

Chapter 1: Physical World and Measurement (NEET 2025)

1. The Physical World – Introduction to Physics

Physics is the most fundamental science — it tries to explain **how and why nature behaves** the way it does.

It deals with **matter, energy, space, and time**, and the laws that govern their interactions.

In simple terms, physics is the *study of the natural world*. From the smallest subatomic particles to galaxies billions of light-years away — physics connects it all through universal principles.

Whenever you see a rainbow, switch on a light, hear sound through your phone, or watch the stars — physics is quietly working behind the scenes.

The word “**Physics**” comes from the Greek word *Physis*, meaning *nature*. So, physics is literally “the study of nature and its laws.”

2. Scope and Importance of Physics

Physics isn't just about theories — it's about finding **patterns in nature** and expressing them mathematically.

Once you know these laws, you can apply them to predict, create, and even control phenomena around you.

For instance:

- The **law of gravitation** explains both how an apple falls and how the Moon orbits the Earth.
- The **laws of electromagnetism** explain how electric fans, generators, and even Wi-Fi work.
- The **laws of optics** explain how glasses, microscopes, and telescopes function.

Physics also serves as the **foundation of other sciences**:

- In chemistry, the motion and bonding of atoms depend on quantum physics.
- In biology, nerve impulses and blood flow follow laws of electricity and fluid mechanics.
- In computer science, semiconductors and circuits are pure applications of modern physics.

In short, physics connects theory with the real world. It's the reason your smartphone exists, why airplanes fly, and why satellites don't fall.

3. Physics, Technology, and Society

Physics → Technology → Society — this cycle drives human progress.

Physics discoveries give rise to **new technologies**, which improve society and open new frontiers in science again.

Physics Concept	Technology Developed	Social Impact
Electricity & Magnetism	Motors, transformers, computers	Power generation, automation
Nuclear Physics	Reactors, medical imaging	Energy, cancer treatment
Optics	Lenses, fiber optics	Communication, vision aids
Semiconductors	Transistors, ICs	Modern computers, phones
Space Physics	Satellites	GPS, communication, weather forecast

So, every breakthrough in physics changes how we live.

4. Fundamental Forces of Nature

All the forces we observe — from gravity to magnetism — can be classified into **four fundamental forces**:

Force	Range	Relative Strength	Example
Gravitational	Infinite	Weakest (10^{-38})	Keeps planets in orbit
Electromagnetic	Infinite	10^{-2}	Light, electricity, magnetism
Strong Nuclear	$\sim 10^{-15}$ m	Strongest (1)	Binds nucleus
Weak Nuclear	$\sim 10^{-18}$ m	10^{-6}	Beta decay, solar fusion

Though gravity is weakest, it dominates at astronomical scales because it's always attractive and acts over infinite distance.

5. Unification of Forces

Physicists always try to find **a single theory that explains all forces**.

- **Maxwell** unified electricity and magnetism into *electromagnetism*.

- **Glashow, Weinberg, and Salam** unified weak and electromagnetic forces into *electroweak theory*.
- The dream is the **Grand Unified Theory (GUT)** — to merge all four forces, including gravity.

Einstein spent decades trying to discover this “Theory of Everything.” Even today, physicists chase it through *string theory* and *quantum gravity*.

6. The Scientific Method

Science progresses by **observation, reasoning, and experiment**.

The **scientific method** follows a pattern:

1. **Observation:** Notice something (like an apple falling).
2. **Hypothesis:** Suggest an explanation. (“Earth pulls objects downward.”)
3. **Experiment:** Test if it’s true.
4. **Law/Theory:** If results match repeatedly, form a law (like gravitation).
5. **Prediction:** Use it to predict new outcomes.

This method makes science **self-correcting** — every law must match experimental results, or it’s revised or replaced.

That’s why Newton’s laws work for daily life, but Einstein’s relativity takes over at high speeds or strong gravity.

7. Branches of Physics

Physics is broad but beautifully interconnected:

Branch	Description	Example
Mechanics	Motion and forces	Planets, cars, projectiles
Thermodynamics	Heat, work, and energy	Engines, refrigerators
Electromagnetism	Electricity & magnetism	Motors, transformers
Optics	Light and vision	Lenses, mirrors
Modern Physics	Quantum & relativity	Atoms, semiconductors

All these together make physics both **deep and practical** — theory meets technology.

8. Units and Measurements

To compare physical quantities, we need **standards of measurement** called **units**.
For example, when we say *10 meters*, “10” is the numerical value and “meter” is the unit.

8.1 Physical Quantities

Quantities that can be measured are called **physical quantities** (like length, mass, time, temperature).

8.2 Fundamental and Derived Units

- **Fundamental Units** (independent):
Length (m), Mass (kg), Time (s), Current (A), Temperature (K), Substance (mol), Luminous Intensity (cd).
- **Derived Units** (formed from basics):
 - Speed = m/s
 - Force = $\text{kg} \cdot \text{m/s}^2$ = Newton (N)
 - Energy = $\text{kg} \cdot \text{m}^2/\text{s}^2$ = Joule (J)
 - Pressure = N/m^2 = Pascal (Pa)

8.3 System of Units

Old systems: CGS, FPS, MKS.

Modern: **SI System (International System of Units)** — universally used for consistency.

9. Accuracy, Precision, and Errors

Every measurement has **some uncertainty**. Understanding this helps us trust our results.

