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Physics Lecture Notes for Diploma Students

Unit 1: System of Units, Measurement and Error Analysis

1.1 Unit of Physical Quantity

A physical quantity is a quantity that can be measured.

Examples:

- Length
- Mass
- Time
- Temperature
- Electric current

Every physical quantity consists of:

[physical quantity = numerical value x unit   ]

Example:[5,m]

Here, 5 is the numerical value and metre (m) is the unit.

1.11 Fundamental and Derived Units

Fundamental Units

Units that are independent and cannot be expressed in terms of other units are called fundamental units.

Physical Quantity	SI 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

Derived Units

Units derived from fundamental units are called derived units.

Examples:

Velocity

[Velocity =]

SI Unit:

[m/s]

Force

From Newton’s second law,

[F = ma]

SI unit:

[kg,m/s^2]

This derived unit is called Newton (N).

1.2 Unit System

1.21 CGS, MKS and SI Systems

System	Length	Mass	Time
CGS	centimetre	gram	second
MKS	metre	kilogram	second
SI	metre	kilogram	second

Advantages of SI System

1. Internationally accepted
2. Easy conversion using powers of 10
3. Rationalized system
4. Coherent system
5. One unit for one quantity

Disadvantages of SI System

1. Some units are too large or too small
2. Difficult to use in microscopic measurements without prefixes

Supplementary Units

Quantity	Unit
Plane angle	radian
Solid angle	steradian

1.3 Dimensional Analysis

1.31 Dimensional Formula and Equation

Dimensions represent the nature of a physical quantity.

Basic dimensions:

Quantity	Dimension
Mass	M
Length	L
Time	T

Example: Velocity

[Velocity =]

Dimensional formula:

[[M^{0L}1T^{-1}]]

Example: Force

[F = ma]

[[M^{1L}1T^{-2}]]

Principle of Dimensional Homogeneity

Dimensions on both sides of a physical equation must be same.

1.32 Applications of Dimensional Equations

1. To check correctness of equations
2. To derive formulae
3. To convert one system of units into another

Example

Check:

[s = ut + at^2]

Dimensions of each term:

[[L] = [LT^{-1}] [T] + [LT^{-2}] [T^2]]

[[L] = [L] + [L]]

Hence correct.

1.33 Numerical Problems

Example

Find dimensional formula of pressure.

Solution:

[Pressure =]

[=]

[= M L^{-1} T^{-2}]

1.4 Measurement

1.41 Accuracy, Precision and Errors

Accuracy

Closeness of measured value to true value.

Precision

Agreement among repeated measurements.

Error

Difference between measured value and true value.

[Error = measured value - true value]

1.42 Absolute, Relative and Percentage Error

1. Absolute Error

The magnitude of the difference between the true value (actual value) and the measured value of a physical quantity is called the **Absolute Error**. It represents the actual amount by which the measurement is off and is always taken as a positive value.

- **Formula:**

  Absolute Error = True Value - Measured Value

- *Note:* If the true value is not known, the arithmetic mean (average) of multiple measurements taken during the experiment is considered the true value.

2. Relative Error

The ratio of the absolute error of a measurement to the true value of the quantity is called the **Relative Error**. It describes how large the error is in comparison to the total size of the object being measured. Since it is a ratio of two similar quantities, it has no units.

- **Formula:**

  Relative Error = Absolute Error /True Value

3. Percentage Error

When the relative error is expressed in the form of a percentage ($\%$), it is called the **Percentage Error**. This is the most common way to communicate accuracy in engineering and experimental data.

- **Formula:**

  Percentage Error = {{{Absolute Error}-{True Value}}/ True Value} x 100%

1.5 Significant Figures and Rounding Off

Rules:

1. All non-zero digits are significant.
2. Zeros between non-zero digits are significant.
3. Leading zeros are not significant.

Example

0.00520 has 3 significant figures.

Unit 2: Force and General Properties of Matter

2.1 Force

Force is an external agent that changes or tends to change the state of a body.

SI Unit: Newton (N)

2.11 Types of Forces

Conservative Force

Work done is independent of path.

Examples:

- Gravitational force
- Electrostatic force

Non-Conservative Force

Work done depends on path.

Example:

- Frictional force

Frictional Force

Force opposing relative motion.

Limiting Friction

Maximum static friction.

[F = N]

where,

- (F) = coefficient of friction
- (N) = normal reaction

Dynamic Friction

Friction acting during motion.

Centripetal and Centrifugal Force

Centripetal Force

Force acting towards centre.

Centrifugal Force

Apparent outward force in rotating frame.

Gravitational Force

Newton's law:

[$F = G\,Mm/r^2$

[$g = GM/r^2$]

Where:

- (G) = universal gravitational constant
- (g) = acceleration due to gravity

Factors affecting g:

- Altitude
- Depth
- Rotation of earth

2.2 Elasticity

Property by virtue of which a body regains original shape.

Hooke's Law

Within elastic limit,

[Stress Strain]

[Stress = E Strain]

Where E = modulus of elasticity.

