracts toner

Spray painting
Charged droplets coat evenly

Smokestack precipitator
Charged plates trap ash & smoke

Four industries built on the humble rubbed comb — electrostatic attraction put to work.

BIHAR

Bihar records among India's highest lightning deaths — 200–400 every year, peaking in the June–July pre-monsoon. The state's **Indravajra app** gives ~40-minute advance lightning alerts. Safety rule: crouch low, never shelter under an isolated tree, and stay off open fields — the tallest point takes the strike.

TRAP "A positively charged body has gained protons" — **wrong**. In electrostatics only electrons move; positive means electrons were *lost*. Also: rubber tyres do NOT make a car lightning-safe; the metal cage does.

18.3 PYQ Zone

PYQ Concept · Easy

Q. A body is negatively charged when it:

(a) loses electrons
(b) gains electrons
(c) gains protons
(d) loses protons

✓ **(b) gains electrons** — electrons carry negative charge and are the only mobile particles in charging by friction.

RAPID RECALL · CHAPTER 18

① Friction moves electrons only, never protons.
② Gain e^- → negative; lose e^- → positive.
③ Charge unit: coulomb; $e = 1.6\times10^{-19}$ C.
④ Like charges repel — the sure test of charge.
⑤ Coulomb force: inverse-square, like gravity.
⑥ Pure water insulates; dissolved salts conduct.
⑦ Lightning conductor: pointed, copper, earthed.
⑧ Car in a storm = Faraday cage, not rubber tyres.
⑨ Precipitators, photocopiers, spray paint = electrostatics.
⑩ Bihar lightning peak: June–July; Indravajra alerts.

18.4 Practice Set

ORIGINAL **1.** A lightning conductor protects a building by: (a) repelling clouds (b) absorbing lightning (c) conducting the discharge to earth (d) insulating the roof

ORIGINAL **2.** Which is the best conductor? (a) glass (b) dry wood (c) copper (d) rubber

ASSERTION **3. A:** A person inside a closed car is safe in a thunderstorm. **R:** The car's rubber tyres insulate it from the ground. (a) Both true, R explains A (b) Both true, unrelated (c) A true, R false (d) Both false

ANSWER KEY – **1(c)** easy earthed path. **2(c)** copper. **3(c)** A true — but the reason is the metal body (Faraday cage), not the tyres.

PART VII · CHAPTER 19

Current Electricity & Household Wiring

Every switch you flip completes a circuit; every heater glows because electrons collide their way through a wire. The most examined chapter of Part VII.

WHY BPSC ASKS THIS

Ohm's law, fuse & earthing, "why tungsten / why nichrome", units of electrical energy — BPSC returns to these nearly every cycle.

FREQUENCY

Very high

PREREQUISITES

Ch 5 (energy, power), Ch 18.

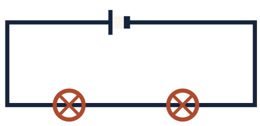
19.1 Current, Voltage, Resistance — and Ohm's Law

Current (I) is the flow of charge — amperes. **Potential difference (V)** is the electrical "pressure" pushing it — volts. **Resistance (R)** is the opposition of the wire — ohms (Ω). Conventional current flows + to −, though electrons actually drift the other way. Resistance grows with length, shrinks with thickness, and **rises with temperature** in metals.

FORMULA

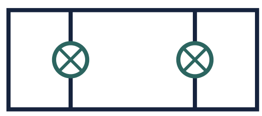
$V = IR$	Ohm's law — at constant temperature. 230 V across 46 Ω draws I = 230/46 = **5 A**.
$P = VI = I^2R$	Power in watts. A "2000 W geyser" at 230 V draws ~8.7 A — why geysers need thick wiring.
1 unit = 1 kWh	The electricity-bill unit = 1000 W for 1 hour = 3.6×10^6 J. *Common slip:* kWh measures energy, not power.

DIAGRAM 19.1 · A CIRCUIT & ITS TWO WAYS OF WIRING



Series

One path. Same current everywhere; one bulb fails → all go dark. Resistances **add**.



Parallel

Many paths, same voltage. One fails → others glow. **Homes are wired in parallel.**

Old fairy lights (series) died together; modern homes (parallel) give every appliance full 230 V independently.

19.2 The Heating Effect — Appliances & Their Metals

DIAGRAM 19.2 · HEATING EFFECT ($H = I^2RT$) IN THE KITCHEN & THE METER BOX

Bulb filament
Tungsten — melts at 3400 °C; argon-filled, not vacuum

Iron, heater, kettle
Nichrome coil — high resistance, doesn't oxidise

Fuse wire
Tin–lead alloy — low melting point, melts first

MCB
Modern reusable fuse — trips on overload

Same law, opposite designs: heaters want the heat (high-R nichrome); fuses sacrifice themselves to it (low-melting alloy).

DEFINITION · EARTHING (THIRD PIN)

The long top pin connects an appliance's metal body to the earth. If the live wire touches the body, current drains to ground and blows the fuse — instead of passing through you. Wire colours (new code): **live brown, neutral blue, earth green**.

DEFINITION · SHORT CIRCUIT & OVERLOADING

Short circuit: live touches neutral directly — resistance ≈ 0, current spikes, fire risk. **Overloading**: too many appliances on one socket. Both are why the fuse sits on the **live** wire.

BIHAR

India's homes run on **230 V, 50 Hz AC**. Bihar's supply comes through NBPDCL (north) and SBPDCL (south); its biggest generators are the NTPC stations at **Barh, Kahalgaon and Barauni**. The "Har Ghar Bijli" scheme took grid power to every willing household — a favourite current-affairs pairing with this chapter.

19.3 PYQ Zone

PYQ Application · Easy

Q. The filament of an electric bulb is made of:

(a) copper (b) nichrome
(c) tungsten (d) iron

✓ **(c) tungsten** — the highest melting point of any metal (~3400 °C), so it can glow white-hot without melting.

RAPID RECALL · CHAPTER 19

① $V = IR$; $P = VI$; $H = I^2Rt$.
② 1 unit on the bill = 1 sc-camel-k-wh = 3.6×10^6 J (energy).
③ Homes are wired in parallel — same 230 V for all.
④ Series: resistances add; one failure kills the circuit.
⑤ Bulb filament: tungsten (m.p. ~3400 °C).
⑥ Heater/iron coil: nichrome (high resistance).
⑦ Fuse: tin–lead alloy, low m.p., on the live wire.
⑧ Earth wire (green) saves lives via the third pin.
⑨ Short circuit: live meets neutral; current spikes.
⑩ India supply: 230 V, 50 Hz AC.

19.4 Practice Set

ORIGINAL **1.** A 2 A current flows through 10 Ω. The voltage is: (a) 5 V (b) 12 V (c) 20 V (d) 0.2 V

ORIGINAL **2.** Fuse wire should have: (a) high melting point (b) low melting point (c) high conductivity only (d) zero resistance

STATEMENT **3.** (I) The kilowatt-hour is a unit of power. (II) Domestic circuits are connected in parallel. (a) I (b) II (c) Both (d) Neither

ANSWER KEY – **1(c)** $V = 2\times10 = 20$ V. **2(b)** it must melt first. **3(b)** kWh is energy, not power.

PART VII · CHAPTER 20

Magnetism & the Earth's Field

The Earth itself is a magnet — sailors trusted it for a thousand years before anyone knew why a compass points north.

WHY BPSC ASKS THIS

"A freely suspended magnet rests…", magnetic materials, and uses of electromagnets (MRI, cranes, bells) are recurring picks.

