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Class

9th

Unique Notes

(Federal Board)

According to SLO Based
Exam System of New Curriculum

PHYSICS

According to NEW NATIONAL CURRICULUM
for Session 2025-26

Subjective
&
Objective

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Chairman's Message

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Together, we work toward the ideal of **"Better Education, Better Pakistan"** — a mission that defines us, drives us, and keeps us striving for greater heights.

Abdul Manan Khurram
Chairman UGI

A Word of Thanks

It is a moment of immense pride and satisfaction for me to declare that this book is not merely a helping guide but a testament to the **Unique Group of Institutions' (UGI)** tenacious commitment to empowering students to perform at their very best. This edition stands as a reflection of the tireless efforts and unparalleled dedication of our esteemed teachers, whose professional expertise, subject mastery, and student-centered approach have truly brought this work to life.

The exceptional dexterity demonstrated by our educators in curating this edition reflects both their individual passion and professional commitment to their respective disciplines. Every effort has been made to ensure that the content is **accessible, comprehensive, and aligned with the desired learning objectives,** keeping in view the individual learning needs of students. Equal emphasis has been placed on formative and summative evaluations, ensuring that assessment and learning outcomes are both measurable and achievable.

This book has been meticulously designed with a focus on [illegible]ty, **brevity, and precision,** while its carefully curated content serves [illegible] *"knowledge booster"* for students. Undoubtedly, **Unique Notes** are [illegible] key to success, empowering students to excel academically and achi[illegible] dreams. I deeply appreciate the **untiring efforts** and profound commi[illegible] of our distinguished teachers who have worked diligently to make this [illegible] possible. Their contributions reflect the very essence of **exce[illegible]ce, innovation, and purpose-driven education** that UGI stands for.

Prof. Amjad Ali Khan
Rector UGI

Foreword

Unique Notes have been meticulously prepared in alignment with the recommendations of the **National Education Policy** and modern pedagogical requirements, ensuring that they meet the highest standards of contemporary education. The exercises included within this material are carefully designed to foster not only academic excellence but also the **mental, personal, and intellectual development** of students. Each section has been curated to ignite critical thinking, enhance problem-solving skills, and cultivate a deep understanding of the subjects.

We firmly believe that achieving the dream of **educational advancement** demands continuous effort, innovation, and an unwavering commitment to excellence. With this realization, we are indefatigable striving to create resources that empower learners and inspire educators. In this pursuit, we warmly invite **valuable opinions and constructive suggestions** from scholars, [illegible]eemed educators, students, parents, and all stakeholders in society. Your [illegible]back is a cornerstone of our progress and will enable us to continually [illegible] and evolve in our mission to deliver the finest educational resources.

Together, let us join our hands and unite our efforts to envision and [illegible] a stronger, smarter, and more enlightened future for our students and our [illegible] a future that shines as a beacon of progress, knowledge, excellence, [illegible]spiration for generations to come.

Prof. Muhammad Abdullah
Additional Director UGI


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CONTENTS

UNIT 01 Physical Quantities and Measurement

Q.1: Define Physics. Describe its revolutionary role in technology.

Ans. In Physics, we study matter, energy and their interaction. The laws and principles of Physics help us to understand nature.

Physics as Science: Physics is the most fundamental of all the sciences. In order to study biology, chemistry, or any other natural science, one should have a firm understanding of the principles of the blood flows through the heart, arteries, and veins. Chemistry relies on the physics of subatomic particles to understand why chemical reactions take place.

Physics and Technology: What are the technological devices that we use on a regular basis? Computers, smart phones, MP3 players, and internet come to our mind. What are technologies that you have only heard of? Rockets and space shuttles, magnetically levitating trains, and microscopic robots that fight cancer cells in our bodies. All of these technologies, whether common place or exciting, are based on the principles of physics.

Physics is behind every technology and plays a key role in further development of these technologies, such as airplanes, computers, PET scans and nuclear weapons.

Q.2: List different branches of Physics.

Ans. **Branches of Physics:** Physics is vast and is therefore further subdivided in many other branches. These branches of physics are increasing as the technology is progressing, however the major branches of physics include mechanics, optics, oscillation and waves, thermodynamic, electromagnetism, astrophysics, quantum physics, atomic physics and nuclear physics.

Physics has strong connection with mathematics, to understand the nature physics we use mathematics as a tool. Therefore learning physics requires mathematical knowledge.

Q.3: What are physical quantities? Distinguish between base physical quantities and derived physical quantities. Give at least three examples to show that derived physical quantities are derived from base physical quantities.

Ans. **Physical Quantities:** "Physical quantities are those quantities which can be measured whereas nonphysical quantities are those quantities which cannot be measured".

Quantities like length, mass, time, density, temperature, can be defined and measured, therefore they are termed physical quantities while taste, feeling and color cannot be measured so they are nonphysical quantities.

Measurement of a physical quantity consists of numerical magnitude (number representing the size of the quantity) and unit in which it is measured.

For example if the length of the person is 1.65 meters (5 feet and 5 inches), 1.65 is the numerical magnitude and meter is the unit.

To record a measurement, an appropriate unit is chosen and the size of quantity is then found with an instrument having a proper scale (like measuring tape).

The base quantities involved in force, pressure and power are "mass, length and time". The base quantities involved in charge are "current and time".

Base and Derived Physical Quantities:

Base (or fundamental) physical quantities (like mass, length and time) are selected as the simplest form of physical quantities, such that all other physical quantities can be derived from them. The physical quantities obtained by multiplying or dividing base physical quantities are termed as the derived physical quantities

Q.4: What do you mean by system of units of a physical quantities? Define base units and derived units.

Ans. System of Unit: A complete set of units for all physical quantities is called system of units.

The international system of units is termed as System International (abbreviated as S.I.), a short form of the French name 'System International Units, which mean International System of Units'.

In System International (S.I.) seven (07) physical quantities are chosen as base and their units are defined and standardized. These units are called base units. Each S.I. unit is defined carefully so that accurate and reproducible measurements can be made. The seven basic physical quantities, their S.I. base units and the symbols of S.I. units are given in the table 1.1.

TABLE 1.1
Base Units for International System of Units

Name	Symbol	Name	Symbol
length	ℓ	meter	m
mass	m	kilogram	Kg
time	t	second	s
electric current	I	ampere	A
temperature	T	kelvin	K
amount of substance	n	mole	mol
light intensity	L	candela	cd

Units of derived quantities are obtained by multiplying and/or dividing base quantities. In S.I. units all other physical quantities can be derived from the seven base units.

For example, the unit for area is 'm × m = m²', in this example base unit of length is used. Similarity the unit for velocity is 'm/s' and acceleration is 'm.s⁻²'. Some derived units are given special names and symbols. For example force has derived units of 'kg m/s² which is given special name as 'newton' and represented as 'N'. Some derived quantities with derived units in term of base units are given in table 1.2.

Table 1.2 Derived units For 'International System of Units'

Derived Quantity		S.I Derived Unit	
Area	A	Square meter	m^2
Volume	V	Cubic meter	m^3
Speed, velocity	v	Meter per second	ms^{-1}
Acceleration	a	Meter per second squared	ms^{-2}
Density	ρ	Kilogram per cubic meter	kgm^{-3}
Force	F	Newton (N)	$kgms^{-2}$
Pressure	P	Pascal (Pa)	$kgm^{-1}s^{-2}$
energy	E, U	Joule (J)	kgm^2s^{-2}

Q.5: What are prefixes? What is their use in measurements?

Ans. Prefixes: A mechanism through which numbers are expressed in power of ten that are given a proper name is called prefix. Prefixes make standard form or scientific notation further easier. Large numbers are simply written in more convenient prefix with units.

The thickness of a paper can be written conveniently in smaller units of millimeter instead of metres. Similarly the long distance between two cities may be expressed better in a bigger unit of distance, i.e., kilometer. Some prefixes in SI to replace powers of 10 are given in table. 1.3.

TABLE 1.3 PREFIXES

Prefix	Decimal Multiplier	Symbol	Prefix	Decimal Sub-multiplier	Symbol
Exa	10^{18}	E	deci	10^{-1}	d
Peta	10^{15}	P	centi	10^{-2}	c
Tera	10^{12}	T	milli	10^{-3}	m
Giga	10^{9}	G	micro	10^{-6}	µ
Mega	10^{6}	M	nano	10^{-9}	n
Kilo	10^{3}	k	pico	10^{-12}	p
hecto	10^{2}	h	femto	10^{-15}	f
deca	10^{1}	da	atto	10^{-18}	a

For example

a. The number of seconds in a day are:
$86400s = 8.64 \times 10^4 s = 86.4 \times 10^3 s = 86.4ks$.

b. The distance to the nearest start Alpha Contauri is:
$4.132 \times 10^{16} m = 41.32 \times 10^{15} m = 41.32\ Pm$

c. The thickness of the page of this book is about:
$4.0 \times 10^{-5} m = 0.04 \times 10^{-3} m = .04\ mm$

d. The mass of grain of salt is:
$1.0 \times 10^{-4} g = \frac{1}{10} \times \frac{1}{10^3} = 0.1 \times 10^{-3}\ g = 0.1\ mg$

Q.6: What is scientific notation or standard form of a measurement? Give at least five examples.

Ans. Scientific Notation: In physics we deal with numbers that are either very small or very large, for example, the width of the observable universe is approximately 880,000,000,000,000,000,000,000,000 metres (88 with 25 zeros). If we use this number often, it is not only time consuming but there are chances of reporting it wrong.

Scientific notation is an easy method of writing very large or small numbers in power of ten.

Therefore the width of the observable universe can scientifically be written compactly as 8.8×10^{26} metres, where '8.8' is the mantissa and '26' is the exponent. Similarly the mass of the earth is 5,980,000,000,000,000,000,000,000 kg which is written as 5.98×10^{24} kg and diameter of hydrogen nucleus is about 0.0000000000000017 metres, which is 1.7×10^{-15} m.

Q.7: Differentiate between scalars and vectors. Justify that distance, speed, mass and energy are scalars while displacement, velocity, acceleration and force are vectors.

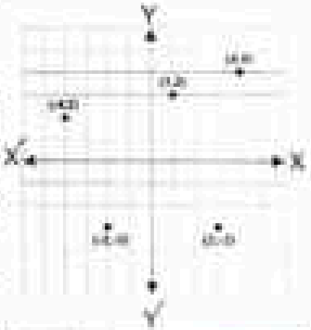
Ans. Scalar Quantities or Scalars: Physical quantities which can be completely described only by its numerical magnitude (or size) with proper unit are termed as scalar quantities or simply scalars. For examples distance, speed, time, mass, energy, and temperature etc. are scalar quantities.

Consider a man travels a distance of 4.5km but its direction is not specified but only this magnitude is given so it is said to be scalar quantity similarly we say that time is a scalar quantity, because when we say that time measurement is 30s, here '30' is the numerical magnitude and 's' is proper unit. We do not need to state the direction of time.

Scalar quantities can be added, subtracted and multiplied by using ordinary rules of algebra. For example if we took 5 s to reach the door of the classroom and another 20 s to reach the gate of school, the total time we took is (5s + 20s) 25 seconds.

Vector Quantities Or Vectors: Physical quantities which require not only numerical magnitude (or size) with proper unit, but also the direction are termed as vector quantities or simply vectors. Vector quantities, such as displacement, force, weight, velocity, acceleration, momentum, electric field strength, and gravitational field strength, require both numerical magnitude and direction. When we refer to a vector quantity, we not only mention its numerical magnitude and unit, but also its direction. To fully describe a vector, its direction must be specified.

Since vector quantities are associated with direction, they cannot be added, subtracted, or multiplied using the usual rules of algebra. They follow their own set of rules known as vector algebra.



Q.8: What is co-ordinate system? Explain.

Ans. Coordinate System: A coordinate system is used to locate the position of any point and that point can be plotted as an ordered pair (x, y) known as coordinates. The horizontal number line is called 'X-axis' and the vertical number line is called 'y-axis' and the point of intersection of these two axis frame is the coordinate system from which the positions of objects are described.

Steps to Represent a Vector in Coordinate System: The following method is used to represent a vector

1. Choose and draw a coordinate system.
2. Select a suitable scale.
3. Draw a line in the fixed direction. Cut the line equal to the magnitude of the vector according to the chosen scale.
4. Put an arrow along the direction of the vector.

FIGURE 1.1 HELICOPTER MOTION

For example the representation of helicopter as it moves to 20 km from origin towards 60° south of west is shown in the figure 1.1. Since displacement, force, weight, velocity, acceleration, momentum, electric field strength, and gravitational field strength are vector quantities or vectors. They will require to follow the rules of vector addition. This means that when we combine two vectors, the resulting value must also result as a vector.

Q.9: How a vector is represented graphically, Explain with an example.

Ans. Representation of a Vector: Symbolically a vector can be represented by a letter either capital or small. (e.g F and f or A and B) with an arrow over it.

Graphically a vector is represented by an arrow, the length of the arrow gives the magnitude with proper unit (under certain scale) and the arrow head points the direction of the vector. To use vectors we place them in coordinate axis.

Aero plane route from Islamabad to Karachi is shown as a vector

in figure. Here a Geographical Coordinate system having directions as North (N), East (E), West (W) and south (S) is used.

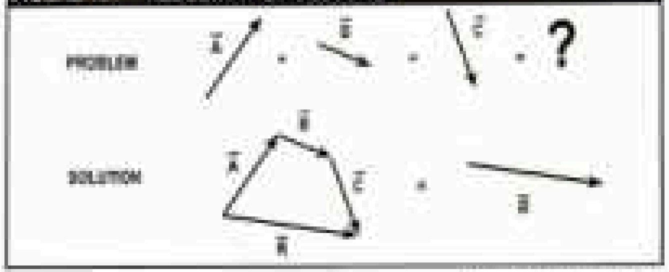
Q.10: What is meant by resultant vector? How vectors are added? Explain with the help of examples with diagrams.

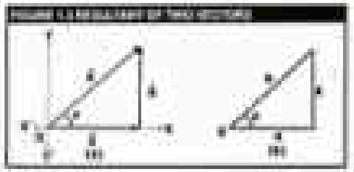
Ans. Resultant Vector: The process of combining two or more vectors into a single vector (called as resultant vector) to determine their cumulated effect is termed as vector addition. In vector algebra, the resultant vector cannot be simply obtained by adding vector values. Vectors may be added geometrically by drawing them to a common scale and placing them head to tail. Joining the tail of the first vector with the head of the last will give another vector which will be its resultant vector.

Examples:

(i) For example, the addition of three vectors is shown in figure 1.2.

FIGURE 1.2 RESULTANT OF VECTORS





(ii) Consider two vectors 'A' (along x-axis) and 'B' (along y-axis), which are perpendicular to each other. We can add the two vectors by placing vector 'B' on head of 'A', the resultant vector 'R' will be obtained by joining tail of vector 'A' with head of vector 'B' as shown in figure 1.3.

Q.11: Write a brief note on (i) Meter rule (ii) Measuring tape.

Ans. (i) Meter rule: We use ruler to draw margin lines on our notebooks. A meter rule is a physics laboratory tool, used to measure the length of objects. Meter rules are one meter long (as compared to standard meter). Meter rulers usually have 100 small divisions on them called millimeters. Such meter rulers have least count of 1mm.

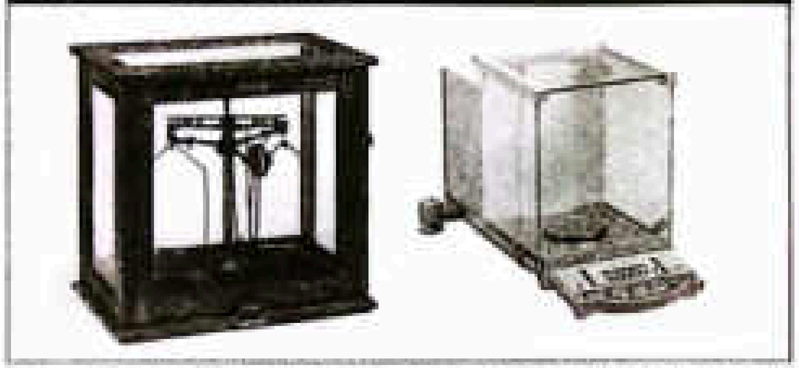
These instruments have similar scale on it as drawn on our rulers, principally rulers are shorter version of meter rule.

(ii) Measuring tape. A measuring tape is a flexible ruler used to measure larger distance or length. It consists of a ribbon of cloth, plastic, metal, or fiberglass with linear measurement markings on it. The tape is usually housed in a compact case, and it can be pulled out and locked in place to measure distance. The most common units of measurement on a measuring tape are inches and centimeters. Measuring tapes come in various lengths, typically ranging from a few feet to several meters.

Q.12: Write the brief note on Physical balance.

Ans. **Physical Balance:** The balance (also balance scale, beam balance and laboratory balance) was the first mass measuring instrument invented. A physical balance is a very sensitive common balance which can measure weights in milligram order. It consists of a vertical pillar having a horizontal beam, resting on knife edge with two pans. A long pointer is attached to the middle of the beam.

FIGURE 1.4 PHYSICAL BALANCE



Leveling screws are used to level the physical balance, while the pointer is set at the center of the scale by adjusting screws. It is placed in a protective glass case so that even dust and wind cannot affect the accuracy of the instrument. A weight box containing standard weights comes with the balance. The mass of body is found by placing the body in one pan, placing some standard weights in the other, and then calculating it from the standard weights placed and the resting point of the pointer.

Q.13: Differentiate between mechanical stop watch and digital stop watch.

Ans. The duration of specific interval of time is measured by a stop watch. Stop watch are of two main types i.e. mechanical stop watch and digital stop watch.

Mechanical/ Analogue Stop Watch:

It has two circular dials, a large circular dial in which a second hand of watch rotates and a small minute hand in which minute hand of watch rotates as shown in figure 1.14. The watch starts and stops by pressing the knob at top it, pressing it for some time will reset the watch back to zero.

Digital Stop Watch:

Digital stop watch is usually controlled by two buttons on the case as shown in the figure. Pressing the left button starts the timer and by pressing it again the time stops, thus the elapsed time is shown in the figure 1.5.

Pressing the right button resets the stopwatch to zero. The right button is also used to record split times or lap times.

FIGURE 1.5 MECHANICAL AND DIGITAL STOP WATCH

Generally the least count of analogue stop watch is 1 s and digital stop watch is 0.1 s

Q.14: Describe construction and working of Vernier callipers in detail.

Ans. **Vernier callipers:** In physics sometimes we need to measure a length smaller than 1mm. A Vernier caliper can help take smaller than a millimeter reading.

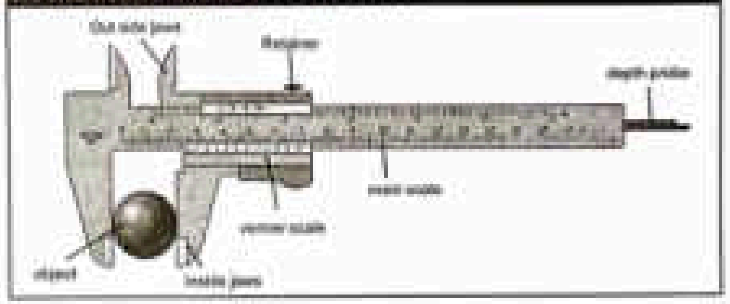
'Vernier caliper is a device used to measure a fraction of a smallest division on scale by sliding another scale over it'.

Construction: There are two scales on Vernier calipers. A main scale which has marking of usually of 1mm each and it contains jaw on its left end.

A sliding scale called Vernier scale which has marking of some multiple of the marking on the main scale.

$$\text{Least Count} = \frac{\text{Smallest division on main scale}}{\text{Total number of divisions on vernier scale}}$$

FIGURE 1.6 VERNIER CALLIPER DIAGRAM



If the smallest main scale division is 1mm and Vernier scale has 10 divisions, then the least count of Vernier caliper is:

$$\text{Least count} = \frac{1\text{mm}}{10} = 0.1\text{mm}$$

On closing the jaws of the Vernier calipers, the zero of the Vernier scale should coincide with the zero of the main scale. If their zeros do not coincide, there is an error in the instrument, called zero error. The zero error can be corrected which you will learn in laboratory work.

Taking Measurement With Vernier Calipers: If we want to measure the diameter of an object (e.g. a small sphere) with Vernier caliper, the following steps can be followed.

i. Note the least count of the Vernier, (it is usually written on Vernier caliper, or we can find it by method already learned). Determine and correct zero error if any.

ii. Fix the small sphere in the jaws and note the complete divisions of main scale past by the zero of Vernier scale. This is main scale reading as shown in figure 1.6.