Stress-Strain Graph

```
Stress
 |
 |      /
 |     /
 |    /
 |___/________ Strain
```

Elastic Limit and Elastic Fatigue

- Elastic limit: maximum stress up to which Hooke's law is valid.
- Elastic fatigue: loss of elasticity due to repeated loading.

2.22 Moduli of Elasticity

In engineering and physics, the stiffness of a solid material is measured using parameters called **Elastic Moduli**. When an external force (stress) is applied to a material, it undergoes deformation (strain). Within the elastic limit, Hooke's Law states that stress is directly proportional to strain.

The constant of proportionality is called the **Modulus of Elasticity**. Depending on how the force is applied, there are three primary moduli:

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1. Young’s Modulus (Y or E)

Young’s Modulus measures a material's resistance to changes in its **length** when stretched or compressed along its axis (longitudinal axis).

- **Type of Stress:** Longitudinal Stress (Tensile or Compressive stress)
- **Type of Strain:** Longitudinal Strain (Linear elongation or compression)
- **Definition:** It is the ratio of longitudinal stress to longitudinal strain within the elastic limit.
- **Application:** Used for wires, rods, beams, and structural pillars subjected to stretching or compression forces.

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2. Bulk Modulus (B or K)

Bulk Modulus measures a material's resistance to uniform compression, meaning a change in its overall **volume** while its shape remains the same.

- **Type of Stress:** Volumetric Stress / Hydraulic Pressure (ΔP)
- **Type of Strain:** Volumetric Strain
- **Definition:** It is the ratio of volumetric stress to volumetric strain within the elastic limit.
- **Application:** Crucial for materials submerged deep underwater, hydraulic systems, and analyzing the compressibility of liquids and gases.

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3. Shear Modulus or Modulus of Rigidity (η or G)

Shear Modulus measures a material's resistance to a change in its **shape** caused by a parallel, sliding force, while its volume remains constant.

- **Type of Stress:** Shearing Stress / Tangential Stress
- **Type of Strain:** Shearing Strain (θ)

- **Definition:** It is the ratio of tangential stress to shearing strain within the elastic limit.
- **Application:** Essential for evaluating drive shafts subjected to twisting (torsion), structural rivets, beams experiencing cutting forces, and earthquakes sliding geological faults.

2.3 Surface Tension

Property of liquid surface due to molecular attraction.

Molecular Force

Cohesive Force

Force between same molecules.

Adhesive Force

Force between unlike molecules.

Surface Energy

Work done per unit area.

Effect of temperature:

Surface tension decreases with increase in temperature.

2.4 Viscosity

Property of liquid due to internal friction.

Newton’s Law of Viscosity

Newton’s Law of Viscosity states that for a steady, streamlined flow of a fluid, the tangential shearing stress between any two adjacent layers is directly proportional to the velocity gradient normal (perpendicular) to the direction of flow.

In simpler terms, it describes how fluids resist flowing when layers slide over one another.

Streamline and Turbulent Flow

Reynolds Number

- R < 2000 → streamline flow
- R > 3000 → turbulent flow

Poiseuille's Equation

Applications:

- Flow of blood
- Lubrication systems

Stoke's Law

[F = 6rv]

Applications:

- Falling raindrops
- Millikan oil drop experiment

Unit 3: Optics, Optical Instruments and Optical Fibre

3.1 Refraction

Bending of light when it passes from one medium to another.

Laws of Refraction

Snell's Law

3.2 Refractive Index

Absolute Refractive Index

Relative Refractive Index

Refraction Through Prism

Minimum Deviation-

the minimum value of deviation from incidence ray to refracted rays is called minimum deviation angle.

3.3 Total Internal Reflection

Occurs when light travels from denser to rarer medium.

Condition:

[$i > c$]

Where c = critical angle.

Applications:

- Mirage
- Optical fibre
- Diamond sparkle

Optical Fibre

Works on total internal reflection.

Applications:

- Communication
- Medical endoscopy

3.4 Optical Instruments

Microscopes are optical instruments used to produce magnified images of small objects. They work by using convex lenses to bend light rays, making an object appear larger to the human eye.

Here is a detailed breakdown of both simple and compound microscopes.

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1. Simple Microscope

A **simple microscope** is essentially a single convex lens of short focal length. A common magnifying glass is the most basic example of a simple microscope.

Working Principle:

When an object is placed within the focal length ($u < f$) of a convex lens, the lens forms an image that is **virtual, erect, and magnified**. This image is formed on the same side of the lens as the object and is typically viewed at the *least distance of distinct vision* ($D \approx 25\text{ cm}$).

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2. Compound Microscope

To achieve much higher magnification, a **compound microscope** uses a system of two separate convex lenses acting in sequence.

Key Components:

- **Objective Lens:** The lens closest to the object. It has a small aperture and a short focal length
- **Eyepiece (Ocular Lens):** The lens closest to the eye. It has a larger aperture and a larger focal length compared to the objective lens.