FREQUENCY

Moderate

PREREQUISITES

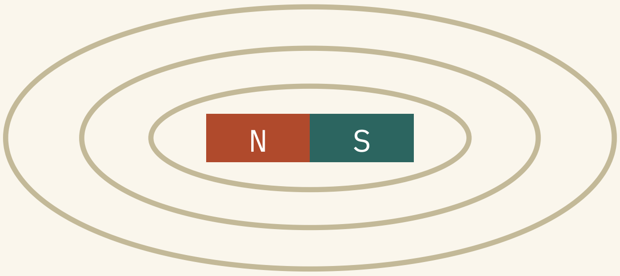
Ch 18–19.

20

20.1 Poles, Field Lines & the Compass

Every magnet has a **north and south pole that cannot be separated** — cut a magnet and you get two smaller complete magnets, never a lone pole. Like poles repel (the only sure test of a magnet), unlike attract, and field lines run N → S outside the magnet, never crossing. A freely suspended magnet settles **north–south** because the Earth behaves as a giant bar magnet — with its magnetic south pole near geographic north. The compass needle's small angular error from true north is the **magnetic declination**.

DIAGRAM 20.1 · A BAR MAGNET'S FIELD



Closed loops from N to S; densest at the poles, where the magnet is strongest. Iron filings trace these lines in seconds — a classic classroom demo.

20.2 Magnetic Materials & the Electromagnet

Ferromagnetic materials (iron, nickel, cobalt) are strongly attracted and can be magnetised; most other substances respond barely at all. Heating a magnet past its **Curie temperature** (~770 °C for iron) destroys its magnetism. An **electromagnet** — a soft-iron core inside a current-carrying coil — beats a permanent magnet in three ways: it can be switched off, its strength is adjustable, and it can be made enormously strong.

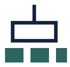
DIAGRAM 20.2 · MAGNETS AT WORK

MRI scanner

Superconducting electromagnet images soft tissue — no radiation

Maglev train

Magnetic repulsion floats the train — no friction, 600 km/h



Scrapyard crane

Electromagnet lifts tonnes of iron — switch off to drop

Electric bell & speaker

Coil pulls, circuit breaks, springs back — many times a second

The electromagnet's party trick — strength on demand — is what a permanent magnet can never offer.

TRAP Attraction is **not** proof of a magnet — a magnet attracts plain iron too. Only **repulsion** proves both bodies are magnets. And "cutting a magnet isolates a pole" is always a wrong option: monopoles don't exist.

20.3 PYQ Zone

PYQ Concept · Easy

Q. A freely suspended bar magnet always comes to rest pointing:

(a) east–west
(b) north–south
(c) northeast–southwest
(d) in any direction

✓ **(b) north–south** — the Earth's own magnetic field torques the needle into alignment; this is exactly how a compass works.

RAPID RECALL · CHAPTER 20

① Poles come in pairs — no monopoles, ever.
② Repulsion, not attraction, is the sure test.
③ Field lines: N → S outside, never cross.
④ Free magnet rests N–S; Earth is a giant magnet.
⑤ Declination = angle between magnetic & true north.
⑥ Ferromagnetic: iron, nickel, cobalt.
⑦ Curie point (~770 °C for iron) kills magnetism.
⑧ Electromagnet: soft-iron core + coil; switchable.
⑨ MRI, maglev, cranes, bells, speakers = electromagnets.
⑩ Earth's field shields us from solar wind (auroras at poles).

20.4 Practice Set

ORIGINAL **1.** Which group is ferromagnetic? (a) iron, nickel, cobalt (b) copper, silver, gold (c) aluminium, zinc, tin (d) carbon, sulphur, phosphorus

ORIGINAL **2.** Cutting a bar magnet in half gives: (a) separate N and S poles (b) two complete magnets (c) two unmagnetised pieces (d) one magnet, one iron bar

ASSERTION **3. A:** An electromagnet uses a soft-iron core. **R:** Soft iron magnetises and demagnetises almost instantly with the current. (a) Both true, R explains A (b) Both true, unrelated (c) A true, R false (d) Both false

ANSWER KEY – **1(a)**. **2(b)** two complete magnets. **3(a)** soft iron follows the current with no lag.

PART VII · CHAPTER 21

Electromagnetism: Motors, Generators & Transformers

In 1820 a Danish lecture-hall compass twitched beside a wire, and two centuries of fans, trains, dynamos and power grids followed from that twitch.

WHY BPSC ASKS THIS

Motor vs generator energy conversion, "transformer works only on AC", and why transmission uses high voltage are classic BPSC picks.

FREQUENCY

High

PREREQUISITES

Ch 19–20.

21.1 Two Discoveries, One Loop

Oersted (1820): a current creates a magnetic field around its wire — electricity makes magnetism. **Faraday (1831):** a *changing* magnetic field through a coil induces a current — magnetism makes electricity. Between them sits every rotating machine in the world. A **motor** uses Oersted's effect: current in a field feels a force (Fleming's **left**-hand rule) → electrical energy becomes mechanical. A **generator** runs Faraday's effect: rotation in a field induces current (Fleming's **right**-hand rule) → mechanical becomes electrical.

MOTOR (Fleming's LEFT hand)

Electrical → mechanical. **Fan, mixer, pump, washing machine, electric vehicle, cooler.** Memory hook: **M**otor–**L**eft — "ML, like millilitre".

GENERATOR (Fleming's RIGHT hand)

Mechanical → electrical. **Dynamo, power-station turbine, bicycle light, inverter's alternator.** **G**enerator–**R**ight — "GR, like generator".

21.2 The Transformer & the Journey of a Unit of Power

A **transformer** is two coils on one iron core: an alternating current in the primary induces a voltage in the secondary, scaled by the turns ratio. More secondary turns = **step-up**; fewer = **step-down**. It has **no moving parts and works only on AC** — a steady DC induces nothing. Power lines run at very high voltage because for the same power, higher V means lower I, and heat loss (I^2R) falls with the *square* of the current.

DIAGRAM 21.1 · FROM TURBINE TO TABLE FAN — ONE UNIT'S JOURNEY

Power station ~11–25 kV → **Step-UP → grid** 132–765 kV lines → **Step-DOWN substation** 33 kV → 11 kV → 440 V → **Your home** 230 V · 50 Hz

High voltage on the highway, low voltage at the doorstep — because doubling V halves I and quarters the I^2R heat loss.

BIHAR

NTPC **Barh** (super thermal) and **Kahalgaon** feed Bihar's 220/132 kV grid; the state's peak demand has crossed 8,000 MW. Every neighbourhood's humming pole-top box is a **step-down transformer** — the last stop on this diagram.

21.3 PYQ Zone

PYQ Concept · Moderate

Q. A transformer is used to:

(a) convert AC to DC
(b) change the voltage of AC
(c) generate electricity
(d) store electrical energy

✓ **(b).** It steps AC voltage up or down via mutual induction. It cannot work on steady DC — a rectifier converts AC to DC.

RAPID RECALL · CHAPTER 21

① Oersted: current → magnetic field (1820).
② Faraday: changing field → induced current (1831).
③ Motor: electrical → mechanical; Fleming's LEFT hand.
④ Generator: mechanical → electrical; RIGHT hand.
⑤ Transformer: AC only; no moving parts.
⑥ More secondary turns = step-up; fewer = step-down.
⑦ Transmission at high V → low I → tiny I^2R loss.
⑧ Home supply: 230 V, 50 Hz, via pole-top step-down.
⑨ Inverter: DC (battery) → AC; rectifier: AC → DC.
⑩ Bihar's big feeders: NTPC Barh & Kahalgaon.