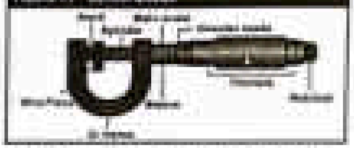
iii. Look for the division of Vernier scale that is coinciding with any division on main scale. This is Vernier scale reading.

iv. Multiply the Vernier scale reading with least count which is the fraction to be added with main scale reading. This fraction will be smaller than the main scale least count, thus Vernier caliper measure the reading to the part of millimeter.

Digital Vernier Caliper: Digital Vernier Calipers has greater precision than mechanical Vernier Calipers. Least count of Digital Vernier Calipers is 0.01 mm.

Q.15: What is screw gauge? What is its pitch and least count? How is it used to measure thickness of thin copper wire?

FIGURE 1.7 SCREW GAUGE



Ans. Screw gauge: Screw gauge is also length measuring device and is used for measurements even smaller than Vernier calipers. 'Screw Gauge is a device used to measure a fraction of a smallest division on scale by rotating circular scale over it'.

The distance traveled by the circular scale on linear (or main) scale in one rotation is called the pitch of the screw gauge.

The minimum length which can be measured accurately by a screw gauge is called least count of the screw gauge. The least count of screw gauge is found by dividing its pitch by the number of circular scale divisions.

$$\text{Least Count} = \frac{\text{Pitch of Screw Gauge}}{\text{Total Number of Divisions on circular Scale}}$$

If the pitch of the screw gauge is 0.5 mm and the number of divisions on circular scale is 50 then:

$$\text{Least Count} = \frac{0.5\,\text{mm}}{50} = 0.01\ \text{mm}$$

Zero Error in Screw gauge: Turn the thimble until the anvil and spindle meet, datum line of the linear scale must meet with the zero on the thimble scale. If the zero mark on the thimble scale (or circular scale) does not lie directly opposite the datum line of the main scale we say that there is zero error. The zero error and its correction will be discussed in laboratory work.

Taking Measurement with Screw Gauge:

If we want to measure the diameter of an object (e.g. a wire piece) with screw gauge, the following steps can be followed:

i. Note the pitch and least count of the screw gauge and determine the zero error (if any).

ii. Place the object (e.g. a wire piece) between with spindle and anvil. Now gently close the gap between the spindle and the anvil by turning the ratchet.

iii. Turn the ratchet until it starts to click. The ratchet prevents the user from exerting too much pressure on the object.

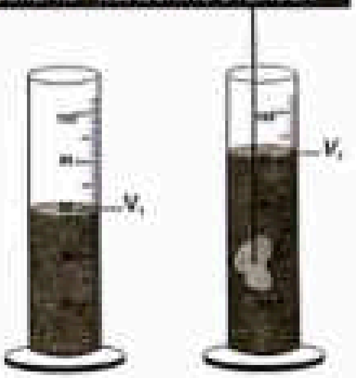
iv. Read the main scale reading, which is the reading shown (or unblocked) by circular scale as shown in figure 1.7.

v. Identify the line of circular scale aligned with datum line, now multiply the least count of screw gauge by this number. This is circular scale reading.

vi. Add linear (or main) scale reading and circular scale reading, which gives the total reading.

Q.16: Justify and illustrate the use of a measuring cylinder to measure the volume of a liquid. (OR) Write a brief note on Measuring cylinder.

FIGURE 1.8 MEASURING CYLINDER



Ans. Measuring Cylinder: A measuring cylinder is a tool used in laboratories to measure the volume of liquids, chemicals, or solutions. It is also known as a graduated cylinder. Measuring cylinders are typically made of transparent plastic or glass and have a vertical scale in milliliters (ml) or cubic centimeters $(cm)^3$. The volume of a liquid can be determined by measuring the height of the liquid in the cylinder. The least count of a measuring cylinder is usually 1 cm^3, meaning that any volume change smaller than this cannot be measured. Measuring cylinders come in various sizes, ranging from small capacities of a few milliliters to larger capacities of several liters. The choice of cylinder size depends on the volume of the liquid being measured.

Q.17: Define Error. Differentiate between random and systematic error. How can these errors be reduced?

Ans. Error: Every measurement, no matter how careful, has a certain amount of doubt known as error. Error is simply the uncertainty that arises during measurement. This means that all measurements are only approximate due to the presence of errors.

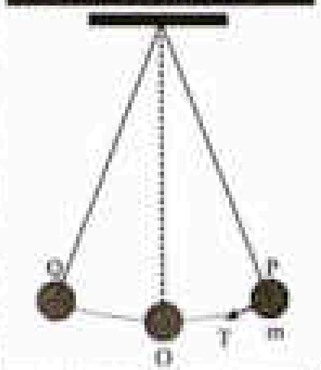
There are two main types of errors in measurement: systematic errors and random errors.

Systematic Errors: Systematic errors tend to occur consistently in one direction, either positive or negative. Some sources of systematic errors include:

(a) Instrumental errors, which result from imperfections in the design or calibration of the measuring instrument, as well as zero errors.

(b) Imperfections in the experimental technique or procedure, such as changes in external conditions like temperature, humidity, or wind velocity, which can systematically affect the measurement.

FIGURE 1.9 PENDULUM



(c) Personal errors, which arise from an individual's bias, improper setup of the apparatus, or carelessness in taking observations without following proper precautions.

Systematic errors can be reduced by improving experimental techniques, choosing better instruments, and minimizing personal bias as much as possible. These errors can be estimated to some extent for a given setup, and the necessary adjustments can be made to the measurements.

Random Errors: Random errors are unpredictable and uncontrollable errors that can happen irregularly. These errors can be caused by fluctuations in experimental conditions or imperfections in measuring instruments. The person conducting the measurements can also introduce variability due to factors like reaction time or technique. Because of this, if the same person repeats an observation multiple times, they are likely to get different readings each time. To minimize random errors, it is important to take repeated measurements and use statistical analysis to account for the variability.

For example: During measurements, it is always a good idea to take multiple of the same measurement and find the mean, as it reduces errors. A simple pendulum is simply a mass that swings back and forth about a fixed point as shown in figure 1.9. One single oscillation of a pendulum is when it swings back to the exact same position and achieves the same state of motion that it started at. For example, if the pendulum started swinging from its right most point (from its position of maximum amplitude), the mass would have to swing towards the left and then come back all the way to the right to complete one oscillation. **The time taken to complete a single oscillation is called a period.** To measure the period of a pendulum, you usually measure the time taken for ten oscillations and then calculate the mean.

That is, you divide the total length of time by 10, to get the period of one oscillation. This will reduce the error in measurement as human reflexes are usually too slow to be completely accurate, and that inaccuracy can have a major impact on something as small as a period.

Q.18: Differentiate between precision and accuracy.

Ans. **Precision And Accuracy:** Precision and accuracy are both important factors in determining the reliability and validity of measurements and experimental results. Precision focuses on the consistency and repeatability of results; accuracy is concerned with how close the measured values are to the true or accepted values.

Precision can be thought of as the degree of agreement between repeated measurements of the same quantity. If a set of measurements consistently yields similar results, with little variation of scatter, then it is considered to be precise. This indicates that the measurement process is reliable and consistent, and that the results can be reproduced under the same conditions. For example, a scale that always gives the same weight within a margin of 0.1 kg is precise, even if it consistently overestimates the true weight by 0.5 kg (not accurate).

Accuracy, on the other hand, refers to how close a measured value is to the true or accepted value. It is a measure of the absence of systematic errors or biases in the measurement process. An accurate measurement is one that is close to the true value, regardless of whether it is consistently reproducible. For example, thermometer that consistently reads 2 degrees Celsius Higher than the actual temperature is not accurate, even if its readings are very precise (always 2 degrees above).

Precision focuses on the consistency and reproducibility of measurements, while accuracy assesses how close the average of those measurements is to the true value.

Imagine throwing darts at a target as shown in figure 1.10. If your darts land close to the center of the target (hitting the bullseye is ideal) your aim will be referred as accurate. Your darts are grouped tightly together, even if they're not in the center (a tight cluster off-center) your aim will be termed as precise, therefore, it's possible for something to be:

Accurate and precise: Your darts hit the bullseye and are tightly grouped.

Accurate but not precise: Your darts land near the center, but they're scattered all over the place.

Precise but not accurate: Your darts are tightly grouped, but they're all off-center in the same direction.

In practice, both precision and accuracy are desirable qualities in measurements. A measurement can be precise but not accurate, or accurate but not precise. Ideally, measurements should be both precise and accurate, meaning that they are both consistent and

close to the true value. Achieving both precision and accuracy often requires careful calibration of instruments, control of experimental conditions, and consideration of sources of error.

FIGURE 1.10 PRECISION AND ACCURACY

Q.19: Define significant figures in measurement. Explain four general rules for writing significant figures with the help of supporting explains.

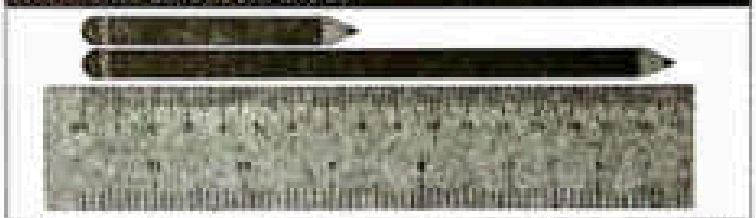
Ans. **Significant Figures:** There are two types of values, exact and measured. Exact values are those that are counted clearly. For example while reporting 3 pencils or 2 books, we can indicate the exact number of these items.

The numerical value of any measurement will always contain some uncertainty. Suppose, for example, that you are measuring the length of two pencils as shown in figure 1.11.

It seems clear that the length of blue pencil is greater than 17 cm but shorter than 17.1 cm, similarly the length of red pencil is greater than 8 cm but shorter than 8.1 cm. But how much longer or shorter? You cannot be certain about the length. As your best estimate, you might say that the pencils are 17.05 cm and 8.05 cm long.

Everyone would agree that you can be certain about the first numbers 17.0 and 8.0 for blue and red pencils respectively. The last number 0.05 has been estimated and is not certain. The two certain numbers, together with one uncertain number, represent the greatest accuracy possible with the ruler being used. Thus the pencils are said to be 17.05 cm and 8.05 cm wide respectively. A significant figure is a number that is believed to be correct with some uncertainty only in the last digit. **'All the accurately known figures and the first doubtful figure are termed as significant figures'.**

FIGURE 1.11 LENGTH OF PENCILS



General Rules for Writing Significant Figures: There are a few simple rules that help us determine how many significant figures are contained in a reported measurement:

1. All digits reported as a direct result of a measurement are significant.

2. The reported NONZERO digits (all digits from 4 to 9) are always significant. For example the number of significant figures in 23.457 is 5.

3. In figures reported as larger than the digit 1, the digit 0 is not significant when it follows a nonzero digit to indicate place. For example, in a report that '29,000 spectators watched a

cricket match'. The digits 2 and 9 are significant but the zeros are not significant. In this situation, the 29 is the measured part of the figure, and the three zeros tell you an estimate of how many watched the match. If this figure is a measurement rather than an estimate, then to avoid confusion it is written in scientific notation with exact number of significant figures as in measurement e.g 2.90×10^4 showing three significant figures or 2.900×10^4 showing four significant figures or even 2.9000×10^4 showing 5 significant figures.

4. In figures reported as smaller than the digit 1, zeros after a decimal point that come before nonzero digits are not significant and serve only as place holders. For example, 0.0029 has two significant figures: 2 and 9. The zeros after a nonzero digit indicate a measurement, so these zeros are significant. The figure 0.00290, for example, has three significant figures.)

Q.20: Explain rounding off numbers in scientific measurement.

Ans. **Rounding off Numbers:** Rounding off numbers is an essential practice in scientific and quantitative contexts as it allows for the presentation of numbers with the appropriate level of precision. In these fields, accuracy and precision are crucial, and rounding off numbers helps to achieve this.

When dealing with measurements or calculations, it is often necessary to express the result in a more manageable or meaningful form. Rounding off numbers allows scientists and researchers to simplify complex figures without sacrificing the overall accuracy of the data.

Significant figures play a vital role in determining which digits in a number are reliable and meaningful. They indicate the precision of a measurement or calculation by identifying the digits that are known with certainty. By using significant figures, scientists can convey the level of uncertainty associated with a particular value. For example, consider a scientific experiment that measures the length of an object to be 3.5678 centimeters. While this measurement may be precise, it is not practical to report it with such detail. Rounding off the number to three significant figures, we can express it as 3.57 centimeters, which provides a more concise representation without compromising the accuracy of the measurement.

Rounding numbers is the act of approximating a number to a simpler value that is easier to use, understand, or work with. It includes reducing the number of digits while maintaining an appropriate level of accuracy for the situation.

(A) Rounding rules for whole numbers: When rounding to a specific whole number of significant figures, we follow these steps: 1. Always choose the smaller place value for an accurate final result. Find the next smaller place to the right of the number being rounded off. For example, if rounding off a digit from the tens place, look at the digit in the ones place. 2. If the digit in the smallest place is less than 5, leave it as it is. Any digit after that become zero, which is called rounding down, 3.If the digit in the smallest place is greater than or equal to 5, add +1 to that digit. Any digit after that become zero, which is called rounding up.

(B) Rounding rules for decimal numbers: The rules for rounding decimal numbers are as follows:

1. Find the digit you want to round and look at the digit to its right.
2. If the digits to the right are less than 5, treat them as zero. 3. If the digits to the right are 5 or greater, add 1 to that digit and treat all other digits as zero.

SHORTRESPONSE QUESTIONS

Q.1: How physics plays an important role in our life?

Ans. In Physics, we study matter, energy and their interaction. The laws and principles of Physics help us to understand nature.

Physics is Science: Physics is the most fundamental of all the sciences. In order to study biology, chemistry, or any other natural science, one should have a firm understanding of the principles of the blood flows through the heart, arteries, and veins. Chemistry relies on the physics of subatomic particles to understand why chemical reactions take place.

Physics and Technology: What are the technological devices that we use on a regular basis? Computers, smart phones, MP3 players, and internet come to our mind. What are technologies that you have only heard of? Rockets and space shuttles, magnetically levitating trains, and microscopic robots that fight cancer cells in our bodies. All of these technologies, whether common place or exciting, are based on the principles of physics.

Physics is behind every technology and plays a key role in further development of these technologies, such as airplanes, computers, PET scans and nuclear weapons.

Q.2: Estimate your age in minutes and seconds.

Ans. Age in years = 14. (suppose) Age in Months = 14×12

Age in days $14 \times 12 \times 30$ Age in hrs = $14 \times 12 \times 30 \times 24$

Age in minutes = $14 \times 12 \times 30 \times 60$

Age in seconds = $14 \times 12 \times 30 \times 60 \times 60 = 435456000$ seconds.

Q.3: What base quantities are involved in these derived physical quantities; force, pressure, power and charge.

Ans. The base quantities involved in force, pressure and power are "mass, length and time". The base quantities involved in charge are "current and time".

For force: $F = \text{mass} \times \text{acceleration} = \text{mass} \times \dfrac{\text{velocity}}{\text{time}} = \text{mass} \times \dfrac{\text{displacement}}{\text{time} \times \text{time}}$

For Pressure:

$$P = \frac{\text{Force}}{\text{Area}} = \text{mass} \times \text{acceleration} \times \frac{1}{(\text{length})^2} = \text{mass} \times \frac{\text{velocity}}{\text{time}} \times \frac{1}{(\text{length})^2}$$

$$P = \text{mass} \times \frac{\text{displacement(length)}}{\text{time} \times \text{time}} \times \frac{1}{(\text{length})^2} = \frac{\text{mass}}{\text{time} \times \text{time}} \times \frac{1}{(\text{length})}$$

For power:

$$P = \frac{\text{work}}{\text{time}} = \frac{\text{Force} \times \text{length}}{\text{time}} = \frac{\text{mass} \times \text{acceleration} \times \text{length}}{\text{time}} = \text{mass} \quad \frac{\text{velocity} \times \text{length}}{\text{time} \times \text{time}}$$

$$P = \text{mass} \times \frac{\text{length} \times \text{length}}{\text{time} \times \text{time} \times \text{time}}$$

For Charge: Charge (Q) = current × time

Q.4: Show that prefix micro is thousand times smaller than prefix milli.

Ans. The prefix milli (10^{-3}) is thousand times greater than prefix micro (10^{-6}).

Calculation: comparing both the prefixes:

$$\frac{\text{milli}}{\text{micro}} = \frac{10^{-3}}{10^{-6}} = 10^3$$

As $10^3 = 1000$, putting in above:

$$\frac{\text{milli}}{\text{micro}} = 1000 \quad \text{or} \quad \text{milli} = 1000 \text{ micro}$$

Hence, milli is 1000 times of micro i.e., the prefix milli is thousand times greater than the prefix micro.

Q.5: Justify that displacement is a vector quantity while energy is a scalar quantity.

Ans. Displacement shows direction from initial position to final position so, it is vector and the energy is simply amount of work done which is scalar quantity.

Q.6: Screw gauge can give more precise length than Vernier calipers. Briefly explain why?

Ans. Screw gauge can give more precise length than Vernier calipers because of the smaller least count of screw gauge.

Explanation: Smaller the least count of an instrument, more precise will be its reading. A typical screw gauge has a least count of 0.01 mm or 0.001 cm while a typical Vernier calipers has a least count of 0.1 mm or 0.01 cm. As least count of screw gauge is about 10 times more precise reading of length than Vernier Calipers.

Q.7: Differentiate between mechanical stop watch and digital stop watch.

Ans. Discussed in long question 13.

Q.8: How measuring cylinder is used to measure volume of an irregular shaped stone?

Ans. Water is poured into a measuring cylinder until the cylinder is about half full and its volume is measured. Now an irregular shaped stone is lowered in the measuring cylinder. This will increase the volume of water a little. Read the reading of cylinder once again. Subtract the first value of volume (without stone) from that of second value (with stone) as:

Volume of pebble = Volume of water (with pebble) – Volume of water (without pebble)

The resultant value will be volume of the irregular shaped stone.

Q.9: What precaution should be kept in mind while taking measurement using measuring cylinder?

Ans. The following precautions should be kept in mind while taking measurement using a measuring cylinder:

i. The measuring cylinder should be placed on a flat surface so that upper surface of water in the cylinder shows same level.

ii. The volume of the liquid should be read or the cylinder should be graduated from the base of the meniscus.

Q.10: Why do we need to consider significant digits in measurements?

Ans. Significant figures are often used for measurements. They are a way to describe how accurate measurements are.

Explanation: Significant digits are defined as the accurately known digits and the first doubtful digit in any measurement. For example, let's imagine you had two scales, one that was accurate to the nearest gram and another that was accurate to the nearest one hundredth of a gram. If they both had a measurement of 3 grams, this number would mean different things. The first measurement you would record as just 3 grams, because you only know that the measurement is accurate to 1 gram. The second measurement you could record as 3.00 grams. This says that the measurement was accurate to the hundredths place. These extra significant figures help to record how accurate the measurement was.

Q.11: How random error can be reduced?

Ans. To minimize random errors, it is important to take repeated measurements and use statistical analysis to account for the variability.

During measurements, it is always a good idea to take multiple of the same measurement and find the mean, as it reduces errors. A simple pendulum is simply a mass that swings back and forth about a fixed point. One single oscillation of a pendulum is when it swings back to the exact same position and achieves the same state of motion that it started at. For example, if the pendulum started swinging from its right most point (from its position of maximum amplitude), the mass would have to swing towards the left and then come back all the way to

the right to complete one oscillation. The time taken to complete a single oscillation is called a period. To measure the period of a pendulum, you usually measure the time taken for ten oscillations and then calculate the mean.

That is, you divide the total length of time by 10, to get the period of one oscillation. This will reduce the error in measurement as human reflexes are usually too slow to be completely accurate, and that inaccuracy can have a major impact on something as small as a period.

Q.12: Differentiate between precision and accuracy.

Ans. Precision can be thought of as the degree of agreement between repeated measurements of the same quantity. If a set of measurements consistently yields similar results, with little variation of scatter, then it is considered to be precise. This indicates that the measurement process is reliable and consistent, and that the results can be reproduced under the same conditions. For example, a scale that always gives the same weight within a margin of 0.1 kg is precise, even if it consistently overestimates the true weight by 0.5 kg (not accurate).

Accuracy, on the other hand, refers to how close a measured value is to the true or accepted value. It is a measure of the absence of systematic errors or biases in the measurement process. An accurate measurement is one that is close to the true value, regardless of whether it is consistently reproducible. For example, thermometer that consistently reads 2 degrees Celsius Higher than the actual temperature is not accurate, even if its readings are very precise (always 2 degrees above).

Precision focuses on the consistency and reproducibility of measurements, while accuracy assesses how close the average of those measurements is to the true value.

