Complete Physics Notes – Part 1: Mechanics

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1. Introduction to Physics

Physics is the branch of science that studies **matter, energy, and their interactions**.
It explains how and why things move, how forces act, and how energy transforms from one form to another.

Major Branches of Physics:

1. **Mechanics** – motion, forces, energy.
2. **Thermodynamics** – heat and temperature.
3. **Electromagnetism** – electricity and magnetism.
4. **Optics** – behavior of light.
5. **Waves and Sound** – motion of waves.
6. **Modern Physics** – atoms, nuclei, quantum theory.

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2. Physical Quantities and Units

Physical Quantity

A property of a material or system that can be measured, e.g., length, mass, time, temperature.

Types

1. **Fundamental Quantities:** Basic independent quantities (length, mass, time, temperature, current, luminous intensity, amount of substance).
2. **Derived Quantities:** Formed from combinations of fundamental ones, e.g.:
   - Speed = Distance / Time
   - Force = Mass × Acceleration

SI Units

Quantity	Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric Current	ampere	A
Temperature	kelvin	K

Quantity	Unit	Symbol
Luminous Intensity	candela	cd
Amount of Substance	mole	mol

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3. Scalars and Vectors

Scalar Quantity:

Has only **magnitude**, no direction.
Examples: Mass, Time, Speed, Distance, Energy, Temperature.

Vector Quantity:

Has **magnitude and direction**.
Examples: Velocity, Force, Acceleration, Displacement, Momentum.

Representation:
Vectors are represented by arrows — the **length** shows magnitude, and **arrow direction** shows direction.

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4. Motion

Motion occurs when an object changes its position with time.

Types of Motion

1. **Linear Motion** – in a straight line (a car moving on a road).
2. **Rotational Motion** – around an axis (a spinning fan).
3. **Vibrational Motion** – back and forth around a point (a pendulum).

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5. Distance and Displacement

- **Distance:** The total path covered by a body (scalar quantity).
- **Displacement:** The shortest straight-line distance between initial and final position (vector quantity).

Example:
A car moves 3 km east and then 4 km north.

- Distance = 3 + 4 = 7 km
- Displacement = $\sqrt{(3^2 + 4^2)}$ = 5 km

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6. Speed and Velocity

- **Speed:** The rate of change of distance.

  Speed=DistanceTime\text{Speed} = \frac{\text{Distance}}{\text{Time}}Speed=TimeDistance

  SI Unit: m/s

- **Velocity:** The rate of change of displacement.

  Velocity=DisplacementTime\text{Velocity} = \frac{\text{Displacement}}{\text{Time}}Velocity=TimeDisplacement

  It is a **vector** quantity.

Example:
A car covers 100 m in 5 s.
Speed = 100 / 5 = 20 m/s.

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7. Acceleration

Acceleration is the **rate of change of velocity** with time.

a=v−uta = \frac{v - u}{t}a=tv−u

where

- u = initial velocity
- v = final velocity
- t = time taken

SI Unit: m/s^2

Example:
A car increases its velocity from 10 m/s to 20 m/s in 5 seconds.

a=20−105=2 m/s2a = \frac{20 - 10}{5} = 2 \, m/s^2a=520−10=2m/s2

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8. Equations of Uniformly Accelerated Motion

1. v=u+atv = u + atv=u+at
2. s=ut+12at2s = ut + \frac{1}{2}at^2s=ut+21at2
3. v2=u2+2asv^2 = u^2 + 2asv2=u2+2as

where
s = distance, *u* = initial velocity, *v* = final velocity, *a* = acceleration, *t* = time.

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9. Newton’s Laws of Motion

First Law (Law of Inertia):

A body remains at rest or continues in uniform motion unless acted upon by an external force.
👉 Explains **inertia** — resistance to change in motion.

Second Law:

The rate of change of momentum is directly proportional to the applied force.

F=maF = maF=ma

where *F* = force, *m* = mass, *a* = acceleration.