21.4 Practice Set

ORIGINAL **1.** An electric motor converts: (a) mechanical → electrical (b) electrical → mechanical (c) chemical → electrical (d) heat → mechanical

ORIGINAL **2.** Long-distance power transmission uses high voltage to: (a) speed up electrons (b) reduce I^2R heat loss (c) charge batteries faster (d) avoid transformers

ASSERTION **3. A:** A transformer cannot run on a battery. **R:** A steady direct current produces no changing magnetic flux. (a) Both true, R explains A (b) Both true, unrelated (c) A true, R false (d) Both false

ANSWER KEY – **1(b)**. **2(b)** higher V → lower I → far less I^2R. **3(a)** induction needs *changing* flux.

PART VIII · CHAPTER 22

Electromagnetic Waves & the Spectrum

Your eye reads one octave of a keyboard that runs from radio to gamma rays — the rest of it cooks your food, images your bones and carries your calls.

WHY BPSC ASKS THIS

Ordering the spectrum by wavelength and matching each band to its use (remote → IR, oven → microwave, bones → X-ray) is a near-certain question.

FREQUENCY

High

PREREQUISITES

Ch 12 (waves), Ch 14 (light).

22.1 One Family, Seven Members

Maxwell predicted (1864) and **Hertz** produced (1887) waves made of oscillating electric and magnetic fields. All EM waves are **transverse**, need **no medium**, and travel at exactly **3×10⁸ m/s in vacuum** — they differ only in wavelength. Since v = fλ is fixed, longer wavelength means lower frequency and **lower energy**: radio waves are gentle giants, gamma rays are tiny bullets.

DIAGRAM 22.1 · THE ELECTROMAGNETIC SPECTRUM

RADIO	MICRO	INFRA-RED	VISIBLE	UV	X-RAY	GAMMA
> 0.1 m	mm–cm	µm	400–700 nm	10–400 nm	0.01–10 nm	< 0.01 nm

← longer wavelength · lower frequency · lower energy · safer

shorter wavelength · higher frequency · higher energy · ionising →

*Memory hook: **R**oyal **M**onarchs **I**nsist **V**isitors **U**se **X**-ray **G**ates — radio to gamma, longest to shortest.*

22.2 Every Band Has a Job

DIAGRAM 22.2 · THE SPECTRUM IN YOUR DAILY LIFE

Radio — broadcast & radar
AM/FM, TV, RADAR, radio astronomy

Microwave — oven & links
2.45 GHz vibrates water molecules; mobile & satellite links

Infrared — remote & heat
TV remotes, night-vision, thermal imaging, physiotherapy

UV — steriliser & vitamin D
Water purifiers, currency checking; excess causes skin cancer — ozone absorbs it

X-ray — bones & baggage
Röntgen, 1895 — first physics Nobel (1901); airport scanners, crystallography

Gamma — cancer therapy
Radiotherapy kills tumour cells; sterilising surgical tools; most penetrating

Exam favourite: match the appliance to the band. The oven is microwave, the remote is infrared — BPSC swaps them in wrong options.

TRAP All EM waves travel at the **same speed in vacuum** — "X-rays are faster than radio waves" is always false. They differ in wavelength, frequency and energy, never in vacuum speed.

22.3 PYQ Zone

PYQ Concept · Easy

Q. Which of the following has the longest wavelength?

(a) gamma rays
(b) X-rays
(c) visible light
(d) radio waves

✓ **(d) radio waves** — the long-wavelength, low-energy end of the spectrum; gamma rays sit at the opposite extreme.

RAPID RECALL · CHAPTER 22

① All EM waves: transverse, no medium, 3×10^8 m/s.
② Longest → shortest: radio, micro, IR, visible, UV, X, gamma.
③ Shorter λ = higher frequency = higher energy.
④ Oven = microwave (2.45 GHz, water molecules).
⑤ Remote, night-vision, thermal camera = infrared.
⑥ UV: sterilising, vitamin D; blocked by ozone.
⑦ X-rays: Röntgen 1895; bones & baggage scans.
⑧ Gamma: radiotherapy; most penetrating.
⑨ UV, X, gamma are ionising — cell damage risk.
⑩ Maxwell predicted; Hertz demonstrated (1887).

22.4 Practice Set

ORIGINAL **1.** A TV remote control uses: (a) ultrasound (b) microwaves (c) infrared (d) UV light

ORIGINAL **2.** The ozone layer protects life by absorbing: (a) infrared (b) ultraviolet (c) radio waves (d) visible light

MATCH **3.** (i) microwave (ii) X-ray (iii) gamma — (P) radiotherapy (Q) oven (R) bone imaging.

ANSWER KEY – **1(c)** infrared. **2(b)** ultraviolet. **3** i-Q, ii-R, iii-P.

PART VIII · CHAPTER 23

Communication Systems

A voice in Patna reaches New York in a fifth of a second — riding a radio wave to a tower, laser light through undersea glass, and a satellite 36,000 km up.

WHY BPSC ASKS THIS

AM vs FM, why the ionosphere matters, geostationary satellites, optical fibre and NavIC pull in both static physics and current affairs marks.

FREQUENCY

Moderate–high

PREREQUISITES

Ch 15 (TIR), Ch 22.

23.1 Transmitter → Channel → Receiver

Every communication system has three blocks: a **transmitter** that puts the message onto a carrier, a **channel** (air, cable, fibre, space) that carries it — adding **noise** along the way — and a **receiver** that recovers it. A voice signal (~20 kHz) cannot be radiated directly: efficient antennas need to be about a quarter-wavelength long, and 20 kHz would demand a *kilometres-tall* antenna. So we ride the message on a high-frequency carrier — that is **modulation**.

DIAGRAM 23.1 · AM VS FM — WHAT GETS VARIED

AM — amplitude varies

Medium wave · long range via ionosphere · noisy (crackle) · Vividh Bharati-era radio

FM — frequency varies

88–108 MHz · shorter, line-of-sight range · noise-free, high fidelity · city FM stations

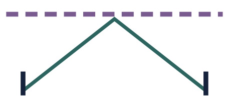
Noise mostly disturbs amplitude — FM ignores it (frequency carries the message), which is why FM sounds cleaner.

23.2 Three Roads for a Radio Wave

DIAGRAM 23.2 · HOW SIGNALS TRAVEL

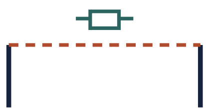
Ground wave

Hugs the Earth's surface. Low frequencies, few hundred km — AM medium-wave radio.



Sky wave

Bounces off the **ionosphere** — shortwave crosses continents. Better at night (denser reflecting layer).



Space wave (line of sight)

Straight-line only — TV, FM, mobile, satellite. Taller tower = farther horizon.

Why shortwave radio reaches villages worldwide but your FM fades outside town: sky wave bounces, space wave cannot bend past the horizon.

23.3 The Modern Stack — Fibre, Satellites, Navigation

DIAGRAM 23.3 · THE TECHNOLOGIES CARRYING YOUR CALL

Optical fibre
Laser pulses via total internal reflection — the internet's backbone, incl. undersea cables

Geostationary satellite
35,786 km up, 24 h orbit — appears fixed; DTH TV, INSAT/GSAT weather & telecom

GPS & NavIC
Position from timing signals of ≥4 satellites; NavIC is India's own 7-satellite system

Mobile tower (4G/5G)
Land divided into "cells"; your phone hands over tower to tower as you travel

RADAR
Microwave echoes locate aircraft, ships, storms — radio's answer to SONAR

DTH dish
Parabolic reflector focuses the satellite's weak microwave beam onto one point

One phone call may use four of these in sequence: tower → fibre → satellite → dish. Physics from Chapters 15, 21 and 22, working together.