Multiple Choice Questions

1. **which one of the following unit is not a derived unit?**
   (a) Pascal (b) kilogram (c) newton (d) watt
2. **Amount of a substance in terms of numbers is measured in:**
   (a) gram (b) kilogram (c) newton (d) mole
3. **The number of significant figures in 0.00650s are:**
   (a) 2 (b) 3 (c) 5 (d) 6
4. **Which of the following numbers show 4 significant digits?**
   (a) 9000.8 (b) 4 (c) 5174.00 (d) 0.001248
5. **Which of following prefix represents largest value?**
   (a) mega (b) pico (c) peta (d) kilo
6. **Micro meter can be used to measure:**
   (a) current (b) force (c) length (d) mass
7. **The instrument best measures the internal diameter of a pipe is:**
   (a) screw gauge (b) vernier caliper (c) metre rule (d) measuring tape
8. **Least count of screw gauge is 0.01 mm. If main scale reading of screw gauge is zero and third line of its circular scale coincides with datum line then the measurement on the screw gauge is:**
   (a) 0 mm (b) 3 mm (c) 0.03 mm (d) 0.3 mm
9. **9.483×10^{3} m is the standard form of**
   (a) 94.83 m (b) 9.483 m (c) 948.3 m (d) 9483 m
10. **Which of the following is a base unit?**
    (a) Pascal (b) coulomb (c) meter per second (d) mole
11. **The numbers having one significant digit is:**
    (a) 1.1 (b) 6.0 (c) 7.1 (d) 6×10^{2}

12. Ratio of millimeter to micrometer is:
(a) 1000 m (b) 0.001 meter (c) 1000 (d) 0.001

13. 0.2 mm in units of meters is:
(a) 0.0002 m (b) 2×10^{4} m (c) both (a) and (b) (d) none

Answers

1	b	2	d	3	b	4	d
5	c	6	c	7	b	8	c
9	d	10	d	11	d	12	c
13	a						

Examples

Example. 1.1: Convert the following numbers in Standard form/scientific notation.

(a) 149,530,000,000 m which is the average distance between earth and Sun.
(b) 0.0008 g which is the average mass of human hair.
(c) The number of seconds in a day.

Solution:

(a) For Standard form / scientific notation we can write the term as:

Distance = 149530000000.0

For Standard from / scientific notation, in order to get mantissa (M), we have to move the decimal 11 digits towards left. Therefore, the power of 10 will be Positive 11, That is

Distance = 1.4953×10^{11} m Ans.

Which is the average distance between earth and sun in standard from / scientific notation **(b)** In Standard form / scientific notation we can write the term as

Mass of hair = 8×10^{-4} g Ans.

(c) We know that there are 24 hours in a day, 60 minutes in an hour, and 60 s in a minute. These three relationships are conversion factors. As

1 d = 86,400 s.

For Standard form / scientific notation we can write the term as:

1 d = $86{,}400.0 \times 10^{0}$ s = 8.64×10^{4} s.

Example. 1.2: Prefixes

Write the numbers in a standard/Scientific notation and also represent using appropriate prefix.
(a) One ton of rice in gram (b) The diameter of neutron is 0.0000000000000018 m.

Solution:

(a) One ton is equal to a mass of 1000 kilograms
1 ton = 1000 kg
As we know that: 1 kg = 1000g, therefore 1 ton = 1000 × 1000 g
1 ton = 1,000,000 g = $1{,}000{,}000.0 \times 10^{0}$ g
In scientific form: For Standard form /scientific notation in order to get mantissa (M), we have to move the decimal 6 digits towards left.
Therefore, the power of 10 will be positive 6, given by:

1 ton = 1.0×10^{6} g Ans.

Using Prefix: As 10^{6} = Mega, therefore.

1 ton = 1.0 Mg Ans.

(b) The diameter of proton is 0.0000000000000017 m, which can be written as

Diameter of proton = $0.0000000000000018 \times 10^{0}$ m.
Diameter of proton = 1.7×10^{-15} m Ans.

Using Prefix: 10^{-15} = femto, therefore

Diameter of Proton = 1.7 fm Ans.

Example. 1.3: Significant Figure

Find the number of significant figures in each of the following values. Also express them in scientific notations.
(a) 100.8 s (b) 0.00580 km (c) 210.0 g

Solution:

(a) All the four digits are significant. The zeros between the two significant figures 1 and 8 are significant. To write the quantity in scientific notation, we move the decimal point two places to the left, thus

100.8 s = 1.008×10^{2} s

(b) The first two zeros are not significant. They are used to space the decimal point. The digit 5, 8 and the final zero are significant. Thus there are three significant figures. In scientific notation, it can be written as

5.80×10^{-3} km.

(c) The final zero is significant it comes after the decimal point. The zero between last zero and 12 is also significant because it comes between the significant figures. Thus the number of significant figures in this case is four. In scientific notation, it can be written as

210.0 g = 2.100×10^{2} g

Example 1.4: Rounding Off

Round off the following numbers to:

(a) Two decimal points
(i) 3.876 (ii) 657.873 (iii) 0.0857

(b) Three significant digits
(i) 24.68 (ii) 0.07683 (iii) 7.847

Solution:

(a) In order to round off a number to two decimal points, we will drop all digits after the decimal except two.

(i) **3.876:** Here the dropping digit is 6, which is greater than 5, so, it will be dropped by increasing the next digit 7. So, the answer is 3.88.

(ii) **657.873:** Here the dropping digit is 3, which is smaller than 5, so, it will be dropped without any change to the next digit. So, the answer is 657.87.

(iii) **0.0857:** Here the dropping digits are 5 and 7. After dropping 7 (which is greater than 5), the next digit will become 6 to get 0.086. Now by dropping 6, the next digit will become 9. So, the answer is 0.09.

(b) In order to round off a number to three significant digits, we will drop or replace with zero all digits except three significant digits.

(i) **24.68:** Here we will drop the digit 3, which is smaller than 5, so it will increase the next digit to 7. So, the answer is 24.7.

(ii) **0.07683:** Here we will drop the digit 3, which is smaller than 5, so it will not change the next digit. So, the answer is 0.0768.

(iii) **7,847:** As this is a whole number so, the digit 7 is replaced by zero. As it is greater than 5, so it will increase the next digit to 5. So, the answer is 7,850.

Numerical Problems

Q.1: Write the following numbers in scientific notations.

a. 1234 m **b. 0.000023 s** **c. 469.3×10^{5} m** **d. 0.00985×10^{7} s**

Ans. **(a)** The decimal should be in between 1 and 2. So, we have to move 3 steps towards left that's why the power will be positive 3. The result will be:

$$1234\ m = 1.234\times10^{3}\ m \qquad \text{Ans.}$$

(b) The decimal should be in between 2 and 3. So, we have to move 5 steps towards right that's why the power will be negative 5. The result will be:

$$0.000023\ s = 2.3\times10^{-5}\ s \qquad \text{Ans.}$$

(c) The decimal should be in between 4 and 6. So, we have to move 2 steps towards left that's why the power will be positive 2. As the number has already a power of 5,2 will be added. The result will be:

$$469.3\times10^{5}\ m = 4.693\times10^{7}\ m \qquad \text{Ans.}$$

(d) The decimal should be in between 9 and 8. So, we have to move 3 steps towards right that's why the power will be negative 3. As the number has already a power of 7, -3 will be added. The result will be:

$$0.0098\times10^{7} s = 9.85\times10^{4}\ s \qquad \text{Ans.}$$

Q.2: Express the followings measurements using prefixes

a. 27.5×10^{-10} m **b. 0.00023×10^{-2} s**

Ans. We will convert the number first to scientific notation. For this, we have to move the decimal to bring it in between 2 and 7.

$$27.5\times10^{-10}\ m = 2.75\times10^{1}\times10^{-10}\ m = 2.75\times10^{-9}\ m$$

As 10^{-9} is equal to nano, so: $\quad 27.5\times10^{-10}\ m = 2.75\ nm \qquad$ Ans.

(b) We will convert the number first to scientific notation. For this, we have to move the decimal to bring it in between 2 and 3.

$$0.00023\times10^{-2}\ s = 2.3\times10^{-4}\times10^{-2}\ s = 2.3\times10^{-6}\ s$$

As 10^{-6} is equal to micro, so: $0.00023\times10^{-2}\ m = 2.3\mu m \qquad$ Ans.

Q.3: If a boy has age of 15 years 2 months and 10 days, convert his age in

a. seconds **b. milli seconds** **c. mega seconds**

Ans. First we will find boy's age in days.

Days in 15 years = 15×365.25 = 5478.75 days

Days in 2 months = 2×30 = 60 days

Days in 10 days = 1×10 = 10 days.

Boy's age in days = 5548.75 days.

(a) As there are 24 hours in a day and 3600 seconds in an hour, so the age in seconds will be:

$$5548.75\times24\times3600\ s = 4.79412\times10^{8}\ s \qquad \text{Ans.}$$

(b)As there are 1000 or 10^{3} milliseconds in a second, so the age in milliseconds will be:

$$4.79412\times10^{8}\times10^{0}\ s = 4.79412\times10^{8}\times10^{3}\ ms = 4.79412\times10^{11}\ ms. \qquad \text{Ans.}$$

(c)As there are 1000,000 or 10^{6} seconds in a mega seconds, so the age in mega seconds will be:

$$4.79412\times10^{8}\ s = 4.79412\times10^{8}\ s\times10^{-6}\ ms = 4.79412\times10^{2}\ Ms. \qquad \text{Ans.}$$

Q.4: How many kilometers are there in 25 micrometers?

Ans. As there are 10^{3} meters in a kilometer and 10^{-6} meters in a micrometer, so the result will be given by:

$$25\mu m = 25\times10^{-6}\ m = 25\times10^{-6}\times10^{-3}\ km.$$

$$25\mu m = 25\times10^{-9}\ km = 2.5\times10^{-8}\ km \qquad \text{Ans.}$$

Q.5: What is pitch and least count of:

a) Vernier calipers if smallest division on main scale is 1mm and total division on Vernier scale are 20.

b) Screw gauge if smallest division on its main scale is 0.5 mm and its movable scale has 50 divisions.

Solution:

(a) Vernier calipers if smallest division on main scale is 1mm and total divisions on Vernier scale are 20.

(b) Screw gauge if smallest division on its main scale is 0.5 mm and its movable scale has 50 division.

Solution:

(a) The least count of Vernier calipers is given by:

$$\text{Least Count} = \frac{\text{Smallest dividion on main scale}}{\text{Number of divisionsons on vernier scale}}$$

Putting values:

$$\text{Least count} = \frac{1mm}{20} = 0.05\ mm = 0.005\ cm \qquad \text{Ans.}$$

(b) The least count of screw gauge is given by:

$$\text{Least Count} = \frac{\text{Pitch of the screw}}{\text{Nuber of divisions on circular scale}}$$

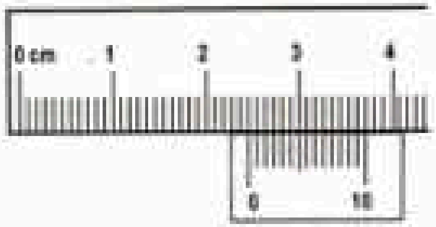
Putting Values: $\quad \text{Least Count} = \frac{0.5\,mm}{50}\ 0.01\ mm = 0.001\ cm \qquad$ Ans.

Q.6: Look at the measurement of Vernier Calipers:

a. What is its main scale reading?

b. What is its coinciding division on Vernier scale?

c. Calculate total reading on the Vernier calipers?



Ans. (a) The main scale reading (reading to which zero of Vernier scale coincides) is 2.5 cm.

(b) The coinciding division on Vernier scale is 8th division.

(c) The total reading will become:

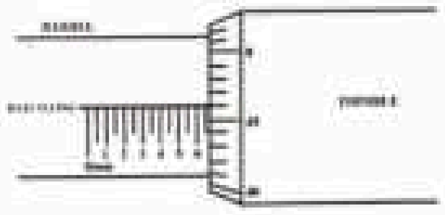
$$2.5 + 8(0.01)\ cm = 2.5 + 0.08\ cm = 2.58\ cm.$$

Q.7: Look at the figure of screw gauge, let a small steel ball is place between its thimble and anvil then:

a. What is its main scale reading?

b. What is coinciding division of circular scale?

c. Calculate the total diameter of the ball?



Ans. (a) The main scale reading (reading which is visible) is 6.5 mm.

(b) The coinciding division on circular scale is 46th division.

(c) The total reading will become.

$$6.5 + 46\ (0.01)\ mm = 6.5 + 0.46\ mm = 6.96\ mm.$$

Unit 02 Kinematics

Q. [illegible] rest and motion [illegible]

Ans. Rest and motion: [illegible]

[illegible]

Q. What are different types of motion? Define each type of motion with examples from daily life.

Ans. Different Types of Motion: [illegible] These different types of motion can be broadly categorized in three types:

(i) Translatory motion

(ii) Rotatory motion

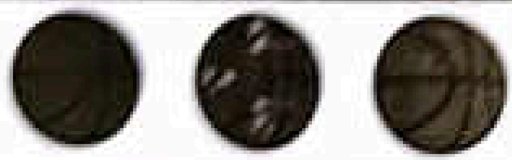
(iii) Vibratory motion

(i) Translatory motion: If all points of a moving object move uniformly in the same direction such that there is no change in the object's orientation, then the object is said to be undergoing translatory motion (also termed as translational motion).

Example

A basketball is shown in figure 2.1 as an example of translatory motion. All the three points 'A', 'B' and 'C' move parallel to each other and there is no change in its orientation relative to a fixed point.

FIGURE 2.1 TRANSLATORY MOTION OF BASKETBALL



(ii) Rotatory motion: When an object rotates on its own axis (a line passing through the object), the object is said to be undergoing rotatory motion (also termed as rotational motion).

Example:

A basketball shown in the figure 2.2 is shown as illustration of rotational motion.

FIGURE 2.2 ROTATORY MOTION OF BASKETBALL

(iii) Vibratory motion: When an object is moving forward and backward repeatedly about mean position (certain fixed position), the object is said to be undergoing vibratory motion (also termed as vibrational motion).

Example:

A basketball in figure 2.3 is shown as an example of vibrational motion. The basketball moves right and left about the mean position.

FIGURE 2.3 VIBRATORY MOTION OF BASKETBALL

Types of Translatory motion:

Translatory motion is further divided into three types:

Rectilinear motion: Rectilinear motion is the translatory motion of the object in straight line path.

Example:

For example the motion of train on track, motion of gunshot and motion of falling apple.

Curvilinear motion: Curvilinear motion is the translatory motion of an object in which it moves in a curved path.

Examples:

For example the motion of a football when kicked, the motion of roller coaster and the motion of a vehicle in a turn are examples of curvilinear motion.

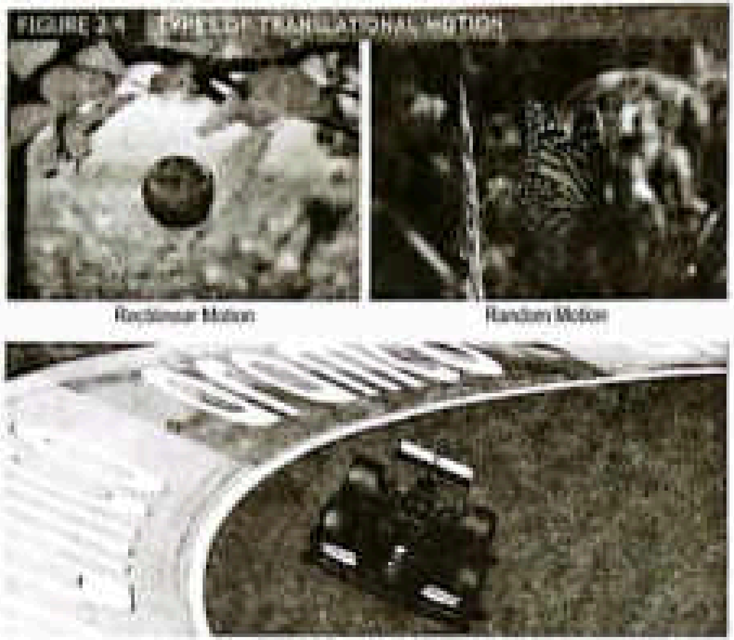
Circular motion is a special case of curvilinear motion in which the radius of rotation remains constant and object moves along a circular path.

An object can have any combination of these types of motion.

Random Motion: Random Motion is the translatory motion of an object with no specific path.

Examples:

For example bees flying through sky, motion of clouds and the motion of butterfly.



Rectilinear Motion   Random Motion

Curvilinear Motion

Explanation:

Translational motion is seen in various scenarios, covering a wide range of situations. Whether in engineering, physics, or everyday life, objects frequently display this type of motion. It is crucial to comprehend the specific motion type in order to accurately analyze and describe the behavior of moving objects.

Q3. Differentiate between distance and displacement.

Ans. Distance: *The length of path traveled between two positions is called distance.*

Explanation: Distance has no direction and therefore it is a scalar quantity. Distance is usually denoted by Δx, Δt, Δs, Δd or Δ , and has S.I unit as meter (m).

Displacement: *The shortest distance from initial position to final position (or straight directed distance) is called displacement.*

Explanation: Displacement has direction and therefore it is a vector quantity. Displacement has SI unit as metre (same as length).

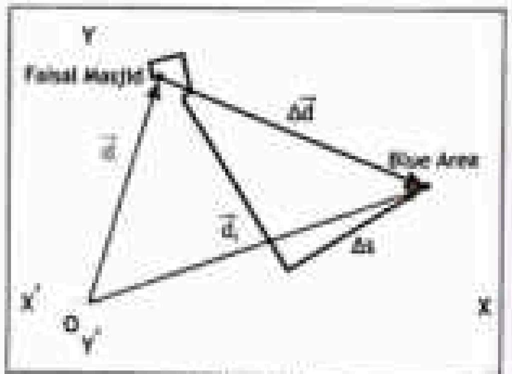


Figure 2.4

If an object moves then the object's position changes. This change in position vector " $\Delta\vec{d}$ " of an object, from initial position 'd_i' to final position 'd_f' is known as displacement. Mathematically:

$$\boxed{\vec{d} = \vec{d}_f - \vec{d}_i}$$

Q4. Differentiate between speed and velocity. Also define average speed, uniform and variable speeds, average velocity, uniform and variable velocities, acceleration and its types.

Ans. **(i) Speed:** *Measure of the distance covered (Δs) with passage of time (Δt) is called speed denoted by v).*

Mathematically:

$$\text{Speed} = \frac{\text{distance}}{\text{elapsed time}} \quad \text{or} \quad v = \frac{\Delta d}{\Delta t} \quad \text{or} \quad v = \frac{s_f - s_i}{t_f - t_i} \text{ —— (2.1)}$$

Explanation: Speed of an object shows us the rate at which the object is moving. Speed is a scalar quantity having S.I unit of meter per second (m/s or ms^{-1}). The speed will be one 'meter per second' if an object cover one meter distance in one second.

Speed tells us how fast an objects is moving. An object is fast if it covers large distance in a short time.

Example:

For example while going from Islamabad to Peshawar through motor-way M1, we leave at Tarnol interchange at 2:00 pm and cross Sawabi interchange at 3:00 pm. Since Sawabi interchange is about 70 km from Tarnol interchange and it took us one hour therefore our speed can be obtained as:

$$V = \frac{70km}{1hr} = 70km/hr$$

A fast-moving object covers a relatively large distance in a given amount of time and thus has high speed. Whereas a slow-moving object covers a relatively small amount of distance in the same amount of time and therefore has a low speed.

This means that our car is moving at 70km/hr neither speeding up nor slowing down. However, it is usually difficult to maintain a same speed. Other cars and distractions can cause us to reduce speed or at times we have to increase speed of our car.

(ii) Average Speed: *The average speed is the total distance (s) covered in total time (t).*

Mathematically:

$$V_{av} = \frac{\text{total distance}}{\text{total time}} = \frac{s}{t} \text{ ______ (2.2)}$$

Interchangeably this equation can also be written as $s = v_{av}t$ ______ (2.3)

(iii). Instantaneous speed: *The speed at any specific instant of time is called the instantaneous speed.*

Explanation:

i) We see sign boards on road reading, sharp turn ahead reduce speed, 'speed limit 70 km/hr'. Certainly this sign board does not refer to our average speed, but the speed at which we are moving at that particular instant of time.

ii) If we are not looking at the speedometer of car we only have a rough idea of how fast we are moving, and how much we should reduce speed. However, looking at the speedometer on the other hand, we will know exactly how fast we are going at that instant of time.

(iv) Uniform Speed: *'If an object covers equal distances in equal intervals of time we say that the object is moving with uniform speed'.* In uniform speed object does not get slower or faster and maintains the same speed.

(v) Variable Speed: *'If an object covers unequal distances in equal intervals of time we say that the object is moving with variable speed'.*

(vi) Velocity: Measure of displacement ($\Delta\vec{d}$) with passage of time (Δt) is called velocity (denoted by $\vec{v}$) .