Third Law:

For every action, there is an equal and opposite reaction.
Example: A gun recoils backward when a bullet is fired forward.

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10. Force

A **force** is a push or pull that changes the state of motion of a body.
SI Unit: Newton (N)

1 Newton = Force required to accelerate 1 kg of mass by 1 m/s^2.

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11. Friction

Friction is a force that **opposes motion** between two surfaces in contact.

Types:

1. **Static Friction** – before motion starts.
2. **Kinetic (Sliding) Friction** – during motion.
3. **Rolling Friction** – for rolling objects like wheels.

Advantages: Walking, writing, driving.
Disadvantages: Wear and tear, energy loss.

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12. Work, Power, and Energy

Work

Work is done when a **force moves an object** in the direction of the force.

W=F×dW = F \times dW=F×d

where *F* = force, *d* = displacement.
SI Unit: Joule (J)

Power

Power is the **rate of doing work**.

P=WtP = \frac{W}{t}P=tW

Unit: Watt (W)

Energy

Energy is the ability to do work.
Types:

- **Kinetic Energy (KE):** KE=12mv2KE = \frac{1}{2}mv^2KE=21mv2
- **Potential Energy (PE):** PE=mghPE = mghPE=mgh

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13. Law of Conservation of Energy

Energy cannot be created or destroyed; it only **changes from one form to another.**
Example: In a falling ball, potential energy converts to kinetic energy.

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14. Momentum

Momentum is the product of mass and velocity.

p=mvp = mvp=mv

Unit: kg·m/s

Law of Conservation of Momentum:
In an isolated system, total momentum before and after interaction remains constant.

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15. Circular Motion and Centripetal Force

When a body moves in a circle, its velocity changes direction continuously — it experiences **centripetal force** directed toward the center.

F=mv2rF = \frac{mv^2}{r}F=rmv2

where *m* = mass, *v* = velocity, *r* = radius.

Example: Motion of a satellite around Earth.

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16. Gravity

Gravitation: The force of attraction between any two masses.

F=Gm1m2r2F = G \frac{m_1 m_2}{r^2}F=Gr2m1m2

where $G = 6.67 \times 10^{-11}$ N·m^2/kg^2

Acceleration due to gravity (g):

g=9.8 m/s2g = 9.8 \, m/s^2g=9.8m/s2

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17. Mass and Weight

- **Mass:** Quantity of matter in a body (constant, measured in kg).
- **Weight:** Force due to gravity acting on mass.

  W=mgW = mgW=mg

  Unit: Newton (N)

Example:
Mass = 50 kg → Weight = 50 × 9.8 = 490 N.

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18. Machines

A **machine** is a device that multiplies force or changes its direction.

Examples: Lever, pulley, inclined plane, wheel and axle.

Mechanical Advantage (M.A.):

M.A.=LoadEffortM.A. = \frac{\text{Load}}{\text{Effort}}M.A.=EffortLoad

Efficiency:

Efficiency=Work OutputWork Input×100\text{Efficiency} = \frac{\text{Work Output}}{\text{Work Input}} \times 100Efficiency=Work InputWork Output×100

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19. Pressure

Pressure is the force acting per unit area.

P=FAP = \frac{F}{A}P=AF

Unit: Pascal (Pa)

Example: Sharp knife cuts easily because it has small area → greater pressure.

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20. Density

Density is the **mass per unit volume** of a substance.

ρ=mV\rho = \frac{m}{V}ρ=Vm

Unit: kg/m³

✅ **Summary (Mechanics Essentials):**

- Force = mass × acceleration
- Work = force × distance
- Energy = ability to do work
- Power = work / time
- Weight = mass × gravity
- Pressure = force / area
- Momentum = mass × velocity

PART 2: PHYSICS – DETAILED TOPIC-WISE EXPLANATION

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6. Heat and Temperature

6.1 What is Heat?

Heat is a form of energy that is transferred between objects due to a difference in temperature. It flows from a **hot body** to a **cold body** until both reach the same temperature (thermal equilibrium).