INDIA CONNECT

J. C. Bose demonstrated millimetre-wave radio in Calcutta in 1895 — before Marconi's celebrated transmission. India's **APPLE** (1981) was its first experimental communication satellite; today the **GSAT/INSAT** fleet and **NavIC** (IRNSS) constellation carry broadcasting, telemedicine, disaster alerts and navigation.

TRAP A geostationary satellite is not "stationary in space" — it orbits at ~3.1 km/s. It merely matches Earth's rotation (24 h, above the equator), so it *appears* fixed from the ground.

23.4 PYQ Zone

PYQ Concept · Moderate

Q. Long-distance shortwave radio broadcasts are possible because of the:

(a) troposphere (b) stratosphere
(c) ionosphere (d) ozone layer

✓ **(c) ionosphere** — its charged layers reflect shortwave (sky-wave) signals back to Earth, letting them hop across continents.

RAPID RECALL · CHAPTER 23

① System = transmitter → channel (+noise) → receiver.
② Modulation rides audio on a high-frequency carrier.
③ AM varies amplitude — long range, noisy.
④ FM varies frequency — 88–108 MHz, clean, short range.
⑤ Ground wave: AM radio. Sky wave: shortwave via ionosphere.
⑥ Space wave: TV, FM, mobile — line of sight only.
⑦ Geostationary: 35,786 km, 24 h, above the equator.
⑧ Optical fibre = TIR; backbone of the internet.
⑨ GPS needs ≥4 satellites; NavIC is India's system.
⑩ J. C. Bose (1895) pioneered radio waves in India.

23.5 Practice Set

ORIGINAL **1.** A geostationary satellite completes one orbit in: (a) 12 h (b) 24 h (c) 48 h (d) 90 min

ORIGINAL **2.** India's regional navigation satellite system is called: (a) GAGAN (b) GLONASS (c) NavIC (d) Galileo

ASSERTION **3. A:** FM radio fades quickly outside a city. **R:** FM uses space-wave (line-of-sight) propagation. (a) Both true, R explains A (b) Both true, unrelated (c) A true, R false (d) Both false

ANSWER KEY – **1(b)** 24 h — that's what makes it "appear fixed". **2(c)** NavIC (IRNSS). **3(a)** line-of-sight cannot bend past the horizon.

PART IX · CHAPTER 24

Atomic Structure & Quantum Physics

In thirty-five years — 1897 to 1932 — physics opened the atom, found its three particles, and discovered that light itself comes in packets. Nearly every year of it won a Nobel Prize.

WHY BPSC ASKS THIS

Particle–discoverer matching, atomic model chronology and the photoelectric effect are among the most repeated Modern Physics questions in state PCS exams.

FREQUENCY

High · scientist–discovery matching

PREREQUISITES

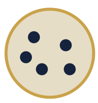
Ch 1 (branches), Ch 22 (EM spectrum).

24.1 Opening the Atom: Three Particles, Three Nobel Stories

"Atom" means *indivisible* — and for 2,300 years everyone believed it was. Then **J. J. Thomson**, experimenting with glowing cathode-ray tubes in 1897, found a particle nearly 2,000 times lighter than hydrogen: the **electron**. The indivisible had parts. **Rutherford** found the dense positive **nucleus** (1911) and named the **proton** (1919); his student **Chadwick** completed the picture with the chargeless **neutron** (1932).

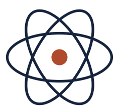
PARTICLE	DISCOVERER · YEAR	CHARGE	LOCATION
Electron (e^-)	J. J. Thomson · 1897	−1	Orbits / shells
Proton (p^+)	E. Rutherford · 1919	+1	Nucleus
Neutron (n^0)	J. Chadwick · 1932	0	Nucleus

DIAGRAM 24.1 · HOW THE MODEL OF THE ATOM EVOLVED



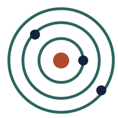
Thomson · 1904

"Plum pudding" — electrons studded in a sphere of positive charge.



Rutherford · 1911

Gold-foil experiment: a tiny, dense, positive **nucleus**; atom mostly empty space.



Bohr · 1913

Electrons in **fixed shells** (K, L, M…); jumps between shells absorb or emit light.

Chronology is the exam favourite: Thomson → Rutherford → Bohr. Rutherford's foil scattered a few α-particles straight back — "as if a shell bounced off tissue paper."

NOBEL

J. J. Thomson — Physics 1906, for the discovery of the electron. Poetic footnote: his son G. P. Thomson won in 1937 for showing the electron is *also a wave*.

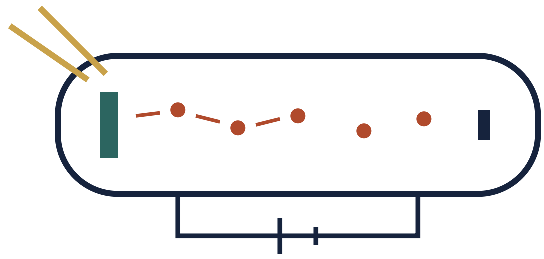
NOBEL

James Chadwick — Physics 1935, for the neutron. **Trap:** Rutherford's own Nobel (1908) was in *Chemistry*, for radioactivity — which amused him greatly.

24.2 The Quantum Idea & the Photoelectric Effect

In 1900 **Max Planck** proposed that energy is not continuous but comes in packets — **quanta** — of energy **E = hν**. In 1905 **Einstein** took the idea seriously: light itself is a stream of particles (**photons**). This explained a stubborn puzzle — the **photoelectric effect**, where light falling on a metal knocks electrons out *instantly*, but only if its frequency crosses a **threshold**. Dim blue light ejects electrons; blinding red light may eject none. Intensity decides *how many*; frequency decides *whether at all*.

DIAGRAM 24.2 · THE PHOTOELECTRIC EFFECT — EINSTEIN'S NOBEL EXPERIMENT



Light (gold rays) strikes the metal **emitter plate** (teal); electrons (red) fly across the vacuum tube to the collector, and a current flows in the circuit below.

Frequency ↑ → each ejected electron is **faster** (more energetic).

Intensity ↑ → **more** electrons, same speed.

Below threshold ν_0 → **zero** electrons, however bright the light.

Everyday descendants: solar cells, automatic doors, camera light meters, streetlight sensors — all photoelectric at heart.

NOBEL

Albert Einstein — Physics 1921, "for the discovery of the law of the photoelectric effect." **The classic trap:** Einstein never received a Nobel for relativity. Planck won 1918 (energy quanta); Bohr won 1922 (atomic structure); de Broglie won 1929 (matter waves).

24.3 Dual Nature: Waves that are Particles, Particles that are Waves

Light behaves as a wave (interference, diffraction) *and* as a particle (photoelectric effect). In 1924 **de Broglie** reversed the logic: if waves can be particles, particles can be waves — every moving object has a wavelength **λ = h/mv**. For a cricket ball it is immeasurably small; for an electron it is real and useful: the **electron microscope** uses electron waves thousands of times shorter than light, resolving viruses and even atoms that no optical microscope can see.

MEMORY HOOK **"PEBNC — Planck Einstein Bohr, de Broglie, Chadwick"** — quanta (1900), photon (1905), shells (1913), matter waves (1924), neutron (1932). Five steps, one revolution.