Mathematically:

$$\text{Velocity} = \frac{\text{displacement}}{\text{elapsed time}} \quad \text{or} \quad \vec{v} = \frac{\Delta\vec{d}}{\Delta t} \quad \text{or} \quad \vec{v} = \frac{\vec{d_f} - \vec{d_i}}{t_f - t_i} \quad \_\_\_\_(2.4)$$

Explanation: Velocity is a vector quantity having same direction as displacement vector. The SI unit of velocity is metre per second (m/s). When we know both the speed and the direction of an object, we simply call it as velocity.

For straight-line motion in one direction, speed and velocity have same magnitudes because the lengths of the distance and the displacement are the same. The distinction between them in this case is that a displacement direction must be specified for the velocity.

(vii) Average Velocity: *The average velocity is the total displacement (d) covered in total time (t).*

Mathematically:

$$\vec{v} = \frac{\vec{d}}{t}$$

(viii) Instantaneous Velocity: *If velocity is measured by keeping the time interval small, such velocity is termed as instantaneous velocity.* To calculate velocity both the speed and direction for that moment of time need to be specified.

(ix) Uniform and Variable Velocity: *(i) 'If an object covers equal displacements in equal intervals of time we say that the object is moving with uniform velocity.* Uniform velocity is the *(ii)* velocity that does not change otherwise it is called variable velocity.

Explanation: To produce variable velocity (a change in velocity), either the speed or the direction is changed) or both are changed.

Example:

A satellite moving with constant speed in a circular orbit around Earth does not have a constant velocity since its direction of movement is constantly changing as shown in figure. 2.5.

FIGURE 2.5 MOTION OF A SATELITE

(x) Acceleration: 'The measure of change in velocity Δv with the passage of time 'Δt' is called acceleration a. (or) Time rate of change in velocity 'Δv' is called acceleration 'a'.

Mathematically:

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{elapsed time}} \quad \text{or} \quad \vec{a} = \frac{\Delta\vec{v}}{t} \quad \text{or} \quad \vec{a} = \frac{\vec{v_f} - \vec{v_i}}{t_f - t_i} \quad \_\_\_\_(2.6)$$

Explanation: Acceleration is a vector quantity with same direction as change in velocity. SI Unit of acceleration is meter per second per second or metre per square second (m/s^2). Acceleration is

a measure of how rapidly the velocity is changing. Since velocity is a vector quantity, therefore only the change in direction of velocity can also produce acceleration. The drone in the figure 2.6 is accelerating because it is changing directions.

FIGURE 2.6 MOTION OF DRONE

(xi) Positive and Negative acceleration: A positive acceleration means an increase in velocity with time, whereas the negative acceleration (deceleration) means a decrease in velocity with time.

(xii) Uniform and Non-uniform acceleration: When an object is changing its velocity at the same rate each second we call it uniform acceleration. A body has uniform acceleration if it has equal changes in velocity in equal intervals of time.

Non-uniform acceleration: occurs when an object's velocity changes, but this change is not steady over time. In simple terms, the rate at which the object's velocity changes is not the same throughout its movement. Acceleration, which is the measure of velocity change, is therefore not constant in non-uniform acceleration. Understanding non-uniform acceleration is important in physics to explain the movement of objects affected by changing forces. This is a common and partial situation since many real-life scenarios involve forces that vary over time, resulting in non-uniform acceleration.

Q5. What are freely falling bodies? What is gravitational acceleration? Write down sign conventions for gravitational acceleration?

Ans. Acceleration due to gravity: *All freely falling objects have the same acceleration called the acceleration due to gravity (g) and is independent of their masses.*

Explanation: The acceleration due to gravity is directed downward, toward the centre of the earth. Near the earth's surface, g is approximately

$$g = 9.8\ m/s^2 \quad \text{or} \quad 32.2\ ft/s^2$$

For large object the presence of air resistance is neglected, however if we drop a small piece of paper and coin. The coin will fall faster than a sheet of paper due to air resistance. However, when air is removed, the coin and the paper will experience the same acceleration due to gravity, and both the coin and the paper will fall at same rate.

Sign convention:

(1) When an object is moving under the action of gravity, acceleration due to gravity is taken as positive (+ g).

(2) When an object moves against gravity, the acceleration due to gravity is taken as negative (-g).

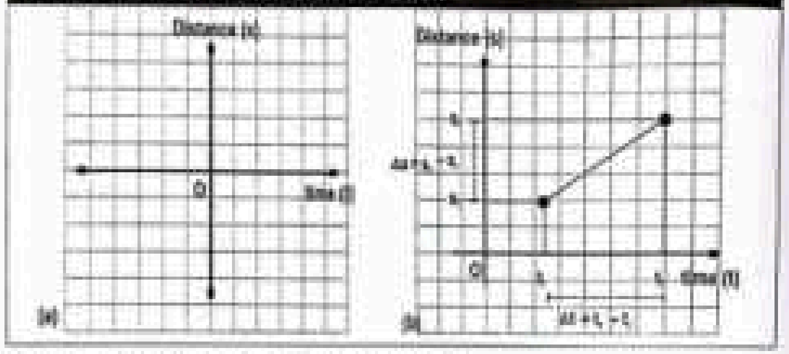
Q6. What is meant by a graph? How gradient of distance-time graph is calculated? Draw distance- time graphs for rest, uniform speed, increasing speed and decreasing speed.

Ans. Graph: *Graph (horizontal and vertical lines at equal distances) is an efficient method to show relationship between physical quantities.*

Distance-time graph: *The distance-time graph is plotted between distance (s) and time (t). the time is plotted along horizontal axis (x-axis) and distance is plotted along vertical axis (y-axis).*

Explanation: Distance time graph is always in the positive XY plane, as with passage of time distance never goes to negative axis, irrespective of the direction of motion.

FIGURE 2.7 GRAPHICAL ANALYSIS OF MOTION



Measurement of speed of an object with the help of graph:

The gradient (or slope) of distance time curve gives speed. The gradient of the graph means vertical coordinate difference divided by horizontal coordinate difference. The gradient in distance-time graph can be calculated as

1) Choose two points P_1 and P_2 for which the gradient is to be determined.
2) Determine the coordinates $P_1(t_1, s_1)$ and $P_2(t_2, s_2)$, by drawing perpendicular on each axis from both points as shown in figure 2.7(b).
3) Determine the difference between horizontal-coordinates ($\Delta t = t_2 - t_1$) and vertical-coordinates ($\Delta s = s_2 - s_1$)
4) dividing the difference in vertical coordinates ($\Delta s = s_2 - s_1$) by difference in horizontal coordinates ($\Delta t = t_2 - t_1$) gives gradient.

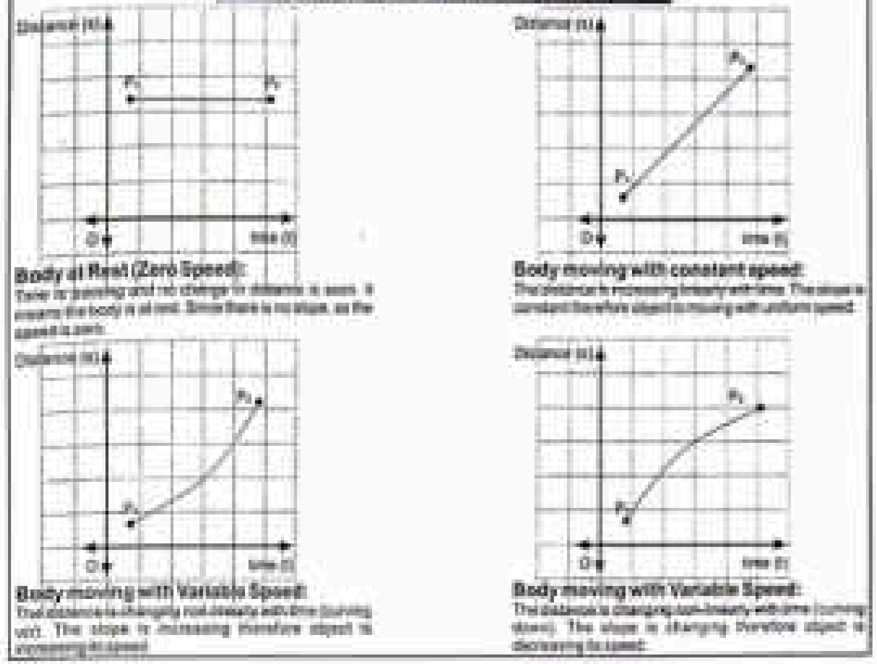
Mathematically:

$$\text{Gradient} = \frac{\Delta s}{\Delta t} = \frac{s_2 - s_1}{t_2 - t_1} = v \quad \text{\_\_\_\_\_\_} (2.7)$$

From equation 2.7 it is definition of speed, therefore, gradient = v.

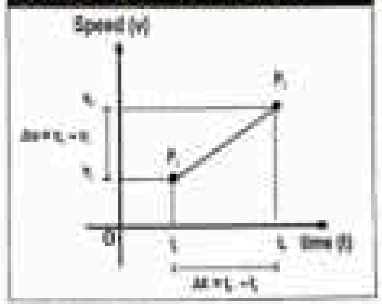
Thus by looking at the graph we get the idea about the speed of a body.

FIGURE 2.8 DISTANCE - TIME GRAPH



Q7. What is speed-time graph? How slope is found out from speed-time graph? Show that area under speed-time represents the distance covered.

FIGURE 2.9 SPEED TIME GRAPH



Ans. Speed-time Graph: *Speed-time graph is the graph plotted between speed (v) and time (t).*

Explanation: In this graphical analysis the speed is plotted along vertical axis (y-axis) and time along horizontal axis (x-axis).

Objectives of speed-time graph:

Speed time graph serve two purposes.

(i) Slope of the graph gives magnitude of acceleration.

(ii) Area under the graph gives distance traveled.

Measurement of magnitude of acceleration with the help of V-t graph:

The gradient (of slope) of speed time curve gives magnitude of acceleration. The gradient of the graph means vertical coordinate difference divided by horizontal coordinate difference.

The gradient in distance-time graph can be calculated as

1) Choose two points 'P_1' and 'P_2' for which the gradient is to be determined.
2) Determine the coordinates '$P_1(t_1,v_1)$' and by $P_2(t_2,v_2)$ drawing perpendicular on each axis from both points as shown in fig. 2.9.

3) Determine the difference between horizontal-coordinates ($\Delta t = t_f - t_i$) and vertical-coordinates ($\Delta V = V_f - V_i$).

4) Dividing the difference in vertical coordinates ($\Delta V = V_f - V_i$) by difference in horizontal-coordinates ($\Delta t = t_f - t_i$) gives gradient. Mathematically:

$$\frac{\Delta V}{\Delta t} = \frac{V_f - V_i}{t_f - t_i} = a \text{ ——— (2.8)}$$

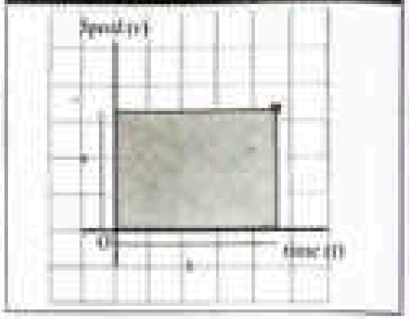
Form equation 2.8 we can conclude that the gradient of velocity- time graph gives the magnitude of acceleration.

B. Area under speed time graph represents the distance traveled: If the motion of a body represented by the speed time graph is symmetric shape then the area can be calculated using appropriate formula for geometrical shapes.

Measurement of distance by graph:

For example consider the figure 2.10 in which the speed time graph of the object in motion is represented by a rectangle. The area of rectangle is

FIGURE 2.10 RECTANGULAR AREA



Area = width x length

Area = v t

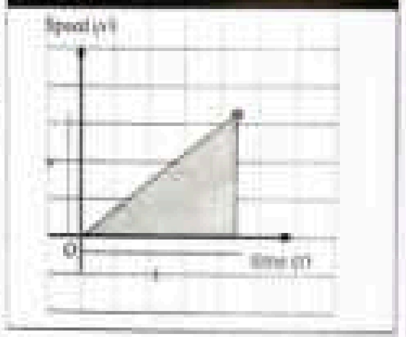
The distance by average speed is given by equation 2.3, is also

s = v t

Thus the area under speed time graphs represent the distance traveled.

Similarly consider the figure 2.11 in which the speed time graph of the object in motion is represented by a triangle. The area of triangle is

FIGURE 2.11 TRIANGULAR AREA



$$\text{Area} = \frac{1}{2}\text{ width x length}$$

$$\text{Area} = \frac{1}{2}\, V \times t$$

The distance by average speed is given by equation is again

$$s = \frac{1}{2}\, V \times t$$

SHORTRESPONSE QUESTIONS

Q1: In a park, children are enjoying a ride on Ferris wheels as shone. What kind of motion the big wheel has and what kind of motion the riders have?

Ans. The motion of big wheel is rotatory around its own axis while that of the riders is circular around the axis of the wheel.

Explanation: The motion of a body around its own axis is called rotatory motion. Here the wheel is moving around its own axis. Therefore, its motion is rotatory.

The motion of a body around any axis outside its body is called circular motion. Therefore, the riders sitting on chairs of the wheel are in circular motion.

Q2: A boy moves for some time, give two situations in which his displacement is zero but covered distance is not zero?

Ans. The displacement of a body along any closed path such as rectangular path, triangular path, or circular path is equal to zero. The distance covered along a circle of radius R is equal to $2\pi R$ (circumference of circle) is not zero.

Q3: A stone tied to string is whirling in circle, what is direction of its velocity at any instant?

Ans. When a stone is tied to a string whirling in a circle, the velocity of stone is away from its circular path and tangent to the circle. If the string is somehow broken, the stone will skid away from its circular path.

Q4: Is it possible to accelerate an object without speeding it up or slowing it down?

Ans. A body moving in a circle is an example of 'constant speed accelerated motion. The body is moving in a circle with uniform speed. Here magnitude of velocity remains constant at all points but direction of velocity changes continuously. Acceleration can be produced by changing either magnitude or direction of velocity. SO, the motion of body in this case is an accelerated motion although it is not speeding up or slowing down

Q5: Can a car moving towards right have direction of acceleration towards left?

Ans. A car is moving towards right with some certain speed. If the driver applies brakes slowly, 'the speed of the car will gradually decrease. Here 'in this case direction of velocity is towards right but direction of acceleration is towards left.

Q6: With the help of daily life examples, describe the situations in which:

a) acceleration is in the direction of motion.

b) acceleration is against the direction of motion.

c) acceleration is zero and body is in motion.

Ans. Following are the three daily life examples in which acceleration is in the direction of motion, against the direction of motion and zero.

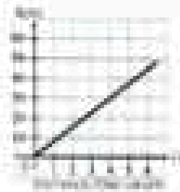
a) Freely falling object has direction of motion downward and acceleration due to gravity is also downward. An apple falling from a tree is an example of acceleration in the direction of motion.

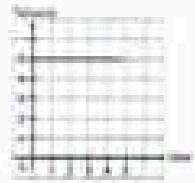
b) A body throwing upward has direction of motion upward and direction of acceleration downward. An upward throwing cricket ball is an example of acceleration against the direction of motion.

c) A uniformly moving body in a fixed direction has zero acceleration. A uniformly moving car in the right direction is an example of zero acceleration and the body is in motion.

Q7: Examine distance-time graph of a motorcyclist (as shown), what does this graph tell us about the speed of motorcyclist? Also plot its velocity-time graph.

Ans. The given distance-time graph show that the motorcyclist is moving with uniform speed.





Explanation: The given graph shows that the motorcyclist is travelling equal distances in equal intervals of time, which gives uniform speed.

Velocity Time Graph:

The velocity-time graph for such kind of motion is shown in the figure. This shows that velocity of the body remains constant with time passing. The given graph shows a uniform velocity, here it is 5m/s, with passing time.

Q8: Which controls in the car can produce acceleration or deceleration in it?

Ans. The accelerator of car produces acceleration while brakes produce deceleration in a car.

Explanation: Accelerator of car accelerates the car from zero to its maximum value. As long as the accelerator is pressed more for a specific gear. Its speed will increase i.e., it will accelerate.

Brakes are used to slow down or stop a car. Brakes apply force to slow down or stop the motion of car.

Q9: If two stones of 10kg and 1kg are dropped from a 1 km high tower. Which will hit the ground with greater velocity? Which will hit the ground first? (Neglect the air resistance)

Ans. By neglecting air resistance, both the stones of 10 kg and 1 kg will hit the ground with same speed and at the same time.

Explanation: Earth attracts every object towards its surface (or centre) with the same force irrespective of the mass of the object. As force on both the bodies is same, therefore both the bodies will have same velocity while falling and hitting the ground. As initial and final speed are same because both the bodies are acted upon by same force, therefore both the bodies will hit the ground at the same time.

Q10: A 100g ball is just released (from rest) and another is thrown downward with velocity of 10 m/s, which will have greater acceleration? (Neglect the air resistance)

Ans. The acceleration due to gravity will be approximately 9.8 m/s^2 downward in both cases. This is because gravity affects all objects equally regardless of their initial velocity and mass or direction of motion whether an object is dropped or thrown upwards, it will experience the same acceleration towards the Earth.

Multiple Choice Questions

1. **Change in position of a body from initial to final point is called:**
   (a) distance (b) displacement (c) Speed (d) Velocity
2. **Motion of a screw of rotating fan is:**
   (a) Circular motion (b) vibratory motion (c) Random motion (d) Rotatory motion
3. **A cyclist is travelling in a westward direction and produces a deceleration of 8 m/s^2 to stop.**
   (a) North (b) East (c) South (d) West
4. **A girl walks 3 km towards west and 4km towards south. What is the magnitude of her total distance and displacement respectively?**
   (a) 7km, 7km (b) 1km, 7km (c) 7km, 1km (d) 7km, 5km
5. **A rider is training a horse. Horse moves 60 meters towards right in 3 seconds. Then it turns back and travels 30 meters in 2 seconds. Find its average velocity.**
   (a) 6m/s (b) 18m/s (c) 35m/s (d) 0m/s
6. **If a cyclist has acceleration of 2m/s^2 for 5 seconds, the change in velocity of the cyclist is:**
   (a) 2m/s (b) 10m/s (c) 20m/s (d) 15m/s
7. **A car is moving with velocity of 10m/s. If it has acceleration of 2m/s^2 for 10 seconds. What is final velocity of the car?**
   (a) 30m/s (b) 20m/s (c) 10m/s (d) 15m/s

8. **When the slope of a body's displacement-time graph increases, the body is moving with:**
   (a) increasing velocity (b) decreasing velocity
   (c) constant velocity (d) all of these
9. **A ball is thrown straight up, what is the magnitude of acceleration at the top of its path?**
   (a) zero (b) 9.8m/s^2 (c) 4.9m/s^2 (d) 19.6m/s^2
10. **slope of distance -time graph is:**
    (a) velocity (b) acceleration (c) speed (d) displacement
11. **Area under speed-time graph is equal to _______ of moving body:**
    (a) distance (b) change in velocity (c) uniform velocity (d) acceleration
12. **In 5 s a car accelerates so that its velocity increases by 20 m/s. The acceleration is:**
    (a) 0.25 m/s^2 (b) 4 m/s^2 (c) 25 m/s^2 (d) 100 m/s^2
13. **Ball dropped freely from a tower reaches ground in 4s, the speed of impact of ball is:**
    (a) 0 m/s (b) 2.45 m/s (c) 19.6 m/s (d) 39.2 m/s
14. **Which of following distance time graphs represents increasing speed of a car?**

A. B. C. D.

Answers

1	b	2	d	3	b	4	d
5	a	6	b	7	a	8	a
9	b	10	c	11	a	12	b
13	d	14	c				

Examples

Example. 2.1: Reaction time of Batsman

Shoaib Akhtar made a record in World cup 2003 against England by bowling at a speed of 161.3 km/h. If the batsman is at a displacement of 17.5 m from the bowler, what should be the reaction time for the batsman to play such a delivery?

Solution:

Given

$$\text{Speed of ball } v = 161.3 \text{ km/h} = \frac{161.3 \times 1000\text{m}}{3600\text{s}} = 44.8 \text{ m/s}$$

Required time = t = ?

Distance covered by ball s = 17.5 m

From the definition of average speed, we have $V_{av} = \frac{\text{total distance}}{\text{total time}} = \frac{s}{t}$

$$t = \frac{S}{V_{av}}$$

Putting values:

$$t = \frac{17.5m}{44.8m/s}$$

Hence $t = 0.39\ s$ **Ans.**

The batsman should react in just 0.39 seconds to play this delivery. These are typical reaction times player deal in game of cricket.

Example. 2.2: Fastest Train in the World

Shanghai's Maglev, the fastest train, travelled a distance of 30 kilometers in 7 minutes and 30 seconds. What is its speed? Convert the speed to km/h.