Units:

- SI unit: **Joule (J)**
- Common unit: **Calorie (cal)**
  1 calorie=4.186 joules1 \, \text{calorie} = 4.186 \, \text{joules}1calorie=4.186joules

6.2 Temperature

Temperature measures how hot or cold an object is.
It shows the **average kinetic energy** of the particles in a substance.

Common Scales:

Scale	Unit	Freezing Point of Water	Boiling Point of Water
Celsius	°C	0°C	100°C
Fahrenheit	°F	32°F	212°F
Kelvin	K	273K	373K

Conversion Formulas:

- K=°C+273K = °C + 273K=°C+273
- °F=(°C×9/5)+32°F = (°C × 9/5) + 32°F=(°C×9/5)+32

6.3 Methods of Heat Transfer

1. **Conduction** – Transfer through solids (e.g., metal rod heated at one end).
2. **Convection** – Transfer through fluids (liquids and gases).
3. **Radiation** – Transfer through electromagnetic waves (no medium needed, e.g., sunlight).

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7. Thermodynamics

7.1 Basic Concepts

Thermodynamics is the study of **energy transformation** between heat and mechanical work.

Key Terms:

- **System:** The part of the universe under study.
- **Surroundings:** Everything outside the system.
- **Boundary:** Separates system and surroundings.

7.2 Laws of Thermodynamics

1. **Zeroth Law:** If body A and B are in thermal equilibrium with C, then A and B are in equilibrium with each other.
   → Basis for measuring **temperature**.
2. **First Law:** Energy cannot be created or destroyed, only transformed.
   → ΔU=Q−W\Delta U = Q - WΔU=Q−W
   (Change in internal energy = Heat added - Work done)
3. **Second Law:** Heat flows spontaneously from a hot object to a cold one, never the reverse.

4. **Third Law:** As temperature approaches absolute zero (0 K), entropy (disorder) approaches minimum.

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8. Light (Optics)

8.1 Nature of Light

Light is a form of **electromagnetic radiation** that travels in straight lines and shows both **wave** and **particle** nature.

8.2 Reflection

The **bouncing back** of light from a surface.

- **Laws of Reflection:**
    1. The angle of incidence = angle of reflection.
    2. The incident ray, reflected ray, and normal all lie in the same plane.

Types of Reflection:

- **Regular Reflection:** From smooth surfaces (mirror).
- **Diffuse Reflection:** From rough surfaces (paper).

8.3 Refraction

The **bending of light** as it passes from one medium to another (like air to water).

- **Laws of Refraction (Snell's Law):**
  sinisinr=n\frac{\sin i}{\sin r} = nsinrsini=n (refractive index)

Applications:

- Lenses, prisms, eyeglasses, cameras, microscopes.

8.4 Lenses

- **Convex Lens:** Converges light rays.
- **Concave Lens:** Diverges light rays.

Lens Formula:

1f=1v−1u\frac{1}{f} = \frac{1}{v} - \frac{1}{u}f1=v1−u1

Where:
f=f =f= focal length, v=v =v= image distance, u=u =u= object distance.

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9. Sound

9.1 Nature of Sound

Sound is a form of **mechanical wave** produced by vibrating objects and requires a medium (solid, liquid, gas).

Key Properties:

- **Amplitude (A):** Loudness
- **Frequency (f):** Pitch (unit = Hertz, Hz)
- **Wavelength (λ):** Distance between two compressions
- **Velocity (v):** v=fλv = fλv=fλ

9.2 Speed of Sound

Depends on medium:

- Fastest in solids
- Slower in liquids
- Slowest in gases

Example:
Speed in air ≈ **343 m/s** at 20°C.

9.3 Reflection of Sound

Echoes occur when sound waves reflect off surfaces (minimum distance ≈ 17 meters for echo).

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10. Electricity

10.1 Electric Charge

Basic property of matter. Two types: **Positive (+)** and **Negative (−)**.
Like charges repel, unlike charges attract.