24.4 PYQ Zone

PYQ Fact · Easy

Q. The neutron was discovered by:

(a) J. J. Thomson (b) E. Rutherford

(c) J. Chadwick (d) N. Bohr

✓ **(c) James Chadwick** (1932) — Thomson: electron; Rutherford: nucleus & proton; Bohr: shell model.

RAPID RECALL · CHAPTER 24

① Electron — Thomson, 1897 (cathode rays).
② Nucleus — Rutherford, 1911 (gold-foil α scattering).
③ Proton — Rutherford, 1919. Neutron — Chadwick, 1932.
④ Model order: Thomson → Rutherford → Bohr.
⑤ Planck 1900: energy in quanta, E = hν.
⑥ Photoelectric: instant; needs threshold frequency.
⑦ Intensity → number of electrons; frequency → their energy.
⑧ Einstein's Nobel (1921): photoelectric effect, NOT relativity.
⑨ de Broglie: every particle has λ = h/mv.
⑩ Electron microscope uses matter waves — sees viruses, atoms.

24.5 Practice Set

ORIGINAL **1.** Increasing the intensity of light above threshold frequency in the photoelectric effect increases: (a) electron speed (b) number of electrons (c) threshold frequency (d) nothing

ORIGINAL **2.** Rutherford's gold-foil experiment established that: (a) electrons are waves (b) the atom has a small dense nucleus (c) neutrons exist (d) energy is quantised

MATCH **3.** (i) Planck (ii) Bohr (iii) de Broglie — (P) matter waves (Q) energy quanta (R) electron shells.

ANSWER KEY – **1(b)** more electrons, same speed. **2(b)** the nuclear atom. **3** i-Q, ii-R, iii-P.

PART IX · CHAPTER 25

Radioactivity & Nuclear Physics

A forgotten photographic plate in a Paris drawer, fogged by a uranium salt — from that accident in 1896 came cancer therapy, carbon dating, the bomb, and a fifth of the world's electricity.

25

WHY BPSC ASKS THIS

α/β/γ properties, fission vs fusion, reactor components and India's nuclear programme are perennial — often two questions in one paper.

FREQUENCY

Very high · every-year territory

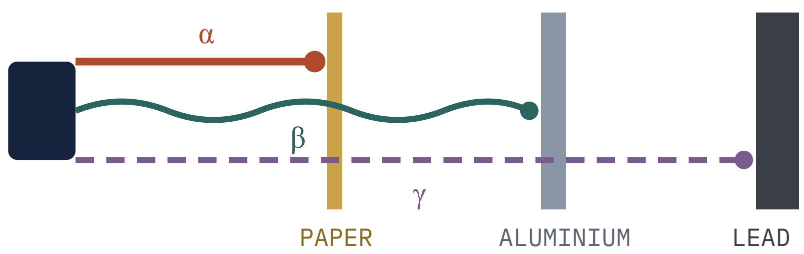
PREREQUISITES

Ch 24 (nucleus, particles).

25.1 Radioactivity: The Nucleus that Cannot Sit Still

Henri Becquerel discovered radioactivity by accident (1896): a uranium salt fogged a wrapped photographic plate with no light present. **Marie and Pierre Curie** isolated two new radioactive elements — **polonium** and **radium** — and shared the 1903 Physics Nobel with Becquerel. Radioactivity is **spontaneous**: no heat, pressure or chemistry can speed it up or stop it. An unstable nucleus sheds energy as three kinds of radiation.

DIAGRAM 25.1 · THE PENETRATION TEST — ONE DIAGRAM BPSC LOVES



α stops at a sheet of paper · β stops at a few mm of aluminium · γ needs thick lead or concrete — and even that only weakens it.

Inverse rule: the most penetrating (γ) is the least ionising; the least penetrating (α) is the most ionising. BPSC swaps these in wrong options.

RAY	NATURE	CHARGE	STOPPED BY
Alpha (α)	Helium nucleus (2p + 2n)	+2	Paper, skin
Beta (β)	Fast electron	−1	~5 mm aluminium
Gamma (γ)	EM wave (no mass)	0	Thick lead / concrete

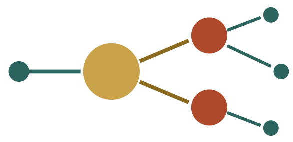
25.2 Half-life & the Peaceful Atom

Every radioactive isotope decays at its own unchangeable pace, measured by its **half-life** — the time for half the nuclei to decay. Carbon-14 (half-life 5,730 years) lets archaeologists date bones and wood; **cobalt-60** γ-rays kill tumours; **iodine-131** treats thyroid disease; radio-tracers follow leaks in pipelines and blood flow in the body.

TRAP After two half-lives, **one quarter** remains — not zero. Halve, then halve again: 100% → 50% → 25% → 12.5%. "Fully decayed after two half-lives" is a standard wrong option.

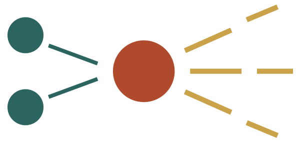
25.3 Fission vs Fusion — Splitting and Joining

DIAGRAM 25.2 · TWO WAYS TO UNLOCK E = MC²



Fission — a heavy nucleus splits

A slow neutron splits U-235 → two fragments + 2–3 new neutrons → **chain reaction**. Controlled: reactor. Uncontrolled: atom bomb (Hiroshima, 1945).

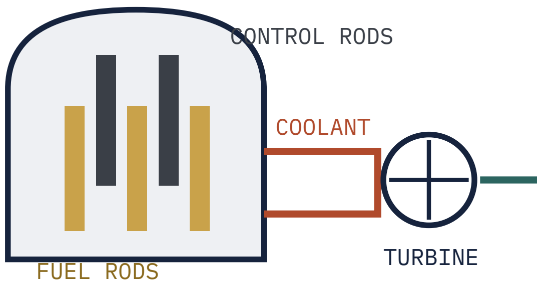


Fusion — light nuclei join

Hydrogen isotopes fuse into helium, releasing even more energy per kg. Powers the **Sun and stars**; hydrogen bomb; ITER seeks controlled fusion.

Both convert a tiny mass loss into enormous energy ($E = mc^2$). Fusion needs millions of degrees — which is why no fusion power station exists yet.

DIAGRAM 25.3 · INSIDE A NUCLEAR REACTOR — FOUR PARTS BPSC ASKS ABOUT



Heat from fission boils water; steam spins a turbine; the turbine turns a generator — a coal plant with a nuclear furnace.

Fuel — enriched uranium-235 (or plutonium-239).

Moderator — heavy water / graphite; **slows** neutrons so they cause fission.

Control rods — cadmium / boron; **absorb** neutrons to throttle the reaction.

Coolant — carries heat out (water, heavy water, liquid sodium).

Trap pair: moderator slows neutrons (helps the reaction); control rods absorb them (restrain it). Swapping these is a classic wrong option.

INDIA CONNECT

Homi J. Bhabha founded India's nuclear programme (TIFR 1945, AEC 1948). **Apsara** (1956, BARC Trombay) was Asia's first research reactor. India's **three-stage programme** aims to run ultimately on its vast **thorium** reserves. Major plants: Tarapur, Rawatbhata, Kudankulam (largest), Kakrapar (first indigenous 700 MWe PHWR).

25.4 PYQ Zone

PYQ Concept · Moderate

Q. The source of the Sun's energy is:

(a) nuclear fission
(b) nuclear fusion
(c) chemical burning
(d) gravitational contraction

✓ **(b) nuclear fusion** — hydrogen fusing to helium in the core. Reactors on Earth use *fission*; the Sun uses *fusion*.