Solution:

Given

Distance travelled 's' = 30 × 1000 m = 30,000 m' speed v = ?

Time taken 't' = 7 min 30 s = (7 × 60) s + 30 s = 420 s + 30 s = 450 s

From the definition of speed, we have: $v = \frac{s}{t}$

Putting values:

$$V = \frac{30,000}{450s}$$

Hence $V = 66.67\ m/s$ **Ans.**

Conversion in km/h

Converting m to km and s to h

$$V = \left[66.67\frac{m}{s}\right] \times \left[\frac{3600}{1}\frac{s}{h}\right] \times \left[\frac{1}{1000}\frac{km}{m}\right] = 240.01\ km/h$$

$V = 240.01\ km/h$ **Ans.**

This is a much greater speed as compared to the speed limits on motor ways (120 km/h)

Example. 2.3: Velocity of a Car

A car travels a curvy track of length 800 meters in 40 seconds. The straight path is about 600 meters between starting point and ending point, which the same car travels in 36 seconds. What is the car's (a) average speed and (b) average velocity?

Solution:

Given:

Length of curvy track = distance Δd = 800m

Time taken 'Δt' = 40 s

Length of straight path = displacement Δd = 600m

Time taken 'Δt' = 40 s

Required:

(a) Average speed V_{av} = ?

(b) Average Velocity $\vec{V}_{av}$ = ?

From the definition of speed and velocity, we have

(a) Average speed = $V_{av} = \frac{\text{total distance}}{\text{total time}} = \frac{s}{t}$

Putting Values: $V_{av} = \frac{800m}{40s} \Rightarrow V_{av} = 20\ m/s$ **Ans.**

(b) Average Velocity $\vec{V}_{av} = \frac{\text{total displacement}}{\text{total time}} = \vec{V}_{av} = \frac{d}{t}$

Putting Values $\vec{V}_{av} = \frac{600m}{36s} \Rightarrow \vec{V}_{av} = 16.67\ m/s$

Example. 2.4: Acceleration of Chetah

Cheetah (fastest land animal) can accelerate its speed from zero to 26.8 m/s in just three seconds. Suppose the cheetah has started running towards East, find its acceleration.

Solution:

Given

Initial velocity $\vec{V}_i$ = 0 m/s (East)

Final Velocity $\vec{V}_f$ = 26.8 m/s (East)

Time taken Δt = 3 s

Required

Acceleration = ?

From the definition of acceleration, 2.6 we have

$$\vec{a} = \frac{\vec{V}_f - \vec{V}_i}{t_f - t_i}$$

Putting values

$$\vec{a} = \frac{26.8m/s - 0m/s}{3s}$$

$\vec{a} = 9.93 m/s^2$ **Ans.**

That is a big value, as typical cars have accelerations of only 3 to 4 m/s^2

Example. 2.5: Acceleration Due to Gravity

A block of mass 2 kg is left from the top of a building. How much time will the block take to reach the ground if it strikes the ground with a speed of 78.5 m/s? (Ignore air resistance).

Solution:

Given

Mass of the block 'm' = 2 kg

Initial speed 'V_i' = 0 m/s

Final velocity 'V_f' = 78.5 m/s

Acceleration due to gravity 'g' = 9.8 m/s^2

From the definition of acceleration, acceleration due to gravity can also be written as

$$\vec{g} = \frac{\vec{V}_f - \vec{V}_i}{t}$$

Rearranging for time $\Delta t = \frac{\vec{V}_f - \vec{V}_i}{g}$

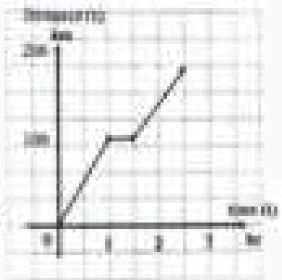
Putting value:

$$\Delta t = \frac{78.5\ m/s - 0m/s}{9.8m/s^2}$$

Therefore $\Delta t = 8\ s$ **Ans.**

So, the block will reach the ground in 8 seconds.

Example. 2.6: Peshawar to Islamabad Through M1



A car travels from Peshawar to Islamabad on Motorway (M1), stops for 30 minutes at 'rest area'. Calculate the speed of the car in km/hr and m/s for

(a) Journey from Peshawar to rest area.
(b) Journey from rest area to Islamabad.
(c) Journey from Peshawar to Islamabad

Solution:

From the graph

(a) Distance between Peshawar to rest area is

$\Delta S = S_2 - S_1$ is $\Delta S = 100\text{ km} - 0\text{ km} = 100\text{km}$

Time taken from Peshawar to rest area is

$\Delta t = t_2 - t_1$ is $\Delta t = 1\text{ hr} - 0\text{ hr} = 1\text{ hr}$

Gradient = V = $\frac{S}{t} = \frac{100\text{km}}{1\text{hr}} = 100\text{ km/hr}$ **Ans.**

In meter per second 100 km = 100,000 m and 1 hr = 60 s = 3600 s, therefore

Gradient = V = $\frac{S}{t} = \frac{100{,}000\text{m}}{3600\text{s}} = 27.78\text{ km/hr}$ **Ans.**

(b) Distance between rest area and Islamabad is

$\Delta s = S_2 - S_1$ is $\Delta s = 175\text{ km} - 100\text{ km} = 75\text{ km}$

Time taken from Peshawar to rest area is

$\Delta t = t_2 - t_1$ is $\Delta t = 2\text{ hr } 30\text{ mins} - 1\text{ hr } 30\text{ mins} = 1\text{ hr} = 60, 60\text{ s} = 3600\text{ s}$, Therefore

Gradient = V = $\frac{S}{t} = \frac{100\text{km}}{1\text{hr}} = 100\text{ km/hr}$ **Ans.**

In meter per second 75 km = 75,000 m and 1 hr = 60' 60 s = 3600 s Therefore

Gradient = V = $\frac{S}{t} = \frac{75{,}000\text{m}}{3600\text{s}} = 20.83\text{ m/s}$ **Ans.**

(c) Distance from Peshawar to Islamabad is:

$\Delta S = S_2 - S_1 \quad = 175\text{ km} - 0\text{ k} = 175\text{ km}$

Time taken from Peshawar to Islamabad is

$\Delta t = t_2 - t_1 \quad = 2\text{ hr } 30\text{ mins} - 0\text{ hr} = 1\text{ hr} = 2.5\text{ hr}$

Gradient = V = $\frac{S}{t} = \frac{175\text{km}}{2.5\text{hr}} = 70\text{ km/hr}$ **Ans.**

In meter per second 175 km = 175,000 m

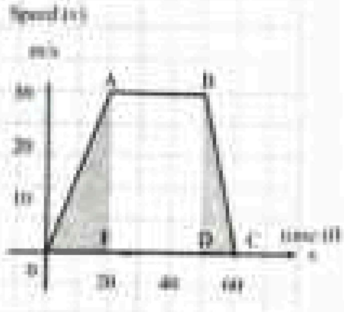
And 2 hr and 30 mins = 2 (60' 60) s + (60' 30) s = 7200 s + 1800 s = 9000 s.

Gradient = V = $\frac{S}{t} = \frac{175000\text{m}}{9000\text{s}} = 19.44\text{ m/s}$ **Ans.**

Example. 2.7: Graphical Representation of Speed of Car.

A car increases its speed from zero to a 30 m/s in 20 s, then it moves with uniform speed for the next 30 seconds and then the driver applies brakes and the speed of the car decreases uniformly to zero in 10 s. The graph is plotted for the journey, use this graph to calculate

(a) magnitude of acceleration (i) in first 20 s (ii) from 20 s to 50 s and (iii) in last 10 s (b). Total distance covered (c). Average speed



Solution:

(a) The slope of the graph will give magnitude of acceleration.

$$\text{Slope} = \frac{\Delta V}{\Delta t} = \frac{V_f - V_i}{t_f - t_i} = \text{Magnitude of acceleration}$$

(i) For the first 20 seconds, OA line represents the slope

$$\text{Magnitude of acceleration} = |a| = \frac{(30 - 0)\text{m/s}}{20 - 0} = \frac{30\text{m/s}}{20\text{s}}$$

$$|a| = 1.5\text{ m/s}^2$$

(ii) From 20 s to 50 seconds, the slope is represented by line AB

$$\text{Magnitude of acceleration} = |a| = \frac{(30 - 30)\text{m/s}}{(50 - 20)\text{s}} = \frac{0\text{m/s}}{30\text{s}}$$

$$|a| = 0\text{ m/s}^2 \quad \textbf{Ans.}$$

(iii) In the last 10 seconds, the slope is represented by BC

$$\text{Magnitude of acceleration} = |a| = \frac{(0 - 30)\text{m/s}}{(60 - 50)\text{s}} = \frac{-30\text{m/s}}{10\text{s}}$$

$$|a| = -3\text{ m/s}^2 \quad \textbf{Ans.}$$

The negative sign shoes that the car is slowing down.

(b) Now the total distance covered is equal to the area under the speed-time graph. Total distance covered = Area of triangle OAE + Area of rectangle ABDE + Area of triangle CBD.

$$S = \frac{1}{2}(30\text{m/s} \times 20\text{s}) + [30\text{m/s} \times 30\text{ s}] + \frac{1}{2}(30\text{m/s} \times 10\text{s})$$

$$S = 300\text{ m} + 900\text{ m} + 150\text{ m} = 1350\text{ m} \quad \text{Ans.}$$

(c) Now the average speed can be calculated when distance 's' is divided by total time 't'

$$\text{Average Speed} = \frac{\text{Total distance Covered}}{\text{Total time}}$$

$$V_{av} = \frac{1350\text{m}}{60\text{s}} = 22.5\text{ m/s} \quad \textbf{Ans.}$$

Numerical Problems

Q1. Convert the following:

(a) 160km/h into m/s (Ans. 44.44m/s)
(b) 36m/s into km/h (Ans. 129.6km/h)
(c) 5km/h² into m/s² (Ans. 0.001m/s²)
(d) 1m/s² into km/h² (Ans. 12960km/s²)

Ans. (a) 160 km/h into m/s

$$= \frac{160 \times 1000\text{m}}{3600\text{sec}}$$

$$= \frac{160 \times 1000}{3600}$$

$$= \frac{1600}{36} = \mathbf{44.44\ m/s}$$

(b) **36m/s into km/h.**

$$= \frac{36 \times 3600}{1000}$$

$$= \frac{36 \times 36\cancel{00}}{10\cancel{00}}$$

$$= 129.6\ km/h$$

(c) $15\ km/h^2$ into m/s^2

$$= \frac{15 \times 1000}{3600 \times 3600}$$

$$= \frac{15 \times 1\cancel{0}\cancel{00}}{360\cancel{0} \times 36\cancel{00}}$$

$$= \frac{15}{360 \times 36}$$

$$= \frac{15}{1296}$$

$$= \mathbf{0.0011\ m/s^2}$$

(d) $1\ m/s^2$ into km/h^2

$$= \frac{1 \times 3600 \times 3600}{1000}$$

$$= \frac{1 \times 360\cancel{0} \times 36\cancel{00}}{1\cancel{0}\cancel{00}}$$

$$= \mathbf{12960\ km/s^2}$$

Q2. In 10 seconds, a cyclist increases its speed from 5km/h to 7km/h, while a car moves from rest to 20km/h in same time. Calculate and compare acceleration in each case.

Ans. To calculate acceleration, we use formula.

$$\text{Acceleration} = a = \frac{\text{change in velocity}}{\text{time taken}}$$

For cyclist:

$$\Delta V = \text{change in velocity} = 7\ km/h - 5\ km/h = 2\ km/h = \frac{2 \times 1000}{3600} = .55 m/s$$

Time taken $= t = 10\ s$

For the car:

$$\Delta V = \text{change in velocity} = 20\ km/h - 0\ km/h = 20\ km/h = \frac{20 \times 1000}{3600} = 5.5 m/s$$

Time taken $t = 10\ s$

For cyclist acceleration $= \frac{.55}{10} = .055\ m/s^2$

For Car acceleration $= \frac{5.5}{10} = .55\ m/s^2$

Comparing the acceleration, we can find car has a higher acceleration than the cyclist, as it goes from a higher speed in the same time frame.

Q3. A ball is thrown straight up such that it took 2 seconds to reach the top after which it started falling back. What was the speed with which the ball was thrown up?

Ans. use the formula

$$a = \frac{\Delta V}{t} = \frac{V_f - V_i}{t}$$

Here $a = g = -9.8 m/s^2$ = acceleration due to gravity

t = 2 second (time to reach top)

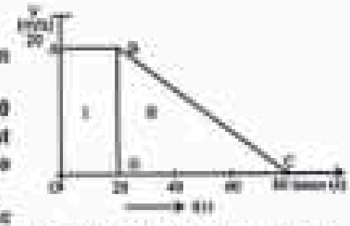
V_f = (0m/s at the top)

Putting values we have:

$$-9.8 = \frac{0 - V_i}{2}$$

$$V_i = 9.8 \times 2 = 19.6\ m/s$$

So, the initial velocity with which the ball was thrown upward was 19.6 m/s.



Q4. A car is moving with uniform velocity of 20m/s for 20 seconds. Then brakes are applied and it comes to rest with uniform deceleration 1 30s. Plot the graph to calculate this distance using speed time graph.

Ans. The velocity time grape is plotted as shown in figure. The total area of enclosed figure in V-t graph represents the distance covered by an object. The area of figures is area of rectangle OABD and area of triangle BCD

So,

Distance = area of rectangle OABD + area of triangle BCD .... (i)

Here, area of rectangle OABD = (length x width)=(OA x OD) = (20 x 20) = 400 m

and area of triangle BCD $= \frac{1}{2}$ (Base × altitude) $= \frac{1}{2}(60 \times 20) = 600$ m

Putting these values in equation (i), we have

Distance = 400 + 600 = 1000 m.

Hence total distance covered is 1000 m.

Q5. A girl starts her motion by a racing bicycle in a straight line at a speed of 50km/h. Her speed is changing at a constant rate. If she stops after 60s, what is her acceleration?

Ans. $V_o = 50\ km/h$

Converting into m/s

$$= \frac{50 \times 1000}{3600}$$

$$= \frac{50 \times 10\cancel{00}}{36\cancel{00}}$$

$$= \frac{500}{36} = 13.8\ m/s.$$

$V = 0$ (Because girl stops)

$t = 60$ seconds

$$a = \frac{\Delta V}{t} = \frac{\text{change in velocity}}{\text{time taken}}$$

So $\Delta V = V - V_o$

$\Delta V = V - 13.8$ (Putting value of ΔV and t in above equation)

Hence $a = \frac{0 - 13.8}{60}$

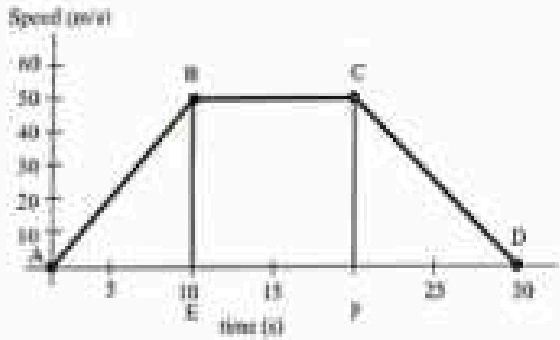
$a = -.23\ m/s^2$ (The negative sign shows deceleration as she comes to rest)

Q6. Consider the following speed time graph. Tell:
a) Which part of the graph is showing acceleration, decoration and zero acceleration?
b) Calculate covered distance from 10 seconds to 20 seconds from the graph.

Ans. (a) Its clear from the figure that AB is accelerating part of graph, BC part is showing zero acceleration because no change in velocity and CD part is showing deceleration of an object.

(b) The distance covered form 10 second to 20 second can be calculated from speed-time graph.
The distance covered during required period is = area of Fig BCFE = Length × width

$$= BE \times EF$$
$$= 50 \times 10$$
$$S = 500\ m$$



SPEED-TIME GRAPH

UNIT 03 Dynamics I

Q.1: Differentiate with examples between contact and non-contact forces. Also, Explain fundamental forces and the role of Dr. Abdus Salam from Pakistan in unifying two fundamental forces.

Ans. **Contact and non-contact Force:** Forces are broadly classified as contact and non-contact forces.

Contact Forces: *The force acting between two objects that are in physical contact are termed as contact forces.*

Example: For example, in game of cricket a batter hitting a cricket ball is a contact force since there is physical contact in between the bat and the ball.

(i) Normal Force: *A force perpendicular to the contact surface that keeps objects from passing through each other is called normal force and is represented as F_N. (In geometry, normal means perpendicular).*

Example: For example the book lying on table, the force perpendicular to the table is normal force.

(ii) Thrust: *The force that propels a flying machine in the direction of motion is termed as thrust.*

Example: For example engines produce thrust, the thrust of engine of car causes it to accelerate.

(iii) Friction: *Force that resist the relative motion of solid surfaces, fluid layers, and material elements in contact and sliding against each other is called friction.* Friction on an object acts in a direction opposite to the direction of the object's motion or attempted motion or attempted motion.

Example: For example air resistance is also frictional force which occurs between air and an object. It is the force that the object experiences as it passes through the air. It is kind of the drag force which resists the motion of a body with fluid.

(iv) Tension: *The force exerted by two or more physical objects that are in contact, through string, rope, cable or spring, we call such force as tension.*

Examples:

(i) For example tension keeps spider web together consists of numerous fine strands that pull on one another.

(ii) The tension in cord attached to a string is shown in the figure 3.3 (d).
The forces that an object exerts to resist a change in its shape are called elastic forces; they arise from forces between the particles in the material. For example when force is applied to a spring or rubber band it will stretch and at same time resists being stretched. It must be noted that the tension is the elastic only during extension not compression.

(d) Tension Force

NON-CONTACT FORCES: *The force acts at a distance, without any physical contact between bodies is termed as non-contact force.*
This force acts even if the objects involved are not touching, also termed as action at a distance force.

Examples:
(i) The attractive force between two objects with mass is called gravitational force. For example, the force experienced by moon because of earth.
(ii) An attractive or repulsive force experienced by charged objects is called electrostatic force. For example the attractive force between a positively charged nucleus and negatively charged electron.
(iii) An attractive or repulsive force experienced between magnetic poles is called magnetic force. For example the repulsive force between the two North poles of magnets.

FUNDAMENTAL FORCES IN NATURE: There are many different types of forces around us, but physicists have classified forces into only four categories based on how objects interact with one another. The four fundamental forces of nature are the gravitational force, the electromagnetic force, the strong nuclear force, and the weak nuclear force. Physicists have classified all forces that exist as one of these four fundamental forces. Physicists explain these fundamental forces through exchange particles. Elementary particles, much less massive than a proton, travel from one object to another "carrying" the force. In this way, each force is 'carried' or mediated by the exchange of a particle.

A. Strong Nuclear Force: The strong nuclear force is the strongest of all the fundamental forces. It keeps the positively charged protons tightly packed in the nucleus of an atom, by overcoming the repulsion between them. The exchange particles of strong force are called pions, with other heavy particles. The strong nuclear force has a very short range, nearly equal to the diameter of a proton.

B. Electromagnetic Force: The electromagnetic force act between electric charges. It includes both electric forces and magnetic forces. The electromagnetic force can exert either an attraction or a repulsion, so on average, the forces tend to cancel each other out and its effect is not observed. The electromagnetic force is mediated by a massless particle known as a photon. The massless nature of the photon makes the effective range infinite, even though the strength of the force decreases rapidly as the distance between the objects increases. The normal force, friction, and tension are caused by the interaction of particles on the contact surfaces and are thus a result of the electromagnetic force.

C. Gravitational Force: The gravitational force, or the force of gravity, is the force of attraction between all objects in the universe. Gravity is by far the weakest of the four fundamental forces (with least relative strength), the force of gravity between two objects is noticed only if at least one of the objects has a large mass such as stars, planets, and moons. It holds them together and controls their motions in the same way that it controls the motion of falling objects here on Earth.
Gravitational force is theorized to be an exchange force with a massless mediating particle 'graviton'. The massless nature of the graviton allows gravity to have infinite range similar to the electromagnetic force. However, the graviton is the only exchange particle not detected yet.

D. Weak Nuclear force: The weak nuclear force is very weak, 10 000 times weaker than the strong nuclear force and has the shortest range of any of the fundamental forces. Despite this, the weak nuclear force plays a major role in the structure of the universe. It is an exchange force mediated by the exchange of three different particles called vector bosons. The weak nuclear force is responsible for radioactive decay. Specifically, the weak force changes the flavor (type) of an elementary particle called a quark. When this process occurs, a neutron in the nucleus transforms into a proton.