10.2 Electric Current

Flow of electric charge through a conductor.
Formula:

I=QtI = \frac{Q}{t}I=tQ

Where:
III = current (ampere), QQQ = charge (coulomb), ttt = time (seconds).

10.3 Ohm's Law

V=IRV = IRV=IR

Where:
VVV = voltage, III = current, RRR = resistance.
→ Resistance opposes the flow of current.

10.4 Electrical Power

P=VI=I2R=V2RP = VI = I^2R = \frac{V^2}{R}P=VI=I2R=RV2

Measured in **Watts (W)**.

10.5 Series and Parallel Circuits

- **Series:** Same current, voltages add up.
- **Parallel:** Same voltage, currents add up.

10.6 Magnetism and Electromagnetism

- Electric current produces a **magnetic field** (Right-hand thumb rule).
- **Electromagnet:** A coil of wire (solenoid) that acts as a magnet when current flows.
- **Applications:** Electric bells, motors, transformers.

✅ **End of Part 2**
Next Part (Part 3) will cover:

- **Modern Physics**
- **Nuclear Physics**
- **Semiconductors**
- **Practical Applications**
- **Common Physics Questions**

PART 3: MODERN & NUCLEAR PHYSICS – DETAILED EXPLANATION

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11. Modern Physics

11.1 Introduction

Modern physics deals with phenomena that classical physics could not explain — especially those involving **very small (atomic/subatomic)** or **very fast (near light-speed)** systems.

It includes theories like:

- Quantum Mechanics
- Relativity
- Atomic and Nuclear Structure

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12. Structure of Atom

12.1 Early Models

1. **Thomson's Model (Plum Pudding Model)**
   - Atom = positively charged sphere with electrons embedded in it.
   - Couldn't explain scattering experiments.
2. **Rutherford's Model (Nuclear Model)**
   - Gold-foil experiment.
   - Atom has a small dense **nucleus** containing protons; electrons revolve around it.
   - Most of the atom is **empty space**.
   - Couldn't explain why electrons don't fall into the nucleus.
3. **Bohr's Model**
   - Electrons revolve in **fixed energy levels (orbits)**.
   - Energy is **quantized**:

     $$E_n = -\frac{13.6}{n^2} \, \text{eV}$$

   - When electrons jump between levels, they emit/absorb photons of energy:

     $$E = hf$$

     where h = Planck's constant.

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13. Quantum Theory of Light

13.1 Wave–Particle Duality

Light behaves both as:

- A **wave** (interference, diffraction)
- A **particle** (photoelectric effect)

13.2 Photoelectric Effect

- Discovered by **Heinrich Hertz**, explained by **Albert Einstein**.
- When light of sufficient frequency strikes a metal surface, **electrons are ejected**.
- Key equation:

  Ek=hf−ϕE_k = hf - \phiEk=hf−ϕ

  where ϕ\phiϕ = work function (minimum energy to remove an electron).

- Proved that energy is carried in discrete packets called **photons**.

13.3 Planck's Quantum Theory

Energy is emitted or absorbed in small packets called **quanta**.

E=hfE = hfE=hf

h=6.626×10−34 J\cdotpsh = 6.626 \times 10^{-34} \, \text{J·s}h=6.626×10−34J\cdotps

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14. Relativity (Einstein's Theory)

14.1 Special Theory of Relativity

Applies to objects moving near the speed of light.

Main postulates:

1. The laws of physics are the same in all inertial frames.
2. The speed of light in a vacuum is constant for all observers.

Consequences:

- **Time Dilation:**

$$t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

- **Length Contraction:**

$$L = L_0 \sqrt{1 - \frac{v^2}{c^2}}$$

- **Mass–Energy Equivalence:**

$$E = mc^2$$

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15. Nuclear Physics

15.1 Structure of Nucleus

- Composed of **protons** and **neutrons** (collectively called nucleons).
- **Atomic number (Z):** Number of protons.
- **Mass number (A):** Number of protons + neutrons.
- **Isotopes:** Same Z, different A (e.g., C-12, C-14).
- **Isobars:** Same A, different Z.