RAPID RECALL · CHAPTER 25

① Radioactivity — Becquerel 1896; term coined by Marie Curie.

② Curies discovered polonium & radium; Nobel 1903.

③ α = He nucleus (+2); β = electron (−1); γ = EM wave (0).

④ Penetration: $\gamma > \beta > \alpha$. Ionisation: $\alpha > \beta > \gamma$.

⑤ Two half-lives → 25% remains.

⑥ C-14 dating; Co-60 radiotherapy; I-131 thyroid.

⑦ Fission: U-235 splits, chain reaction. Fusion: Sun, H-bomb.

⑧ Moderator slows neutrons; control rods (Cd/B) absorb them.

⑨ Bhabha — father of India's nuclear programme; Apsara 1956.

⑩ Stage 3 of India's programme targets thorium.

25.5 Practice Set

ORIGINAL **1.** A sample has a half-life of 10 days. After 20 days, the fraction remaining is: (a) zero (b) 1/2 (c) 1/4 (d) 1/8

ORIGINAL **2.** In a reactor, the material used to slow down neutrons is called the: (a) coolant (b) moderator (c) control rod (d) fuel

ASSERTION **3. A:** Gamma rays need thick lead shielding. **R:** Gamma rays carry a +2 charge. (a) Both true, R explains A (b) Both true, unrelated (c) A true, R false (d) Both false

ANSWER KEY – **1(c)** 1/4 — two half-lives. **2(b)** moderator. **3(c)** γ is chargeless — that's α.

PART IX · CHAPTER 26

Electronics & Semiconductors

A sliver of sand — silicon — sits between conductor and insulator. Learning to control it gave us the transistor, the chip, the LED and the solar cell: the entire modern world.

WHY BPSC ASKS THIS
Device–function matching (diode, LED, transistor, solar cell), doping, and current-affairs hooks like the India Semiconductor Mission.

FREQUENCY
Moderate–high

PREREQUISITES
Ch 19 (current), Ch 24 (electrons).

26.1 The In-between Material

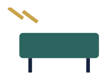
Metals conduct; rubber insulates; **silicon and germanium** sit in between — **semiconductors**. Their magic: conductivity *rises* with temperature (opposite of metals) and, crucially, can be engineered by **doping** — adding one atom in a million of an impurity. Dope with phosphorus (5 valence electrons) and spare electrons carry current: **n-type**. Dope with boron (3) and missing-electron "holes" carry it: **p-type**. Join the two and you get the building block of all electronics — the **p–n junction**.

26.2 The Device Family

DIAGRAM 26.1 · FIVE DEVICES BUILT FROM ONE JUNCTION

Diode
One-way valve for current — converts AC to DC (**rectifier**) in every charger

LED
Diode that emits light — bulbs, screens; blue LED won the 2014 Nobel



Solar cell
Reverse of the LED: light in, current out — photoelectric effect at work

Transistor
Amplifier & switch (1947, Bell Labs) — replaced bulky vacuum tubes

Integrated circuit (chip)
Billions of transistors on one silicon flake — CPU of phone & computer

Superconductor
Zero resistance near absolute zero (Onnes, 1911) — MRI magnets, maglev

Match-the-device is the exam pattern: rectifier→diode, amplifier→transistor, light-to-current→solar cell, current-to-light→LED.

NOBEL

Shockley, Bardeen & Brattain — Physics 1956, for the transistor. **John Bardeen** is the only person to win the Physics Nobel *twice* — again in 1972, for superconductivity theory. The blue LED earned **Akasaki, Amano & Nakamura** the 2014 prize — it completed white LED light.

INDIA CONNECT

The **India Semiconductor Mission** (2021) funds domestic chip fabs — Micron's Sanand plant and Tata's Dholera fab are flagships. UJALA's LED push cut household lighting bills nationwide; solar parks like Bhadla (Rajasthan) rank among the world's largest.

26.3 PYQ Zone

PYQ Fact · Easy

Q. Which device converts alternating current into direct current?

(a) transformer
(b) rectifier
(c) amplifier
(d) dynamo

✓ **(b) rectifier** — a diode circuit. Transformer changes AC voltage; dynamo generates; amplifier strengthens signals.

RAPID RECALL · CHAPTER 26

① Semiconductors: Si, Ge — conductivity rises with temperature.
② n-type: phosphorus/arsenic (extra electrons); p-type: boron (holes).
③ Diode = one-way valve; rectifier converts AC → DC.
④ LED: current → light. Solar cell: light → current.
⑤ Transistor (1947): amplifier + switch; Nobel 1956.
⑥ Bardeen: only double Physics laureate (1956, 1972).
⑦ IC/chip: billions of transistors on one silicon die.
⑧ Superconductivity: zero resistance (Onnes, 1911).
⑨ Blue LED — Nobel 2014 — enabled white LED lighting.
⑩ India Semiconductor Mission: Sanand, Dholera fabs.

26.4 Practice Set

ORIGINAL **1.** Adding phosphorus to pure silicon produces: (a) p-type semiconductor (b) n-type semiconductor (c) an insulator (d) a superconductor

ORIGINAL **2.** A solar cell works on the principle of the: (a) heating effect (b) photoelectric/photovoltaic effect (c) magnetic effect (d) chemical effect

MATCH **3.** (i) diode (ii) transistor (iii) LED — (P) amplification (Q) rectification (R) light emission.

ANSWER KEY – **1(b)** n-type — 5 valence electrons. **2(b)** photovoltaic. **3** i-Q, ii-P, iii-R.

PART IX · CHAPTER 27

Relativity & Frontier Physics

Time slows for a moving clock, mass is frozen energy, and space itself ripples. The strangest physics is also the most current-affairs-rich — Higgs, LIGO, quantum computers.

WHY BPSC ASKS THIS

E = mc², "God particle", gravitational waves, LIGO-India and quantum missions bridge static physics and science current affairs.

FREQUENCY

Moderate–high · current-affairs driven

PREREQUISITES

Ch 24–25.

27.1 Einstein's Two Relativities

Special relativity (1905) starts from one fact: light's speed is the same for every observer. Consequences follow relentlessly — moving clocks run slow, moving objects contract, nothing outruns light, and mass and energy are one currency: **E = mc²**. One gram fully converted equals the energy of ~21,000 tonnes of TNT — the arithmetic behind fission and fusion. **General relativity** (1915) reimagines gravity: mass curves space-time, and everything — including light — follows the curve. It predicted black holes, gravitational lensing and gravitational waves, all since observed.

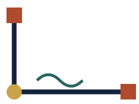
MEMORY HOOK Relativity is in your pocket: **GPS satellites' clocks** run ~38 microseconds/day fast relative to Earth's surface. Uncorrected, maps would drift ~10 km *per day*. Your phone applies Einstein every second.

27.2 The Frontier: Three Machines, Three Nobels

DIAGRAM 27.1 · THE GREAT MACHINES OF 21ST-CENTURY PHYSICS

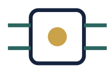
LHC · CERN, Geneva

27-km ring smashes protons near light speed. Found the **Higgs boson** (2012) — the particle that gives others mass, nicknamed the "God particle". Nobel 2013: Higgs & Englert.



LIGO — gravitational waves

Two 4-km laser arms sense space stretching by less than a proton's width. First detection 2015 (two merging black holes). Nobel 2017. **LIGO-India** is being built at Hingoli, Maharashtra.



Quantum computers

Superconducting circuits behave as single quantum objects — the 1980s experiments behind them won the **2025 Nobel** (Clarke, Devoret, Martinis). India's **National Quantum Mission** (2023) joins the race.