Working Principle:

1. The object is placed just outside the focus of the objective lens
2. The objective lens forms a **real, inverted, and magnified image** inside the microscope tube.
3. This first image acts as the object for the eyepiece. The position of the eyepiece is adjusted so that falls *within* its focal length
4. The eyepiece acts like a simple microscope, forming a final **virtual, inverted, and highly magnified image** relative to the original object.

Spectrometer

Used to measure angle of prism and wavelength.

Main parts:

- Collimator
- Telescope
- Prism table

3.5 Electromagnetic Spectrum

Radiation	Wavelength
Gamma rays	Shortest
X-rays	
UV	
Visible	400–700 nm
Infrared	
Microwaves	
Radio waves	Longest

Pure and Impure Spectrum

Pure Spectrum

Contains only one wavelength.

Impure Spectrum

Contains mixture of wavelengths.

Unit 4: Electrostatics, Electric Current and Magnetism

4.1 Electric Charge and Coulomb's Law

Like charges repel and unlike charges attract.

[$F = q1.q2/r^2$]

4.2 Electric Field

[$E = qF$]

Unit: N/C

Electric Potential

[$V = E/r$]

Unit: Volt

Equipotential Surface

Surface having same potential at every point.

Properties:

- No work done along equipotential surface.
- Electric field is perpendicular.

4.3 Dielectrics

Insulating materials used in capacitors.

Types:

- Polar dielectric
- Non-polar dielectric

Dielectric Strength

Maximum electric field dielectric can withstand.

4.4 Capacitor

Device used to store charge.

Capacitance

[$C = Q/V$]

Unit: Farad

Parallel Plate Capacitor

Factors affecting capacitance:

- Area
- Distance
- Dielectric constant

Types of Capacitors

- Air capacitor

- Paper capacitor
- Electrolytic capacitor

4.5 Magnetism

Magnetic Lines of Force

Properties:

- Closed curves
- Never intersect

4.6 Current Electricity

Resistance

[R = V/I]

Where:

Series Combination

[R = R_1 + R_2 + R_3]

Parallel Combination

[1/R =1/R1 +1/R2]

Internal Resistance of Cell

[V = E - Ir]

Where:

- E = emf
- r = internal resistance

Combination of Cells

Series Combination

[E = E_1 + E_2]

Parallel Combination

Current capacity increases.

Wheatstone Bridge

Condition of balance:

[=]

Applications:

- Measurement of resistance

Metre Bridge

Based on Wheatstone bridge principle.

Potentiometer

Used to compare emf.

Advantages:

- More accurate
- No current drawn from cell

Electrical Power

[P = VI]

Also,

[P = I^2R]

Unit 5: Modern Physics

5.1 Photoelectric Effect

Emission of electrons from metal surface when light falls.

Laws of Photoelectric Emission

1. Photoelectric current proportional to intensity.
2. Kinetic energy depends on frequency.
3. There exists threshold frequency.

Einstein’s Photoelectric Equation

[hv= ϕ+ mv^2]

Where:

- ϕ = work function
- h =plank contant
- v= frequency

Threshold Frequency

Minimum frequency required to eject the electron.

Photo Cell

Converts light energy into electrical energy.

Applications:

- Automatic doors
- Burglar alarm

5.2 X-rays

Production of X-rays

Produced when high speed electrons strike metal target.

Properties of X-rays

1. Travel in straight line
2. High penetrating power
3. Affect photographic plates

Uses of X-rays

- Medical diagnosis
- Crystal structure analysis
- Industrial radiography

5.3 LASER

LASER = Light Amplification by Stimulated Emission of Radiation

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Spontaneous Emission

Atom emits photon naturally.

Stimulated Emission

Incoming photon stimulates emission of another photon.

Population Inversion

Condition in which higher energy state has more atoms.

Pumping Scheme

Method used to achieve population inversion.

Ruby Laser

Active medium: Ruby crystal

Characteristics:

- Red light
- Pulsed output

Semiconductor Laser

Active medium: Semiconductor junction

Applications:

- Optical communication
- Barcode reader

5.4 Ultrasonics

Sound waves having frequency greater than 20 kHz.

Methods of Production

Magnetostriction Method

Based on change in dimensions due to magnetization.

Piezoelectric Method

Based on inverse piezoelectric effect.

Crystal used:

- Quartz

Properties of Ultrasonics

1. High frequency
2. High penetrating power
3. Carry high energy

Applications of Ultrasonics

1. SONAR
2. Medical imaging
3. Crack detection
4. Cleaning delicate instruments

Important Formula Summary

Topic	Formula
Force	F = ma

Topic	Formula
Gravitational force	$F = Gm_1 m_2 / r^2$
Young's modulus	Y = Stress/Strain
Surface tension	$T = F/l$
Capillary rise	$h = 2T\cos\theta / r\rho g$
Lens formula	$1/f = 1/v - 1/u$
Coulomb law	$F = kq_1 q_2 / r^2$
Capacitance	$C = Q/V$
Resistance	$R = \rho l/A$
Electric power	$P = VI$
Photoelectric equation	$hv = \varphi + KE$