15.2 Radioactivity

Spontaneous decay of unstable nuclei into stable ones with emission of radiation.

Types of Radiations:

Radiation	Nature	Charge	Penetration	Effect
Alpha (α)	Helium nucleus (2p + 2n)	+2	Weak	Least penetrating
Beta (β)	Electrons or positrons	−1 or +1	Moderate	More penetrating
Gamma (γ)	High-energy photons	0	Very strong	Most penetrating

Laws:

- Radioactive decay is **spontaneous** and **independent** of external factors.
- Follows **Exponential Law**:

$$N = N_0 e^{-\lambda t}$$

where λ = decay constant.

15.3 Half-Life (T½)

Time required for half of a radioactive substance to decay.

T1/2=0.693λT_{1/2} = \frac{0.693}{\lambda}T1/2=λ0.693

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16. Nuclear Reactions

16.1 Fission

- Splitting of a heavy nucleus (e.g., Uranium-235) into smaller nuclei with huge energy release.
- Used in **nuclear power plants** and **atomic bombs**.

235U+n→141Ba+92Kr+3n+energy{}^{235}U + n \rightarrow {}^{141}Ba + {}^{92}Kr + 3n + \text{energy}235U+n→141Ba+92Kr+3n+energy

16.2 Fusion

- Two light nuclei combine to form a heavier one.
- Occurs in **stars** (like the Sun).

2H+3H→4He+n+energy{}^{2}H + {}^{3}H \rightarrow {}^{4}He + n + \text{energy}2H+3H→4He+n+energy

16.3 Comparison

Feature	Fission	Fusion
Nuclei	Heavy	Light
Control	Possible	Difficult
Energy	High	Very High
Example	Nuclear reactor	Sun

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17. X-Rays

17.1 Discovery

Discovered by **Wilhelm Roentgen (1895)**.

17.2 Production

When high-speed electrons strike a metal target, X-rays are produced.

17.3 Properties

- Electromagnetic radiation.
- Penetrate soft tissues, absorbed by bones.
- Cause fluorescence and ionization.

17.4 Uses

- Medical imaging (X-ray scans).
- Cancer treatment.
- Detecting cracks in metals.

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18. Semiconductors and Electronics

18.1 Conductors, Insulators, and Semiconductors

Type	Example	Conductivity
Conductor	Copper	High
Insulator	Rubber	Very low
Semiconductor	Silicon, Germanium	Moderate

18.2 Doping

Adding impurities to semiconductors to improve conductivity.

- **n-type:** Extra electrons.
- **p-type:** Electron holes.

18.3 p-n Junction Diode

Allows current in one direction only (rectifier).

18.4 Transistor

A semiconductor device with **three terminals** — emitter, base, collector.
Used for **amplification and switching**.

Types:

- **NPN** and **PNP**

18.5 Logic Gates

Basic building blocks of digital electronics.

Gate	Symbol	Function
AND	·	Output 1 if both inputs 1
OR	+	Output 1 if any input 1
NOT	¬	Inverts the input

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19. Practical Physics and Measurements

19.1 Units and Dimensions

- **Base Quantities:** Length (m), Mass (kg), Time (s), Electric current (A), Temperature (K), Luminous intensity (cd).
- **Derived Quantities:** Velocity, Force, Energy, Pressure, etc.

Dimensional Formula Example:
Force = MLT−2MLT^{-2}MLT−2

19.2 Measurement Errors

- **Systematic Error:** Due to faulty instruments.
- **Random Error:** Due to unpredictable fluctuations.
- **Human Error:** Due to observation mistakes.

Accuracy: Closeness to true value.
Precision: Repeatability of results.

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20. Physics in Everyday Life

- Refrigerators use **thermodynamics**.
- Cell phones use **electromagnetic waves**.
- Solar panels use **photoelectric effect**.
- MRI uses **nuclear magnetic resonance**.
- Optical fibers use **total internal reflection**.