*India connect: the boson itself honours Kolkata's **Satyendra Nath Bose**, whose statistics with Einstein define all such particles.*

TRAP The Higgs boson gives particles mass; **S. N. Bose did not discover it** — the class of particles ("bosons") is named for his statistics. Peter Higgs proposed the particle (1964); CERN confirmed it (2012).

27.3 PYQ Zone

PYQ Current affairs · Moderate

Q. The "God particle" refers to the:

(a) neutrino
(b) Higgs boson
(c) graviton
(d) photon

✓ **(b) Higgs boson** — confirmed at CERN's LHC in 2012; Nobel Prize 2013 to Higgs and Englert.

RAPID RECALL · CHAPTER 27

① Special relativity 1905: $E = mc^2$, time dilation, c is the limit.
② General relativity 1915: gravity = curved space-time.
③ GPS must correct for relativistic clock drift daily.
④ Higgs boson: gives mass; found 2012 at CERN LHC.
⑤ "Boson" honours S. N. Bose (Bose–Einstein statistics).
⑥ Gravitational waves: predicted 1916, detected 2015 (LIGO).
⑦ LIGO-India site: Hingoli, Maharashtra.
⑧ Nobel 2025: quantum tunnelling in circuits — basis of qubits.
⑨ National Quantum Mission approved 2023.
⑩ Black hole imaging (EHT, 2019); Nobel 2020 for black hole physics.

27.4 Practice Set

ORIGINAL **1.** In $E = mc^2$, c stands for: (a) speed of sound (b) speed of light (c) a constant of gravitation (d) electric charge

ORIGINAL **2.** LIGO-India, for detecting gravitational waves, is coming up in: (a) Karnataka (b) Gujarat (c) Maharashtra (d) Odisha

ASSERTION **3. A:** Einstein won the Nobel Prize for relativity. **R:** The 1921 prize cited the photoelectric effect. (a) Both true, R explains A (b) Both true, unrelated (c) A false, R true (d) Both false

ANSWER KEY – **1(b)** speed of light. **2(c)** Hingoli, Maharashtra. **3(c)** — the famous exception.

PART X · CHAPTER 28

Scientific Instruments — A Visual Gallery

"What measures what" is the single most reliable question family in BPSC Physics. Learn each instrument as a picture, not a word.

WHY BPSC ASKS THIS
Instrument–quantity matching appears in virtually every paper — usually as one direct MCQ plus wrong options in other questions.

FREQUENCY
Very high · guaranteed marks

PREREQUISITES
None — pure reference.

28.1 Measuring the Physical World

GALLERY 28.1 · MECHANICAL & THERMAL INSTRUMENTS

Vernier callipers
Length to 0.1 mm

Screw gauge
Diameter to 0.01 mm

Thermometer
Temperature · clinical: 35–42 °C

Barometer
Atmospheric pressure · falls → storm

Hydrometer
Density / specific gravity of liquids

Hygrometer
Humidity of air

Anemometer
Wind speed (cup wheel)

Seismograph
Earthquake waves (Richter scale)

GALLERY 28.2 · ELECTRICAL & OPTICAL INSTRUMENTS

Ammeter
Current · in **series**, low resistance

Voltmeter
Voltage · in **parallel**, high resistance

Galvanometer
Detects tiny currents & direction

Oscilloscope (CRO)
Displays waveforms on a screen

Compound microscope
Two convex lenses; cells & microbes

Telescope
Distant objects; Galileo 1609

Periscope
See over obstacles — submarines; two 45° mirrors

Spectrometer
Splits light into its spectrum — element fingerprints

Ammeter/voltmeter connection rules (series/parallel) are asked as often as the instruments themselves.

GALLERY 28.3 · DETECTION, MEDICINE & NAVIGATION

Geiger–Müller counter
Detects radioactivity (clicks per second)

X-ray machine
Bones & security scans — Röntgen 1895

MRI scanner
Soft tissue via magnetic fields — no radiation

Sonar
Ultrasound ranging under water (Ch 15)

Radar
Radio-wave ranging — aircraft, weather

Altimeter
Altitude of aircraft (pressure-based)

Compass
Direction — aligns with Earth's field

Speedometer / odometer
Instant speed / distance travelled

Sound-alike traps: hydrometer (density) vs hygrometer (humidity); barometer (pressure) vs altimeter (height); sonar (sound) vs radar (radio).

RAPID RECALL · CHAPTER 28

① Ammeter — series, low R; Voltmeter — parallel, high R.
② Hydrometer: density. Hygrometer: humidity. Don't swap.
③ Barometer: pressure (falling = storm). Altimeter: height.
④ Anemometer: wind. Seismograph: earthquakes.
⑤ Geiger counter: radioactivity. CRO: waveforms.
⑥ Sonar = ultrasound (water); Radar = radio waves (air).
⑦ MRI: magnetism, no radiation. X-ray: ionising radiation.
⑧ Periscope: two mirrors at 45°. Spectrometer: splits light.
⑨ Vernier: 0.1 mm. Screw gauge: 0.01 mm.
⑩ Electron microscope beats optical — matter waves (Ch 24).

28.2 Practice Set

PYQ **1.** The instrument used to measure the humidity of air is the: (a) hydrometer (b) hygrometer (c) barometer (d) lactometer

ORIGINAL **2.** An ammeter must be connected in ______ with ______ resistance: (a) parallel, high (b) series, high (c) series, low (d) parallel, low

MATCH **3.** (i) seismograph (ii) anemometer (iii) Geiger counter — (P) wind speed (Q) radioactivity (R) earthquakes.

ANSWER KEY – **1(b)** hygrometer. **2(c)** series, low. **3** i-R, ii-P, iii-Q.

PART X · CHAPTER 29

Discoveries & Discoverers

One master timeline: who found what, when. Every entry here has appeared — or will appear — as a matching question.

WHY BPSC ASKS THIS

"Match the scientist with the discovery" is the most formulaic — and most bankable — question type in the science section.

FREQUENCY

Very high · every paper

PREREQUISITES

All previous chapters — this is their index.

29

29.1 The Master Timeline

DIAGRAM 29.1 · FOUR CENTURIES OF PHYSICS IN ONE LINE

1600s — **Galileo** — telescope astronomy, pendulum, falling bodies · **Newton** — laws of motion, gravitation, spectrum of white light (1687, *Principia*)

1700s — **Franklin** — lightning is electricity · **Coulomb** — law of electric force · **Volta** — first battery (1800)

1800s — **Oersted** — current makes magnetism (1820) · **Ohm** — V = IR (1827) · **Faraday** — electromagnetic induction (1831) · **Joule** — heat–work equivalence · **Maxwell** — EM wave theory (1865) · **Hertz** — radio waves (1887) · **Röntgen** — X-rays (1895) · **Becquerel** — radioactivity (1896) · **Thomson** — electron (1897)

1900–50 — **Planck** — quanta (1900) · **Einstein** — relativity + photon (1905) · **Onnes** — superconductivity (1911) · **Rutherford** — nucleus (1911), proton (1919) · **Bohr** — atomic model (1913) · **de Broglie** — matter waves (1924) · **Chadwick** — neutron (1932) · **Hahn** — fission (1938) · **Shockley, Bardeen, Brattain** — transistor (1947)

1950–now — **Maiman** — laser (1960) · **Kilby & Noyce** — integrated circuit (1958–59) · **CERN** — Higgs boson (2012) · **LIGO** — gravitational waves (2015) · **EHT** — first black hole image (2019)

29.2 India's Physicists

GALLERY 29.2 · SIX NAMES BPSC RETURNS TO AGAIN AND AGAIN

C. V. Raman

Raman effect (28 Feb 1928 → National Science Day). **Nobel 1930** — first Asian science laureate. Also explained why the sea is blue.