Prof Dr Abdus Salam

Role of Pakistani Scientist Dr. Abdus Salam: For years physicists have sought to show that the four basic forces are simply different manifestations of the same fundamental force. The most successful attempt at such a unification is the electroweak theory, proposed during the late 1960s by Abdus Salam (Pakistani physicist), Steven Weinberg, and Sheldon Lee Glashow. This theory, which incorporates quantum electrodynamics (the quantum field theory of electromagnetism), treats the electromagnetic and weak forces as two aspects of a more-basic electroweak force that is transmitted by four carrier particles, the so-called gauge bosons.
One of these carrier particles is the photon of electromagnetism, while the other three- the electrically charged W^+ and W^- particles and the neutral Z_0 particle- are associated with the weak force. Unlike the photon, these weak gauge bosons are massive, and it is the mass of these carrier particles that severely limits the effective range of the weak force.

Q.2: Represent the forces acting on a body using free body diagrams. OR What is free body diagram? Explain.

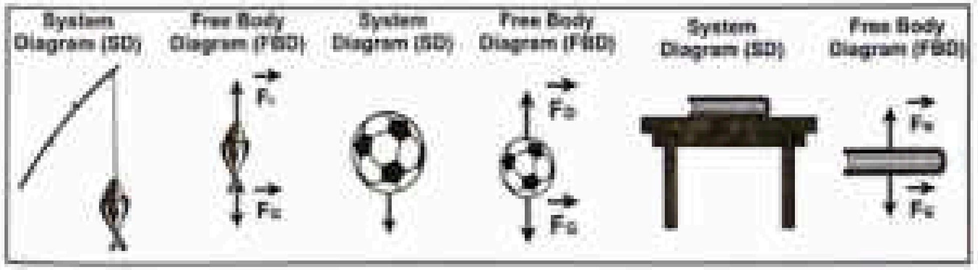
Ans. **Representation of Force:** *A free-body diagram (FBD) is a schematic representation in which only the object being analyzed is drawn with their lengths proportional to the magnitudes of the forces; each force vector is labelled with the symbol F, with a subscript (for example, F_g is the force of gravity, F_N is the normal force, F_f is friction, F_T is tension, and F_A is the applied force.*

Explanation: In order to study forces and their effects on the objects, we should familiarize ourselves with the skill of drawing force diagrams. Commonly two types of force diagram, 'system diagrams' and 'free-body diagrams', are used.

A system diagram (SD):
A system diagram (SD) is a visual expression of all the objects required.

A free-body diagram (FBD):
A free-body diagram (FBD) is a schematic representation in which only the object being analyzed is drawn, with arrows showing all the forces acting on the object.

Examples:
Three examples SDs and FBDs: the force vectors are drawn with their lengths proportional to the magnitudes of the forces; each force vector is labelled with the symbol '$\vec{F}$', with a subscript (for example, '$\vec{F}_g$' is the force of gravity, '$\vec{F}_N$' is the normal force, '$\vec{F}_f$' is friction, '$\vec{F}_T$' is tension, and '$\vec{F}_A$' is the applied force).



Q.3. What is meant by resultant force (Net force)? Explain with examples.

Ans. Resultant Force: *The net force is defined as the vector sum of all the forces acting on an object.*

Explanation: More than one force can act on the object, net force (also termed as resultant force) 'is the combined effect of all these forces. The net force tells us whether the forces on the object are balanced or unbalanced.

Examples:

3.6 (a)

(i) When the forces on an object produce a net force of 0 N, the forces are balanced. There is no change in the state of motion of the object.
For example, in a tug of war shown in figure 3.6 (a) the forces F_1 and F_2 are equal in magnitude and opposite in direction, the forces cancel the effect of each other and there is no net force.

3.6 (b)

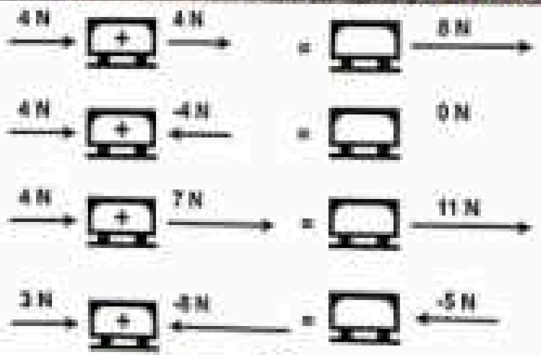
(ii) when the net force on an object is not 0 N, the forces are unbalanced and produce a change in motion of an object. For example, for tug of war in figure 3.6 (b) one force F_2 exceeds the other force F_1, and there is a net force F_{net} to the right.

FREE-BODY DIAGRAMS AND RESULTANT (NET) FORCES: To study the effects of forces acting on any object, we can apply the skill of drawing force diagrams. Since force is a vector quantity, the vector sum of all the forces acting on an object is the resultant force. The resultant force can also be called the net force. These two terms can be used interchangeably. They will be represented by the same symbol, F_{net} in this text.

The net force or resultant force can be obtained by simply adding forces. A resultant force is a single force that has the same effect as the combined effect of all the forces to be added.

Forces are vector quantities which require both magnitude with proper unit as well as direction for its complete description. Therefore it is required that we should draw the forces to a common scale as vectors (arrow diagram). Simply add the magnitudes of vectors in case of like parallel forces and subtract the magnitudes of vectors in case of unlike parallel forces. Few examples are shown in the figure 3.7.

FIGURE 3.7 NET FORCE FOR LIKE AND UNLIKE PARALLEL FORCES



However, we cannot make such algebraic addition of vectors when vectors are making certain angle. In such cases we draw vectors on a coordinate axis and then according to the same scale we can add them by head to tail rule of vector addition.

Q.4: State and Explain Newton's First law of motion. (OR) State first law of motion. Explain with the help of examples. Why is it called law of inertia?

Ans. Statement: *"If the net external force acting on an object is zero, the object will maintain its state of rest or uniform motion (constant velocity)".*

It means that in absence of external net force, an object at rest, it will remain at rest; While an object in motion will continue to move with constant velocity (no change in velocity or no acceleration.

Mathematically:

$$\vec{F}_{net} = 0 \qquad \text{then} \quad \Delta\vec{v} = 0 \qquad \vec{a} = 0$$

NEWTON'S FIRST LAW OF MOTION

This means that object in motion would continue to move in a straight line for ever. However on the Earth, it is difficult to observe an object in a state of uniform motion, because of presence of space, where there is no friction and negligible gravitational attraction, an object initially in motion maintains a constant velocity.

Explanation: An object can continue to move when the unbalanced forces are removed. For example, when it is kicked, a soccer ball receives an unbalanced force. The ball continues to roll on the ground after the ball was kicked until another unbalanced force changes its motion as shown in

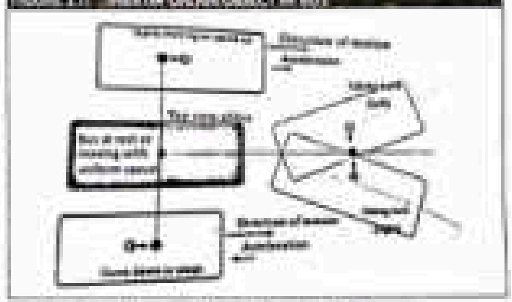
FIGURE 3.10 INERTIA AND SUDDEN MOTION OF BUS

First Law and inertia: First law of motion specifies that there is a natural tendency of an object to remain in a state of rest or in uniform motion in a straight line termed as **inertia**. Does all objects have equal tendency to resist its state of rest or uniform motion?

Absolutely not, the object with more mass (the measure of the amount of matter in a body) has greater resistance to change (inertia), is the reason why it is difficult to move massive objects. Inertia is a characteristic of a body that depends on mass. (the greater the mass of an object, the greater its inertia, and vice versa).

Examples from daily life:

FIGURE 3.11 INERTIA ON AN OBJECT IN BUS



(i) Newton's first law of motion is applied when we ride standing in the aisle of a bus holding a pole as shown in figure 3.10 (a). As the bus begins to move, we tend to remain at rest, therefore we feel a push to back (as our lower body start moving with the bus, but the upper part of body maintains the state of inertia). The same principle is again applied when the bus start to slow down or stops, we feel to move forward due to inertia as shown in the figure 3.10 (b).

As the bus start moving with uniform speed if we hold on to the pole, it supplies the forces needed to give us the same motion as the bus, we no longer feel pushed. But when the bus goes around a curve, again we feel a tendency to move to the side of the bus. The bus has changed its straight line motion, but we tend to move straight ahead. The same principle is again at work when the bus start to slow down or stops, we feel to move forward as shown in the figure 3.11. Thus the forces we feel when the bus starts moving, speeds up, slows down or turn around a corner are a result of our tendency to remain at rest or follow a straight path.

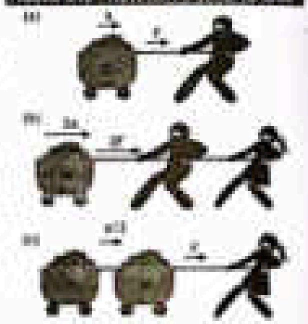
(ii) An object thrown in outer space, tends to move in a direction to infinity. This is because outer space lacks environment like air and force of gravity. Hence, the object does not receive any resistance to the motion, therefore, it continues to exhibit motion until it hits a celestial body, strikes a meteorite, are enters the gravitational field of a planet.

(iii) Place a card on top of a glass, and put a coin above this arrangement. If you quickly flick the card horizontally, the inertia of the coin will keep it at rest horizontally. The vertical force of gravity will pull it straight down into glass.

Q.5: State and prove Newton's second law of motion.

Ans. Statement: Newton's second law of motion which can be formally stated as, *"the acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object".*

FIGURE 3.12 NEWTON'S SECOND LAW



Mathematically:
Commonly written in terms of force in magnitude form, we have Newton's second law of motion.

$$\vec{F}_{net} = m\vec{a} \quad \text{\_\_\_\_\_\_\_\_\_\_} \quad (3.1)$$

Explanation: (i) The acceleration produced by a net force acting on an *object* (or mass), is directly proportional to the magnitude of the force ($a \propto F_{net}$) and in the direction of the force (the $\propto$ symbol is a proportionality sign). In other words, the greater the unbalanced net force, the greater the acceleration.

The acceleration of an object being acted on by a net force is inversely proportional to the mass of the object ($a \propto 1/m$). That is, for a given unbalanced net force, the greater the mass of an object, the smaller the acceleration.

Combining these effects of net force and mass on acceleration gives

$$\text{Acceleration} = \frac{\text{net force}}{\text{mass}}$$

Using appropriate units we can write $\quad \vec{a} = \dfrac{\vec{F}_{net}}{m}$

(ii) As an example consider the figure 3.12 (a), mass m is the mass of the system, when net force acts it produces an acceleration 'a'. In figure 3.12 (b) the force is doubled by keeping the mass same, the acceleration also doubles where as in figure 3.12 (c) the mass is doubled while force is kept the same the acceleration in halved.

(iii) Newton's second law of motion also enables to define System international (SI) unit of force newton represented by symbol N. *One newton is defined as the force that produces acceleration of one meter per second squared ($a = 1\ m/s^2$) in a body of mass one kilogram (1 kg).*

$$1\ N = 1\ kg \times 1\ m/s^2 \qquad \text{or} \qquad N = kgm/s^2$$

Q.6: State Newton's 3rd law of motion. Explain with examples from daily life.

Ans. Statement: *"Newton's third law of motion, which can be stated as whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first object".*

Mathematically: When an object 'A' exert force on object 'B' Written as "F_{AB}", object 'B' also exert equal force on object 'A' written as "F_{BA}" but in opposite direction.

$$\vec{F}_{AB} = -\vec{F}_{BA}$$

Here the negative sign show that force F_{BA} is opposite to force F_{AB}.

Explanation with Examples: These two forces are termed as action- reaction pair. Action and reaction cannot cancel each other because they act on different bodies (action on one body and reaction on another body).

(i) When we kick a football as shown in figure 3.13, the foot exerts the action force F_{AB} on the football and as a reaction the football exerts an equal and opposite force F_{BA} on our foot. Both these forces are equal in magnitude and opposite in direction.

FIGURE 3.13 NEWTON'S THIRD LAW OF MOTION

FIGURE 3.14 NEWTON'S THIRD LAW

(ii) Example of Newton's third law of motion are present everywhere, because when we talk of force we also consider its reaction. For example, when we jump, our legs apply a force to the ground, and the ground applies an equal and opposite reaction force that pushes us into the air.

(iii) When we punch an object or kick something as an action, we also get a force onto our hands and legs as a reaction force. That is why we feel pain when punching a wall, or falling on the ground. The exhaust from the rocket creates a downward force which creates an equal and opposite thrust in the upward direction as shown in figure 3.14.

Applying Newton's third law of motion allow us to explore two important forces normal force and tension force.

Q.7: State the limitations of Newton's laws of motion.

Ans. Limitations of Newton's Laws of motion: Although Newton's laws of motion are a fundamental set of principles and are applied in variety of situations. While they are very useful for describing the behavior of everyday objects, there are some limitations to their applicability.

(i) Newton's law are not readily applied on the very small scale; as one goes to extremely low energies on the atomic scale, position and acceleration are not well defined, where the concepts of quantum mechanics takes over.

(ii) Newton's laws are not applied for objects moving at high speed (speeds close to the speed of light) relativistic effects complicate the dynamics at high speeds and high energies. In such situations we would require to use relativistic mechanics.

However, Newton's laws are not exact but provide a good approximation on the large (macroscopic) scale and over the vast range of practical energies and forces. Newton's laws are still work spectacularly well in physics and engineering.

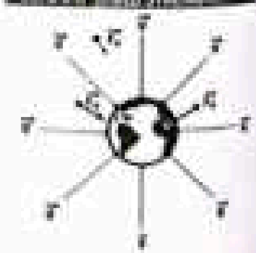
Q.8: Differentiate between mass and weight of body.

Ans. Difference between Mass and weight:

Sr.#	Mass	Weight
i.	Mass of a body is the quantity of matter possessed by the body.	Weight of a body is equal to the force with which Earth attracts the body towards its centre.
ii.	It is a scalar quantity.	It is a vector quantity.
iii.	It is represented by m.	It is represented by W.
iv.	It does not change with change of place.	It varies from point to point depending upon the value of g.
v.	It is measured by Physical balance.	It is measured by spring balance.
vi.	Its unit is kg.	Its unit is Newton.
vii.	Formula of mass is $m = \frac{F}{a}$	Formula of weight is $w = mg$

Q.9: What are gravitational field and gravitational field strength? Explain.

Ans. Gravitational Field: The region around a non-contact forces where a magnetic force is operative is termed as force field. Whereas the region around a massive object (such as earth, sun etc.) where gravitational force is operative is termed as gravitational field.



Gravitational Field strength: The gravitational field strength is the amount of force per unit mass acting on objects in the gravitational field. The value of 'g' is equal to the magnitude of the gravitational force exerted on a unit mass at that point, mathematically

$$g = F_g/m$$

Explanation: The gravitational field strength (g) is a vector with a magnitude of 'g' that points in the direction of the gravitational force.

The gravitational field strength 'g' for earth is shown in the figure 3.17. since, from newton's second law of motion:

$$\vec{a} = \frac{\vec{F}}{m}$$

similarly $$\vec{a}_g = \frac{\vec{F}_g}{m} = \vec{g}$$

Unit: In S.I units, gravitational field strength is measured in newton per kilogram (N/kg). It is a vector quantity that has the direction downward or toward the centre of Earth.

Since the gravitational field strength and the acceleration due to gravity are equal in magnitude, the same symbol, g is used for both. Therefore, on Earth's surface, g = 9.8 N/kg [↓]. Or g = 9.8 m/s^2 [↓].

The gravitational field strength is not the same everywhere. Gravitational force decreases as we move away from the surface of earth, therefore gravitational field strength also decreases. Also on different planets we have different gravitational field strengths as shown in table 3.2.

Table 3.2: Gravitational Field Strength in the Solar System

Planet	g (N/kg)
Mercury	3.7
Venus	8.9
Earth	9.8
Mars	3.7
Jupiter	24.7
Saturn	9.0
Uranus	8.7
Neptune	11.0
Sun	274

Q.10: Define momentum. What is its formula and unit? Is it a scalar or vector quantity? Show that units of momentum, Ns and kg m/s are equal.

Ans. Momentum: *The Product of the object's mass 'm' and velocity 'v' is called momentum, denoted by 'P'*

Mathematically:

$$\vec{P} = m\vec{v} \quad \text{\_\_\_\_\_\_\_} \quad (3.3)$$

Nature of Quantity: Momentum is a vector quantity that points in the same direction as the velocity.

Units: SI unit of momentum is kilogram-meter per second (kgm/s), or newton-second (Ns). Newton's second law is used to relate force and momentum.

Q.11: State and prove Newton's second law of motion in term of momentum.

Ans. Relation Between second Law of motion and momentum: A force 'F' produces acceleration 'a' in a body of mass 'm'. By Newton's second law of motion it is written as

$$F_{net} = ma \quad \_\_\_\_\_\_ \quad (1)$$

The acceleration produced changes the velocity of the body from initial velocity 'v_i' to final velocity 'v_f' during time interval 'Δt' then by definition of acceleration

$$a = \frac{\vec{V}_f - \vec{V}_i}{\Delta t} \quad \_\_\_\_\_\_ \quad (2)$$

Putting equation (2) in equation (1)

$$\vec{F}_{net} = m\frac{\vec{V}_f - \vec{V}_i}{\Delta t}$$

or

$$F_{net} = \frac{m\vec{V}_f - m\vec{V}_i}{\Delta t}$$

Hence
$$F_{net} = \frac{\vec{P}_f - \vec{P}_i}{\Delta t} = \frac{\Delta \vec{P}}{\Delta t} \quad \_\_\_\_\_\_ \quad (3.4)$$

The rate of change of linear momentum of a body is equal to the net force acting on the body. This means that for sudden change in momentum force is large and vice versa.

Example: For example, catching a ball with your bare hands will hurt depending on the force of the ball. However, if you allow your hands to move with the ball as you catch it, duration of time 'Δt' will increase, and force will be smaller, and your hands will hurt less.

Q.12: Define and Explain concept of impulse.

Ans. Impulse: *Impulse is the product of the force exerted on an object and the time interval over which the force acts, and is often given the symbol 'J'.*

Nature of Quantity: Impulse is a vector quantity, and the direction of the impulse is the same as the direction of the force that causes it.

Unit: It has the same S.I units as momentum.

Explanation: (i) Newton's second law enable us to write force and change in momentum relation as:

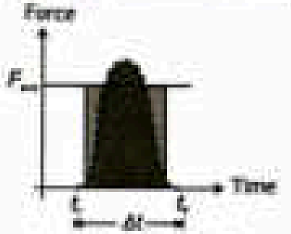
$$F_{net} = \frac{\vec{P}_f - \vec{P}_i}{t} = \frac{\Delta \vec{P}}{t} \quad \_\_\_\_\_\_ \quad (3.5)$$

$F_{net} \times t = \Delta P$ (3.5) This relation show that impulse is equal to change in momentum. Equation 3.6 enable us to define a new quantity termed as "impulse"

(ii) In many situations, the net force on the object is not constant and the force applied to an object changes non-linearly during its time of application. The equation 3.8 still applies, provided the net force 'F_{net}' is equal to the average force acting on the object over the time interval Δt.

For example, when a batter hits a cricket ball, initially the force is very small. Within milliseconds, the force is large enough to deform the ball. The ball then begins to move by return to its original shape and the force soon drops back to zero. Graph in figure 3.19 shows how the force changes with time. We can find the impulse by calculating the area under the curve in force versus time graph.

FIGURE 3.19



In many collisions, it is difficult to make the precise measurements of force and time that you need in order to calculate the impulse. The relationship between impulse and momentum provides an alternative approach to analyzing such collisions, as well as other interactions. By analyzing the momentum before and after an interaction between two objects, We can determine the impulse.

Q.13: Define an isolated system. State law of conservation of linear momentum. Explain with example.

Ans. Isolated System and Law of conservation of linear momentum: For an isolated system there is no net force acting 'F = 0', therefore Newton's second law in terms of momentum (equation 3.6) can be written as

$$0 = \frac{\Delta \vec{P}}{\Delta t} \quad \text{or} \quad 0 = \frac{\vec{P}_f - \vec{P}_i}{\Delta t}$$

$$\vec{P}_f - \vec{P}_i = 0 \quad \text{or} \quad m_f\vec{V}_f = m_i\vec{V}_i$$

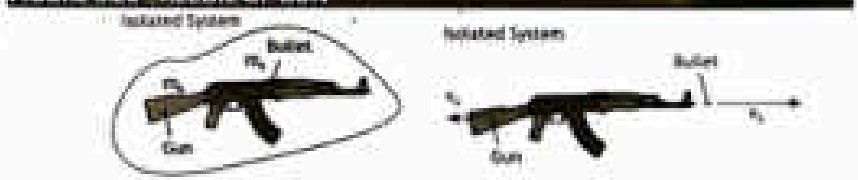
In the absence of external force (isolated system) the final momentum 'P_f' of the system must be equal to initial momentum 'P_i'. If no net external force acts on a system of particles, the total momentum of the system cannot change.