- **Accuracy** → How close a measurement is to the true value.
- **Precision** → How consistent repeated measurements are.

A value can be precise but inaccurate — if your clock runs fast, it gives the same wrong time precisely!

Types of Errors

1. **Systematic errors** – instrument or procedural flaws (same direction each time).
2. **Random errors** – unpredictable variations.
3. **Gross errors** – human mistakes.

Mean and Absolute Error

If x_1, x_2, \dots, x_n are measured values:

$$\text{Mean} = (\Sigma x) / n$$

$$\text{Mean absolute error} = (\Sigma |x_i - \bar{x}|) / n$$

Relative and Percentage Error

$$\text{Relative error} = (\Delta x / \bar{x})$$

$$\text{Percentage error} = (\text{Relative error} \times 100)\%$$

These calculations help report results like:

$$\text{Acceleration due to gravity} = 9.80 \pm 0.05 \text{ m/s}^2$$

10. Significant Figures

Significant figures tell us **how reliable a measured value** is.

Rules:

1. Non-zero digits are significant.
2. Zeros between non-zero digits are significant.
3. Leading zeros aren't.
4. Trailing zeros after decimal are significant.

Example:

0.00450 \rightarrow 3 significant figures.

3.200 \rightarrow 4 significant figures.

Arithmetic Rules:

- For addition/subtraction \rightarrow least decimal places.
- For multiplication/division \rightarrow least significant figures.

So, $12.5 \times 2.3 = 28.75 \rightarrow$ rounded to **29** (2 significant figures).

11. Dimensional Analysis

Every physical quantity can be expressed in terms of **Mass (M), Length (L), and Time (T)**.

For example,

Velocity $\rightarrow [L T^{-1}]$

Force $\rightarrow [M L T^{-2}]$

Energy $\rightarrow [M L^2 T^{-2}]$

11.1 Principle of Homogeneity

Dimensions must balance on both sides of any valid equation.

Example:

$$v^2 = u^2 + 2as \rightarrow \text{both sides } [L^2 T^{-2}] \checkmark$$

11.2 Applications

1. Checking correctness of equations:

$$F = ma^2 \quad \times \text{ (wrong dimensions).}$$

2. Deriving relations:

Suppose $T \propto l^a g^b$ for pendulum.

$$[T] = [L^a (L T^{-2})^b] \rightarrow a + b = 0, -2b = 1 \rightarrow b = -\frac{1}{2}, a = \frac{1}{2}$$

$$\rightarrow T \propto \sqrt{l/g} \quad \checkmark$$

3. Unit conversion:

Ensures you can move between systems (e.g., cm/s \rightarrow m/s).

Dimensional analysis is like a “logic check” for physics equations — if the dimensions match, your formula probably makes sense.

12. Measurement and Error Propagation

When you use measured quantities in equations, their **errors combine**.

If $Q = a \pm \Delta a$ and $b \pm \Delta b$,

For **addition/subtraction**:

$$\Delta Q = \Delta a + \Delta b$$

For **multiplication/division**:

$$(\Delta Q / Q) = (\Delta a / a) + (\Delta b / b)$$

Example:

$$\text{If } L = 100 \pm 1 \text{ cm, } B = 50 \pm 1 \text{ cm}$$

$$\rightarrow \text{Area} = L \times B = 5000 \text{ cm}^2$$

$$\text{Relative error} = (1/100 + 1/50) = 0.03$$

$$\Delta A = 0.03 \times 5000 = 150 \text{ cm}^2$$

$$\rightarrow A = (5000 \pm 150) \text{ cm}^2$$

This shows both the value and reliability — essential in lab reports and NEET experimental questions.

13. Physics in the Real World

Physics isn't limited to equations — it's the reason civilization evolved.

- **Mechanics** \rightarrow helps design vehicles, bridges, aircraft.

- **Thermodynamics** → governs engines and refrigerators.
- **Electromagnetism** → powers every electronic device.
- **Optics** → from microscopes to fiber networks.
- **Modern physics** → semiconductors, lasers, nuclear energy.

Even medical science depends on physics:

- **MRI, X-rays, CT scans, Ultrasound** — all based on physical principles.
- **Radiotherapy** uses nuclear decay.
- **Optical fibers** enable surgical cameras.

■ 14. Physics, Curiosity, and Humanity

The journey of physics began with simple curiosity.

- Why do objects fall? (Newton)
- What is light? (Maxwell, Einstein)
- What is matter made of? (Rutherford, Bohr, Schrödinger)

Each question reshaped how humans think.

Physics teaches us not just “what happens,” but “why it happens” — it trains the mind to question, reason, and explore.

Even today, physics pushes frontiers: **quantum computing, space travel, black holes, and nuclear fusion** are all born from the same curiosity that made Newton look at a falling apple.

📋 15. Summary – Key Takeaways

1. **Physics** is the study of nature’s fundamental laws.
2. **Four forces** govern all interactions — gravitational, electromagnetic, strong, weak.
3. **Scientific method** ensures accuracy through observation and experiment.
4. **Measurements** link theory with reality.
5. **Units** standardize quantities across the world (SI system).
6. **Errors and significant figures** define reliability.
7. **Dimensional analysis** is a powerful tool for checking and deriving relations.
8. Physics connects deeply with **technology, medicine, and life itself**.