S. N. Bose

Bose–Einstein statistics (1924); the **boson** is named after him. Never won a Nobel — a famous omission.

S. Chandrasekhar

Chandrasekhar limit (1.4 solar masses) — fate of dying stars. **Nobel 1983**. NASA's Chandra X-ray telescope honours him.

Homi J. Bhabha

Father of India's **nuclear programme**; founded TIFR (1945) and AEC (1948). BARC bears his name.

Vikram Sarabhai

Father of India's **space programme**; founded ISRO (1969). Chandrayaan-3's lander *Vikram* honours him.

Meghnad Saha & J. C. Bose

Saha: ionisation equation — reads starlight. **J. C. Bose**: microwave pioneer, pre-dating Marconi's radio work.

*Trap pair: **Bhabha** = nuclear, **Sarabhai** = space. And J. C. Bose (microwaves) ≠ S. N. Bose (bosons).*

MEMORY HOOK The 1895–97 hat-trick, one per year: **X-rays (Röntgen, 1895) → radioactivity (Becquerel, 1896) → electron (Thomson, 1897)**. Three consecutive years that opened modern physics — and a favourite chronology question.

RAPID RECALL · CHAPTER 29

① Volta: battery. Oersted: current→magnetism. Faraday: induction.
② Maxwell predicted EM waves; Hertz produced them.
③ 1895 X-rays → 1896 radioactivity → 1897 electron.
④ Hahn: fission (1938). Transistor: Bell Labs, 1947.
⑤ Laser: Maiman 1960. IC: Kilby & Noyce 1958–59.
⑥ Raman effect: 28 Feb 1928 = National Science Day.
⑦ Raman 1930 — first Asian science Nobel.
⑧ Chandrasekhar limit: 1.4 solar masses; Nobel 1983.
⑨ Bhabha: nuclear (TIFR/AEC). Sarabhai: space (ISRO).
⑩ J. C. Bose: microwaves. S. N. Bose: boson statistics.

29.3 Practice Set

PYQ **1.** National Science Day (28 February) commemorates: (a) Bhabha's birthday (b) the Raman effect (c) India's first nuclear test (d) ISRO's founding

ORIGINAL **2.** Arrange chronologically: (i) electron (ii) X-rays (iii) neutron (iv) radioactivity — (a) ii-iv-i-iii (b) i-ii-iii-iv (c) iv-ii-i-iii (d) ii-i-iv-iii

MATCH **3.** (i) Faraday (ii) Oersted (iii) Volta — (P) first battery (Q) electromagnetic induction (R) magnetic effect of current.

ANSWER KEY – 1(b) Raman effect, 1928. **2(a)** 1895 → 1896 → 1897 → 1932. **3** i-Q, ii-R, iii-P.

PART X · CHAPTER 30

Nobel Prizes in Physics

Awarded since 1901 from Alfred Nobel's dynamite fortune. BPSC asks two kinds: the classic laureates (Röntgen to Raman) and the last five years' winners.

WHY BPSC ASKS THIS

Laureate–work matching for the classics, plus a near-guaranteed current-affairs question on the latest prize.

FREQUENCY

High · classics + current affairs

PREREQUISITES

Ch 24–29 — this chapter ties them together.

30.1 The Classics — Prizes That Built This Book

GALLERY 30.1 · TWELVE NOBEL STORIES IN BOXES — EACH WITH ITS ICON

1901 · RÖNTGEN
The very first prize — **X-rays**. He refused to patent them: "they belong to humanity."

1903 · BECQUEREL & THE CURIES
Radioactivity. Marie Curie: first woman laureate — and won Chemistry too (1911), the only person with Nobels in two sciences.

1906 · J. J. THOMSON
The **electron** — first subatomic particle. Seven of his students went on to win Nobels of their own.

1918 · PLANCK
Energy quanta ($E = h\nu$) — the reluctant revolutionary who started quantum physics to fix a formula.

1921 · EINSTEIN
Photoelectric effect — NOT relativity. The most-asked Nobel trap in the entire syllabus.

1922 · BOHR
Atomic structure — electron shells. His son Aage won in 1975: one of several father–son Nobel pairs.

1930 · C. V. RAMAN
Raman effect — light scattering with colour change. First Asian science laureate; worked in Kolkata with ₹200 equipment.

1935 · CHADWICK
The **neutron** — the chargeless particle that made fission (and reactors) possible.

1956 & 1972 · BARDEEN
Transistor, then **superconductivity theory** — the only double Physics laureate in history.

1983 · CHANDRASEKHAR
Stellar evolution — the 1.4-solar-mass limit deciding whether a star becomes a white dwarf or collapses further.

2013 · HIGGS & ENGLERT
The **Higgs boson** — proposed 1964, confirmed at CERN 2012. A 48-year wait for the prize.

2017 · WEISS, BARISH & THORNE
Gravitational waves at LIGO — hearing two black holes collide 1.3 billion light-years away.

30.2 The Recent Five — Current-Affairs Zone

YEAR	LAUREATES	FOR
2021	Manabe, Hasselmann, Parisi	Climate modelling & complex systems
2022	Aspect, Clauser, Zeilinger	Quantum entanglement experiments
2023	Agostini, Krausz, L'Huillier	Attosecond light pulses — filming electrons
2024	Hopfield, Hinton	Neural networks — foundations of machine learning
2025	Clarke, Devoret, Martinis	Quantum tunnelling in electric circuits — basis of qubits

TRAP The 2024 prize to **Hinton** (the "godfather of AI") was in *Physics*, not any computing prize — examiners love this crossover. Likewise Rutherford's Nobel was Chemistry, and Marie Curie won both.

RAPID RECALL · CHAPTER 30

① First Physics Nobel: Röntgen, 1901 (X-rays).
② Marie Curie: first woman; only person with Physics + Chemistry.
③ Einstein 1921: photoelectric effect, never relativity.
④ Raman 1930: first Asian science laureate; effect dated 28 Feb 1928.
⑤ Bardeen: only double Physics winner (1956, 1972).
⑥ Chandrasekhar 1983: stellar evolution limit.
⑦ Higgs boson: proposed 1964, found 2012, Nobel 2013.
⑧ LIGO gravitational waves: detected 2015, Nobel 2017.
⑨ 2024: Hopfield & Hinton — neural networks in Physics.
⑩ 2025: Clarke, Devoret, Martinis — quantum circuits.

30.3 Practice Set

PYQ **1.** C. V. Raman received the Nobel Prize for his work on: (a) radioactivity (b) scattering of light (c) atomic structure (d) superconductivity

ORIGINAL **2.** The 2024 Nobel Prize in Physics recognised foundations of: (a) quantum entanglement (b) machine learning (c) climate modelling (d) attosecond physics

ASSERTION **3. A:** Marie Curie won two Nobel Prizes. **R:** Both her prizes were in Physics. (a) Both true, R explains A (b) Both true, unrelated (c) A true, R false (d) Both false

ANSWER KEY – **1(b)** light scattering — the Raman effect. **2(b)** Hopfield & Hinton. **3(c)** — 1903 Physics, 1911 Chemistry.

END OF PARTS I–VIII · CHAPTERS 1–23

More Physics is on the way

Modern Physics, Instruments, Discoveries, Nobel Prizes and the 500-MCQ bank follow — each built to this same architecture. Chemistry ships as Volume II.

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