This enable us to write the law of conservation of momentum which states:

The momentum of an isolated system remains constant.

Explanation: (i) Consider an isolated system of bullet of mass m_B and gun of mass m_G. Such that before firing the total initial momentum ($P_i = 0$) of the system is zero shown in Figure

FIGURE 3.20 RECOIL OF GUN



After firing the bullet moves with velocity 'V_B' in one direction and the rifle recoils with velocity 'V_G' in the other direction such that the total final momentum ($P_f = 0$) is again zero. By conservation of momentum

$$\vec{P}_f - \vec{P}_i = 0 \quad \text{or} \quad m_B v_B + m_G v_G = 0$$

$$m_B v_B = -m_G v_G$$

$$\boxed{v_G = -\frac{m_B v_B}{m_G}}$$

Negative sign indicates that velocity of the gun is opposite to the velocity of the bullet, i.e. the gun recoil. Since mass of the gun is much larger than the bullet, therefore, the recoil is much smaller than the velocity of the bullet.

(ii) In rockets, hot gases produced by burning of fuel rush out with large momentum. The rockets gain an equal and opposite momentum, The rockets gain an equal and opposite momentum. Thereby causing them to accelerate.

SHORTRESPONSE QUSTIONS

Q.1: When a motor cyclist hit a stationary car, he may fly off the motor cycle and driver in the car may get neck injury. Explain.

Ans. The motor cyclist may be thrown off due to sudden change in velocity upon impact, while the driver in the car may experience much injury because neck is attached to sudden jerking motion, such as those caused by a collision.

Q.2: In autumn, when you shake a branch, the leaves are detached. Why?

Ans. As you shake a branch suddenly, the leaves of the branch come in motion immediately. The leaves try to keep their initial state that is the state of rest. For this reason, the leaves get detached from its branch as you shake a branch.

Q.3: Why it is not safe to apply brakes only on the front wheel of a bicycle?

Ans. When a cyclist applies only the front wheel brakes, the front wheel suddenly comes to rest while the back wheel tends to continue its motion along with the rider's body. Due to this the rider will feel a forward push and will fall to his front. That's why it is not safe to apply brakes only to the front wheel of a bicycle.

Q.4: Deduce Newton's first law of motion form Newton's second law of motion.

Ans. Newton's 2nd law of motion states that $\vec{F} = m\vec{a}$

If the applied net force is zero on a body, i.e., $\vec{F} = 0$, putting in above equation: $\vec{F} = m\vec{a}$, $0 = m\vec{a}$.
Either mass (m) is zero or acceleration (a) of body is zero. As mass of body cannot be equal to zero so acceleration will be zero. This means that if no external force is applied on a body, there will be no change in state of body i.e., a moving body will continue its uniform motion and a body at rest will remain at rest. This is the statement of Newton's 1st law of motion. Hence Newton's first law can be derived from second law of motion.

Q.5: Action and reaction are equal but opposite in direction. These forces always act in .pair. Do they balances each other? Can bodies move under action - reaction pair.

Ans. Action and reaction cannot cancel each other although both are equal in magnitude and Opposite in direction but both these forces act on two different bodies.

Explanation: Two equal and opposite forces on a single body cancel each other and the resultant force is zero. But in case of action-reaction, they act on two different bodies. Action is on one body and reaction on another body, they do not neutralize, this is result of motion e.g. while waking on earth body can move under action – reaction forces.

Q.6: A man slips on the oily floor; he wants to move out of this area. He is alone. He throws his bag to move out of this slippery area. Why is it so?

Ans. According to Newton's third law of motion, for every action there is an equal but opposite reaction. As the man throws his bag, for example in the forward direction, he will feel a force as a reaction in the backward direction. As action and reaction are equal in magnitude, as greater the force with which the bag is thrown in the forward direction greater will be the force on the man in the backward direction. Hence, he may come out of the oily floor without the help of anyone else.

Q.7: How would you use Newton's 3rd law of motion and law of conservation of momentum to explain motion of rocket?

Ans. Newton's third law of motion states that for every action, there is an equal but opposite reaction. In case of rockets, the fuel burns out from the lower part of the rocket which gives propulsion to the rocket and it moves in the forward direction.

The propulsion of a rocket through space can be explained in terms of momentum conservation. Hot gases produced by the burning of the fuel rush out at the rear end of the rocket at a greater speed.

The equal and opposite reaction of the backward going gases pushes the rocket in forward direction.

Q.8: Why are batsman gloved padded with foam?

Ans. The batsman gloves are padded with foam in order to increase the impact time thus reducing acceleration ($\vec{a} = \frac{\Delta\vec{v}}{t}$) and ultimately force acting on hands of batsman given by equation F = ma will decrease and his hands will not hurt.

Q.9: Where will your weight be greater, near earth or near moon? What about mass?

Ans. The weight of an object is given by formula w = mg. Here 'm' and 'g' are mass and acceleration due to gravity. Mass 'm' is a constant and acceleration due to gravity near Earth is 9.8 m/s^2. As compare to its value on moon. i.e., 1.6 m/s^2. Hence your weight will be greater near Earth while mass remains same near Earth and near moon because it is quantity of matter which is same everywhere.

Q.10: When Ronaldo kicks the ball, at the highest point of ball both Earth and ball attract each other with the same magnitude of force. Why then the ball moves towards Earth and not the Earth?

Ans. Ball and Earth attract each other with an equal and opposite gravitational force. But the mass of Earth is very large as compared to the mass of ball. The gravitational force acting on earth produces negligible acceleration in the Earth due to high mass where as mass of ball is much smaller as compared to the earth, therefore the same force produces a considerable acceleration in the ball that is why we are able to see a ball moving toward earth not earth moving toward the ball.

Multiple Choice Questions

Q.1: Inertia of a body is related to which of the following quantities:
(a) mass (b) force (c) weight (d) friction

Q.2: A force on 5N is applied to a body weighting 10N. Its acceleration in m/s^2 is:
(a) 0.5 (b) 2 (c) 5 (d) 50

Q.3: SI unit of linear momentum is:
(a) $kgm^{-1}s^{-1}$ (b) $kgm^{1}s^{-1}$ (c) N m (d) $kg\ m\ s^{-1}$

Q.4: The rate of change of momentum of free falling body is equal to its:
(a) momentum (b) velocity (c) weight (d) size

Q.5: Change in momentum of a body is equal to:
(a) (force)(velocity) (b) (force)(time) (c) (mass)(time) (d) force

Q.6. A book of mass 5 kg is placed on the table, the magnitude of net force acting on the book is:
(a) 50N (b) 5 N (c) 25N (d) 10N

Q.7. Thrust force is a consequence of which law of motion:
(a) first (b) second (c) third (d) fourth

Q.8: A force acts on a body for 2 seconds and it produces 50 kg m/s change in its momentum. The force acting on the body is:

(a) 100 N (b) 50 N (c) 25 N (d) 2 N

Q.9: At the fairground, the force that balances your weight is:

(a) gravitational force (b) centripetal force
(c) electrostatic force (d) frictional force

Q.10: When a hanging carpet is beaten by stick. Dust flies off the carpet. It is mainly due to:

(a) Action force on carpet (b) Reaction force by carpet
(c) Inertia of dust (d) Rate of change of momentum of carpet

Q.11: A bucket having some water is revolved in vertical circle. Water does not spill out, even the bucket is upside down, due to:

(a) Weight of water (b) Centrifugal force on water
(c) Inertia of water (d) Action and Reaction balance each other

Q.12: The force which moves the car is:

(a) Force developed by engine (b) Force of friction between road tyre
(c) uniform velocity (d) Water spilt on the road

Q.13: N kg-1 is equivalent to:

(a) $m\,s^{-1}$ (b) $m\,s^{-2}$ (c) $kg\,m\,s^{-1}$ (d) $kg\,m\,s^{-2}$

Q.14: An object of mass 1 kg placed at earth's surface experiences a force of:

(a) 1 N (b) 9.8 M (c) 100 N (d) any value

Q.15: Net force on the body falling in air with uniform velocity is equal to ________:

(a) Weight of the body
(b) are resistance on the body
(c) difference of weight of body and air resistance on it
(d) zero

Answer Key

1.	(a)	2.	(c)	3.	(d)	4.	(c)	5.	(b)
6.	(a)	7.	(c)	8.	(c)	9.	(b)	10.	(c)
11.	(b)	12.	(b)	13.	(b)	14.	(b)	15	(d)

Examples

3.1: If the same engine is installed in a bus and car that applies a force of 3000 N. What acceleration will this engine produce in a bus of mass 12,000 kg and a car of mass 1200 kg.

Ans. Given:-

Mass of bus = m_b = 12000 kg
Mass of car = m_c = 1200 kg
Force = F = 3000 N
Acceleration in bus = a_b = ?
Acceleration in car = a_c = ?

Solution:

From Newton 2nd law of motion $a = \frac{F}{m}$

For bus $a_b = \frac{F}{m_b}$, Putting values $a_b = \frac{3000N}{12000kg} = \frac{3000kgm/s^2}{12000kg}$

Therefore $a_b = 0.25\ m/s^2$ Answer

For car $a_c = \frac{F}{m_c}$, Putting values $a_c = \frac{3000N}{1200kg} = \frac{3000kgm/s^2}{1200kg}$

Therefore $a_c = 2.5\ m/s^2$ Answer

3.2: Mass of your school bag is 8 kg. How much will it weigh (a) here on Earth and on (b) the surface of moon? [Take acceleration due to gravity for Earth as $g_E = 9.8\ m/s^2$ and for Moon as $g_M = 1.625\ m/s^2$].

Ans. Given:-

Mass of school bag = m = 8 kg Acceleration due to gravity for Earth = g_E = $9.8\ m/s^2$
Acceleration due to gravity for Moon g_m = $1.625\ m/s^2$
(a) Weight on surface of Earth W_E = ?
(b) Weight on surface of Moon W_m = ?

Solution:

Weight of a body is given by: W = mg

(a) The weight on surface of earth is $W_E = mg_E$

Putting values $W_E = 8kg \times 9.8\ m/s^2$

$W_E = 78.4 kg\ m/s^2 = 78.4\ N$ Answer

(a) The weight on surface of moon is $W_m = mg_m$

Putting values $W_m = 8kg \times 1.625\ m/s^2$

$W_m = 13\ kg\ m/s^2 = 13\ N$ Answer

3.3: A box weighs 400 N on earth while 150 N on an unknown planet. Find the gravitational field strength on that planet.

Ans. Given:-

Weight on Earth = W_E = 400 N
Weight of unknown Planet = W_u = 150 N
Gravitational field strength on Earth = g_E = $9.8\ m/s^2$
Gravitational field strength on the unknown planet = g_u = ?

Solution:

Since, weight of a body is the product of its mass and acceleration due to gravity, given by:

$$W = mg \quad \text{or} \quad m = \frac{W}{g}$$

Since, mass of a body remains constant, therefore,

$$\frac{W_E}{g_E} = \frac{W_u}{g_u} \quad \text{or} \quad g_u = \frac{W_u}{W_E}\, g_E$$

Putting values $g_u = \frac{150_N}{400_N} \times 9.8\ m/s^2$

$g_u = 3.675\ N/kg$ Answer

3.4: A golfer hits a ball having mass 45g. If after the shot, the ball travels with a speed of 80 m/s, what magnitude of momentum does the golfer imparted to ball.

Given:-

Mass of ball = m = 45 g = 0.045 kg Velocity of ball = v = 80 m/s
Momentum of ball = P = ?

Solution:

From the mathematical form of linear momentum P = mv
For magnitude ignoring the vector signs: P = mv

Putting values P = 0.045 kg × 80 m/s

Therefore, P = 3.6 kg m/s Answer

3.5: Why it is difficult to stop if their brakes fail and are travelling from an inclined road:
(a) A car of mass 1200 kg moving with a velocity of 8 m/s in 5 seconds,
(b) A truck of mass 10,000 kg moving with the same velocity in the same time?

Ans. Given:-

Mass of car = m_c	=	1200 kg
Mass of truck = m_t	=	10,000 kg
Initial Velocity v_i	=	8 m/s
Change in time Δt	=	5 s
Final Velocity v_f	=	0 m/s (As both car and truck have to stop)
(a) Average force required to stop car F_c	=	?
(b) Average force required to stop truck F_t	=	?

Solution:

From the relation between force and momentum: $F_{net} = \frac{\Delta P}{\Delta t} = \frac{mv_f - mv_i}{\Delta t}$ ——— (1)

Putting values in equation 1 for car: $F_c = \frac{(1200)(0) - (1200)(8)}{5}$

Therefore $F_c = 1920$ N Answer

Putting values in equation 1 for truck: $F_t = \frac{(10{,}000)(0) - (1200)(8)}{5}$

Therefore $F_t = 16{,}000$ N Answer

It would be difficult to stop the car and truck because large forces are required to stop them.

3.6: Ahmad fired a bullet of mass 17 g from his hunting gun, of mass 3 kg. If the velocity of the bullet were 350 m/s, what would be the recoil velocity of the air gun?

Given:-

Mass of Gun = m_g	=	3 kg
Mass of bullet = m_B	=	17 g = 0.017 kg
Velocity of bullet after firing V_B	=	350 m/s
Velocity of gun after firing V_g	=	?

Solution:

By law of conservation of momentum the total final momentum must be zero, therefore

$m_B v_B + m_g v_g = 0$ or $m_g v_g = - m_B v_B$ Hence $v_g = \frac{-m_B v_B}{m_g}$

Putting values $v_g = \frac{-0.017 \times 350}{3}$

Therefore $v_g = -1.98$ m/s

Numerical Problems

Q.1: A boy is holding of mass 2 kg. How much force is he applying on the book? If he moves it up with acceleration of 3 m/s², How much should he apply total force in the book?

Ans. Given:-

Mass = m	=	2 kg
Force = F_g	=	mg (Force is equal to weight)
F_g	=	2 x 9.8
F_g	=	19.6 N
m	=	2 kg
acceleration = a	=	3 m/s²
To Find F_t	=	?

As we know $F_a = ma$

Putting values, we have $F = 2 \times 3 = 6$ N $\quad F_t = F_g + F_a$

Total force $F_t = 19.6 + 6 = 25.6$ N

Thus total force on book will be 25.6 N

Q.2: A girl of mass 30 kg is running with velocity of 4 m/s. Find her momentum.

Ans. Given:-

Mass = m	=	30 kg
Velocity = v	=	4 m/s
Momentum = P	=	?

As we know $P = mv$

Putting values, we have $P = 30 \times 4 =$ **120 kg.m/s**

Q.3: A 2 kg steel ball is moving with speed of 15 m/s. It hits with bulk of sand and comes to rest in 0.2 second. Find force applied by sand bulk on the ball.

Ans. Given:-

Mass = m	=	2 kg
Initial velocity v_i	=	15 m/s
Final velocity v_f	=	0 m/s
Time taken Δt	=	0.2 sec
Force applied F_s	=	?

As we know $F = \frac{\Delta P}{\Delta t} = \frac{mv_f - mv_i}{\Delta t} = \frac{0 - 2 \times 15}{.2} = -150$ N

Thus total force applied on ball will be -150 N

(The negative sign shows that force will be opposite to the direction of motion of ball).

Q.4: A 100 grams bullet is fired from 5 kg gun. Muzzle velocity of bullet is 20 m/s. Find recoil velocity of gun.

Ans. Given:-

Velocity of Bullet U_b	=	0 (Bullet is at rest before firing)
Velocity of Gun U_g	=	0 (gun is at rest before firing)
Mass of bullet m_b	=	100 kg
Velocity of bullet V_b	=	20 m/s
Mass of gun m_g	=	5 kg
Recoil Velocity of gun V_g	=	?

As we know $m_b U_b + m_g U_g = m_b V_b + m_g V_g$ (Law of conservation momentum)

Putting values, we have

$0 + 0 = \frac{100}{1000} \times 20 + 5V_g$

$-2 = 5V_g$

or $V_g = \frac{-2}{5}$

$V_g = -0.4$ m/sec

Thus recoil velocity of gun will be **-0.4 m/s** (The negative sign is due to recoil of gun.)

Q.5: A robotic car of 15 kg is moving with 25 m/s. Brakes are applied to stop it. Brakes apply constant force of 50 N. How long does the car take to stop?

Ans. Given:-

mass m	=	15 kg
Initial Velocity V_i	=	25 m/s
Final velocity V_f	=	0 m/s
Force F	=	-50N (Brakes force in opposite direction)
Time taken Δt	=	?

As we know $F = \frac{\Delta P}{\Delta t} \Rightarrow \Delta t = \frac{\Delta P}{F} = \frac{mv_f - mv_i}{F} \Rightarrow \frac{0 - 15 \times 25}{50} \Rightarrow -7.5$s

UNIT 04 Dynamics II

Q.1: Define (i) line of action of force (ii) parallel forces (iii) like and unlike parallel forces with examples.

Ans. **(i) Line of action of Force:** Some times we need to extend the direction in which the force acts. The line along which a force acts is called the line of action of the force as shown in figure 4.1.

FIGURE 4.1 LINE OF ACTION OF FORCE

Multiple forces may act on bodies at same time, under such conditon we have to determine the net force 'F_{net}'.

However in such situations the line of action of these forces become importants. Suppose you are trying to move a heavy piece of furniture, if a friend helps and you both push toghether, now the ease at wich the furniture will depend on the line of action of both forces on the obejct.

(ii) Parallel Force: If the directions of forces are parallel to each other, even if they are in opposite direction, those forces are called parallel force'.

(iii) Like and unlike parallel forces: *If they are in the same direction they are called 'like parallel force. If they are in the opposite direction they will be known as 'Unlike' parallel Force.*

FIGURE 4.2 PARALLEL FORCES

Examples:

(i) For example, when we push a cart with both hands, we are applying like parallel forces from each support as shown in the figure 4.2 (a)

(ii) when we apply force with our both hands on handle of a bike to tun it the force from one hand may be greater or equal, we are applying unlike parallel forces as shown in the figure 4.2 (b).

Q.2: What is moment of force or torque? On what factors it depends? Write its methamatical formula.

Ans. **Moment of Force or Torque:** Turning effect produced in a body about a fixed point due to applied force is called moment of force (or torque).

Explanation: Moment of force or torque is a vector quantity and have the SI unit as N m.

FIGURE 4.3 MOMENT OF FORCE OR TORQUE

Just like force causes change in motion, moment of force causes change in rotation. This means that moment of force plays the same role in rotational motion as force in translational motion.

It implies that an object at rest tends to remain at rest, and an object that is rotating (or spinning) tends to spin with a constant angular velocity, unless it is acted on by a nonzero next external moment of force. Similarly, the moment of force tend to produce acceleration in rotational (or spinning) motion.

The moment of force or torque 'τ' is equal to the magnitude of the force 'F' multiplied by the perpendicular distance from the axis of rotation to the line of action of force 'd'.

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Mathematically:

$$\tau = F \times d \quad \_\_\_\_\_\_ \quad (4.1)$$

Here the perpendicular distance from the axis of rotation 'd' is termed s moment arm. So we can redefine moment of force as the product of force and moment arm.

Moment of force can cause rotation in a wrench to tighten a nut, for a wrench the axis of rotation is at the center of the nut as shown in the figure 4.3 (a). similarly moment of force can cause the rotation in a door, for door the axis of rotation is at its hinges as shown in the figure 4.3 (b).

Increasing the magnitude of applied force 'F' or the moment arm 'd' increases the moment of force and vice versa. Thus for same force we can use a long handle wrench to produce more moment of force or torque.

However moment arm 'd' and force 'F' is not always perpendicular, in this situation we have to extend the line of action of force applied 'F' and take the moment arm 'd' as perpendicular distance from the axis of rotation to the line of action of force as shown in figure.

Moment arm is key to the operation of the lever, pulley, gear, and many other simple machines.

Types of Moments: There are two senses of rotation. If the force is capable of rotating the body in clockwise direction, the moment is known as clockwise moment. Similarly, the force is capable of produces rotation in the anti-clockwise direction, the torque is known as anti-clock wise moment.

Sign Convention in Moments: Conventionally, clockwise moment is taken as negative, whereas anticlockwise moment is taken as positive.

Torque is Rotational Force: Newton's laws when applied to rotating bodies we see that moment of force is rotational analogue for force. It implies that an object at rest tends to remain at rest, and an object that is rotating (or spinning) tends to spin with a constant angular velocity, unless it is acted on by a nonzero net external moment of force. Similarly the torque tend to produce acceleration in rotation (or spinning).

Q.3: Define center of mass. What is effect of mass distribution in a body on its center of mass?

Ans. **Center of Mass (C.M:** A rigid body (a body that does not deform or change shape) is made of large number of small interconnected particles. The center of mass (abbreviated CM) of a ridgid body is the point about which mass is equally distributed.

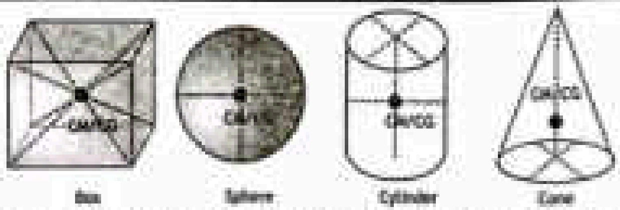
Explanation: If the line of action of force passes through the center of mass of a body it will not produce any rotation in it. As an example, consider the motion of the center of mass of the hammer as shown in the Figure 4.4. When the hammer is thrown from handler the center of mass follows a smooth parabolic path while other points in the rotating hammer travel along more complicated paths.

Q.4: Define and Explain center of gravity. (OR) What is center of gravity? Where will be center of gravity of these regular shaped bodies; circular plate, rectangular and square shaped plate, triangular shaped palte, cylinder, sphere (also draw figures to support your anser). Differentiate between center of mass and center of gravity.

Ans. **Center of Gravity:** The center of gravity (abbreviated 'CG') is the point where whole weight of the body appear to act.

Explanation: The center of mass and center of gravity (CM/CG) are same for small objects. But since the value of acceleration due to gravity decrease with altitude, therefore for tall objects (like mountains and building) there is a slight difference.

FIGURE 4.5 CENTER OF MASS OF SYMMETRICAL OBJECTS



The CM/CG of a homogeneous cube or sphere is at its geometric center, whereas the CM/CG of a right circular cylinder or cone is on the axis of symmetry, and so on as shown in the figure 4.5. Similarly the CM/CG of a uniform wooden rod is at its mid-point, and therefore it can balanced from its center.

Q.5: How can you find center of gravity of an irregular shaped thin sheet of plastic?

Ans. Determination of center of gravity of irregular shaped thin sheet: For irregular objects one way to determine the center of gravity is to hang it randomly from at least three different points, and then connecting vertical lines drawn with the help of plumb line.

Irregular object (sheet) as shown in figure 4.6.

The CM/CG doesn't always lie inside the mass and may change its location depending upon the orientation of the object. For example the arm is stretched out the CM/CG lies inside the mass distribution, but when the arm is bent, the CM/Cg shifts to the new location outside the mass distribution as shown in figure 4.7.

CENTER OF GRAVITY MAY CHANGE POSITION

Q.6: Define Equilibrium and Discuss conditions of equilibrium in detail.

Ans. Equilibrium: Forces produce change in translational motion, therefore, when the net force on the object is zero the object will either be at rest or move with uniform velocity in a straight line. The same is also true for the moment of force which produces change in rotational motion, therefore, when the net torque on the object is zero the object will not rotate or will rotate with uniform velocity. The effect of force is to produce change in translational motion and effect of moment of force or torque is to produce change in rotational motion.

Equilibrium is the state in which all the individual forces and moment of forces or torques exerted upon an object are balanced. This means that net force and torque on the object are zero the object is said to be in equilibrium.

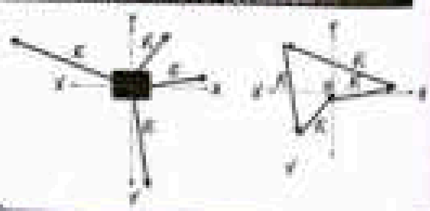
CONDITION OF EQUILIBRIUM: Therefore for complete equilibrium two conditions must be met.

A. First Condition of Equilibrium: When the vector sum of all the forces acting on the body is ZERO) then the first condition of equilibrium is satisfied. Mathematically if F_{net} is the sum of forces $F_1, F_2, F_3, \ldots, F_n$ then

$$F_{net} = F_1 + F_2 + F_3 + \ldots\ldots\ldots F_n = 0$$

For an object to satisfy the first condition of equilibrium the force polygon must close.

For example if there are four forces on the object and their vector sum is zero as shown in the figure 4.8, the first condition of equilibrium will be satisfied and the object will either be at rest or will move



with uniform velocity. Mathematically if F_{net} is the sum of forces F_1, F_2, F_3, and F_4 by head to tail rule it must be ZERO.

$$F_{net} = F_1 + F_2 + F_3 + F_4 = 0$$

B. Second Condition of equilibrium: When the vector sum of all the torques acting on the body is ZERO then the second condition of equilibrium is satisfied. τ_{net} is the sum of torques $\tau_1, \tau_2, \tau_3 \ldots \tau_n$ then mathematically

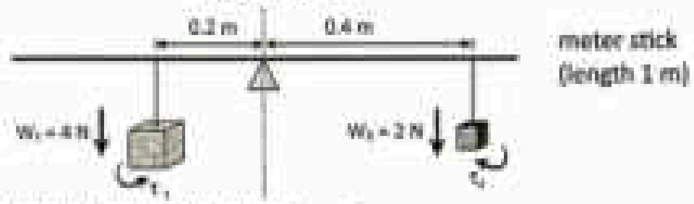
$$\tau_{net} = \tau_1 + \tau_2 + \tau_3 + \ldots\ldots\ldots\ldots \tau_n = 0$$

For complete equilibrium both the first and second conditions of equilibrium must be satisfied.

PRINCIPLE OF MOMENTS: Second condition of equilibrium is also called the principle of moments, which states that 'For an object in equilibrium, the sum of the clockwise moments taken about the pivot must be equal to the sum of anti-clockwise moments taken about the same pivot'. To balance torques or moment of force, the perpendicular distance from the axis of rotation play an important role. By convention the anticlockwise torques are taken as positive while clockwise torques are taken as negative, which leads to second condition of equilibrium that the sum of both these torques must be zero, For example, Let a uniform meter stick is balanced from center. Now if we suspend weight of 4 N at 0.1 m from the pivot, it exerts the same torque as 2 N weight at 0.4 m from the fulcrum. A uniform meter stick will balance on pivot under these conditions as shown in the figure 4.9.

Similarly three or more torques around a pivot (as axis of rotation) can also balance each other.

FIGURE 4.9 VERIFICATION OF PRINCIPLE OF MEMENTS



Q.7: Define and Discuss types of Equilibrium.

Ans. Types of Equilibrium:

The equilibrium is divided into two types

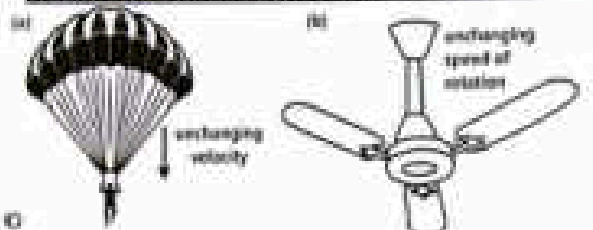
A. Static equilibrium: When a body is at rest under the action if several forces acting together and several torques acting the body is said to be in static equilibrium. For example a book resting on the table is in static equilibrium, the weight mg of the book is balanced by a normal reaction force from the table surface.

B. Dynamic equilibrium: When a body is moving at uniform velocity under the action of several forces acting together the body is said to be in dynamic equilibrium. It is further divided in to two types.

i. Dynamic Translational Equilibrium: When a body is moving with uniform linear velocity the body is said to be in dynamic translational equilibrium. For example a paratrooper falling down with constant velocity is in dynamic translational equilibrium as shown in figure 4.10 (a).

ii. Dynamic Rotational equilibrium: When a body is moving with uniform rotation the body is said to be in dynamic rotational equilibrium. For example when the ceiling fan is rotating with unchanging speed as shown in figure 4.10 (b).

FIGURE 4.10 : DYNAMIC EQUILIBRIUM



Q.8: Define and Explain three states of equilibrium.

Ans. There are three states of Equilibrium:

(i) STABLE EQUILIBRIUM: A body is in stable equilibrium if when slightly tilt and after releasing it returns to its original position, its centre of mass rises when it is displaced. It regain its position back because its weight has a Moment of force about the point of contact that acts to reduce the displacement. For example consider a book lying on the table, Tilt the book slightly about its one edge by lifting it from the opposite side, It returns to its previous position when sets free, Such a state of the body is called a stale equilibrium,

(ii) UNSTABLE EQUILIBRIUM: A body is in unstable equilibrium if it moves further away from its previous position when slightly displaced and released, its centre of mass falls when it is displaced, because there is a moment which increases the displacement. for example Take a pencil and try to keep it in the vertical position on its tip. Whenever you leave it, the pencil topples over about its tip and falls down. This called an unstable equilibrium.

FIGURE 4.12 : STABLE, UNSTABLE AND NEUTRAL EQUILIBRIUM

(iii) NEUTRAL EQUILIBRIUM: A body is in neutral equilibrium if it stays in its new position when displaced. its center of mass does not rise or fall because there is no moment to increase or decrease the displacement. For example take a ball and place it on a horizontal surface. Roll the ball over the surface and leave it after displacing from its previous position. It remains in its new position and does not return to its previous position. This is called a neutral equilibrium. The Illustrations in figure 4.12 shows the three states of equilibrium for the cone and ball and bowl,

Q.9: Define and Explain stability.

Ans. **Stability:** 'A measure of the ability of an object to return to its original position when the force that changed its position is removed is called stability'. Stable objects are very difficult to topple over, while unstable objects topple over very easily.

The position of the center of gravity or center of mass (CG/CM) of a body affects whether or not it topples over easily. This is important in the design of such things as tall vehicles (which tend to overturn when rounding a corner), racing cars, reading lamps and even drinking glasses.

Q.10: Propose how the stability of an object can be improved. Illustrate the applications of stability of physics in real life.

Ans. **Improvement in system:** An object's stability can be improved by:

(a) lowering the center of mass; or

(b) increasing the area of support: or

(c) by both.

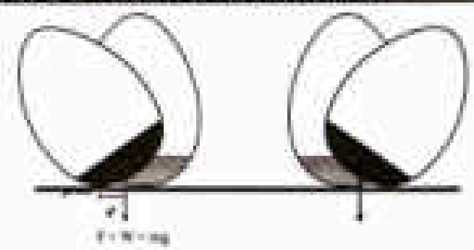
When the object's center of mass is directly beneath the point of support, it is in a stable equilibrium state. The center of mass represents the average position of the mass distribution within the object. In simple terms, "vertically below" means that the center of mass is aligned vertically beneath the point of support.

When an object is in stable equilibrium, it means that if it is slightly disturbed or tilted, it has a tendency to return to its original position. This is because the gravitational force acting on the object causes it to rotate around the point of support, and the object's weight acts through its center of mass. As a result, the object naturally realigns itself to maintain its stable equilibrium state,

FIGURE 4.13 : SELF BALANCING TOY

Various toys and equipment use the principle of stable equilibrium to regain their balance after being disturbed. These objects are often called "self-righting" or "self-balancing" toys. They are designed with their center of mass below the support point and have a specific weight distribution that helps them restore their original position. These objects might include balancing birds, wobbling dolls, or weighted-bottom drinking cups, all of which exhibit the stable equilibrium principle as shown in figure 4.13

FIGURE 4.14 : EGG SHAPED SELF BALANCING TOY



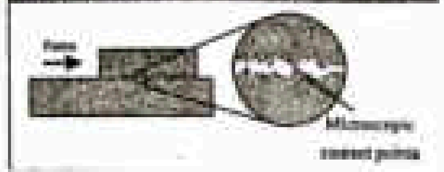
Once such toy is of shape of an egg, when it is tilted, the position of the pivot changes because of its round bottom. In figure 14.14 (a), when tilted to the left, the weight "W" from the center of gravity (CG) is to the right of the pivot with moment arm (perpendicular distance) 'd'. This creates a clockwise moment that makes the toy turn clockwise. Due to inertia, the toy will go past the vertical position and tilt to the right, as shown in the figure 14.14 (b). Similarly, since the weight is to the left of the pivot, it creates an anti-clockwise moment.

Therefore, this toy always has a restoring mechanism that brings it back to its vertical position, where the weight is directly above the pivot. In the position, the weight passing through the pivot does not create any moment (no perpendicular distance). Hence, the toy will be at rest.

Q.11: Define and Explain Friction. (OR) How friction can be reduced? What are advantages and disadvantages of friction. Explian with examples.

Ans. Friction: The resistance to relative motion that occurs whenever two materials are in contact with each other, whether they are solids, liquids, or gases. Since it is a force therefore it is a vector quantity and has unit as newton (N) Friction (denoted by letter 'f ').

FIGURE 4.15



Explanation: Friction always acts in a direction to oppose motion. If you push a solid block along a floor to the right, the force of friction on the block will be to the left. When an object falls downward through the air, the force of friction, air resistance, acts upward.

Microscopic description of friction: Every surface is rough, even surfaces that appear to be highly polished can actually look quite rough when examined under a microscope as shown in figure 4.15. There is no such thing as a perfectly flat surface. As a result the two surfaces that are touching are not really touching across the entire area that appears to be touching.

FIGURE 4.16 BICYCLE BREAKS

Thus roughness of both surfaces interlock which makes friction.

Sliding friction is the resistance created by any two objects that slows the rolling wheels

It is the sliding friction between the brake pads and our bike rims, that slows the rolling wheels so we can stop our bike in time.

Rim brakes, are the most effective and most popular bicycle brakes, as they provide adequate Braking power without too much maintenance, They are controlled by hand a levers which are attached to the actual brake by a cable. When the rider pulls on the brake lever the cable attached to it moves the two pads, break leather press against the rim, causing the wheel to slow down due to friction as shown in figure 4.16.

ADVANTAGES AND DISADVANTAGES OF FRICTION: Friction is required in many situations, for example

(i) Friction between the soles of our shoes (or feet) and the ground help us walk.
(ii) Friction between tyre and road helps to drive cars.
(iii) Friction holds the screw and nails in wood.

Friction can sometime be a hindrance, for example

(i) It slows down moving objects and causes heating of moving parts in machinery.
(ii) Energy is wasted to overcome friction in machinery.
(iii) Produce wear and tear.

METHODS OF REDUCING FRICTION: There are many ways to reduce unwanted friction, few are discussed below.

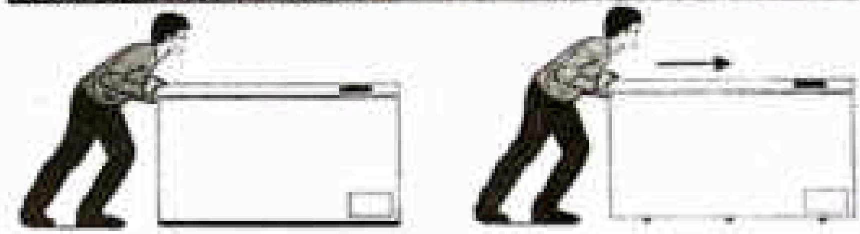
(i) **By polishing:** If we polish the rough surfaces, they become smooth and friction is reduced.
(ii) **By using Ball Bearing:** This method converts the sliding friction is converted into rolling friction by use of ball bearings.
(iii) **By applying Lubricants (oil or Grease) to surfaces:** Friction of certain liquids is less than that of solid surfaces, therefore, oil or grease is applied between the parts of machinery.

Q.12: Define Rolling friction.

Ans. Rolling Friction: If we set a heavy spherical ball, ring, or cylinder rolling, it experiences an opposing force called rolling friction. When a body rolls over a surface, the force of friction is called rolling friction.

This is reason why discovery of the wheel has been a major milestone in human history. It is rolling friction that helps a heavy deep freezer with wheels to easily move as shown in figure 4.18.

FIGURE 4.18 : ROLLING FRICTION



Q.13: Define and Explain Fluid and Fluid friction.

Ans. Fluid: A fluid is a collection of molecules that are held together by weak cohesive forces and the forces exerted by the walls of container. Both liquids and gases are fluids as they can flow and can exert force on the walls of their container.

Fluid Friction: When an object moves through a fluid, the fluid exerts a retarding force that tends to reduce the speed of the object. The moving body exerts a force on the fluid to push it out of the way. By Newton's third law, the fluid pushes back on the body with an equal and opposite force. This retarding force experienced by an object moving through a fluid is called the drag force, which is the result of fluid friction.

FIGURE 4.19 FLUID FRICTION

Explanation: For example when you extend your hand out of the window in a moving vehicle as shown in figure 4.19. If you set the palm of your hand in the direction of motion you can observe the fluid friction and the drag force it exerts on your palm. You can also see variation in the drag force by changing its orientations.

The drag force depends upon the

Size, shape and orientation of the object

Type (Properties) of the fluid

Speed of the object relative to the fluid

Skydivers and swimmers change their effective size and orientation by bending, twisting and stretching their body parts. This allow them to manipulate drag and thereby allowing them to control speed and direction of motion. During free fall the objects does not speed up indefinitely. The speed of free falling object initially increases because of weight of the object, but as the speed increases the drag force also increase, slowing the object down.

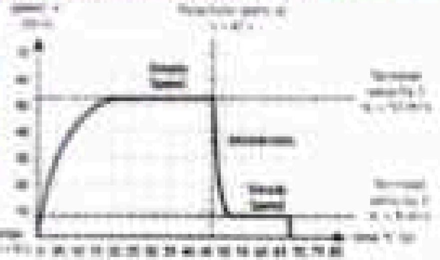
A point reaches where both the weight and drag force become equal and dynamic translational equilibrium is achieved. The object has now attained its maximum velocity termed as terminal velocity. At terminal speed, the diver's acceleration is zero; in other words, the speed remains constant.

Q.14: Define and Explain terminal velocity (OR) Analyse the dynamics of an object reaching terminal velocity.

Ans. **Terminal Velocity:** The constant maximum velocity that is attained and maintained by an object while falling through air (or any other resistive medium) is called terminal velocity.

Explanation: For Humans, terminal speed in air is about 53 m/s or 190 km/h. After the parachute opens, the terminal speed is reduced to between 5 m/s and 10m/s, as shown in figure 4.20.

FIGURE 4.20: SPEED TIME GRAPH OF PARACHUTE JUMP



Frictional dissipation: Dissipative force decreases the mechanical energy in a system. Dissipative forces acting on an object always oppose the motion of the object, for example in case of the sky diver, when the parachute opens some energy is dissipated into the air thereby increasing its temperature. The sky diver safety depends on air resistance as a dissipative force.

Fig 4.21 (a)

In winter when we rub our hands together we feel the sensation of warmth as shown in figure 4.21 (a). It is because friction causes the increase in the temperature our hands, which makes our hands war. Similarly you would have noticed shooting stars (a small piece of rock or dust that hits Earth's atmosphere from space) as shown in figure 4.21 (b). when they plow through the atmosphere, meteors are heated, and they glow. A meteor compresses air in front of it. The air heats up, in turn heating the meteor. The intense heat vaporizes most meteors, creating what we call shooting stars.

Fig 4.21 (b)

Q.15: Define centripetal force. Describe the motion of a body in a circular path under the action of centripetal force.

Ans. **Centripetal Force:** The force that pulls an object out of its straight-line path and into a circular path is called centripetal (center-seeking) force.

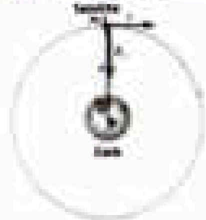
Explanation: (i) when the speed of the moving object does not change as it travels in the circular path is called uniform circular motion.

The speed of the object may remain constant however the direction is continuously changing, giving rise to a change in velocity and an acceleration a shown in figure 3.22. This acceleration is perpendicular (or at a right angle) to the velocity. In uniform circular motion, it is towards the center of the circle called centripetal acceleration.

Now there must be some unbalanced force acting on the object which is pulling it towards the center.

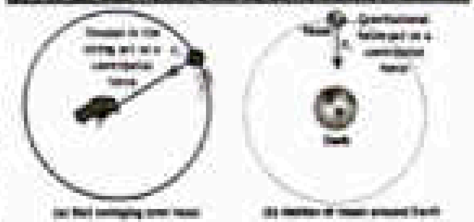
(ii) Consider a communications satellite that is moving at a uniform speed around Earth in a circular orbit as shown in figure 4.23. According to the first law of motion there must be some unbalanced force acting on the satellite that is pulling it out of a straight-line path. This unbalanced force is termed as centripetal force. The magnitude of the centripetal force 'F', of an object with a mass m, that is moving with velocity v, in a circular orbit of a radius r, is:

FIGURE 4.23: SATELLITE



$$F_c = \frac{mv^2}{r} \quad \text{------ (4.4)}$$

FIGURE 4.24: CENTRIPETAL FORCE EXAMPLES



Equation 4.4 gives the magnitude of centripetal force, where negative sign in dictates that force is directed towards the center of the circular path.

Perhaps you have swung a ball on the end of a string in a circle over your head. Once you have the ball moving, the tension on the string keeps it moving in a circular path as you twirl it. That tension is centripetal force, which pulls the ball from its natural straight-line path into a circular path as shown in figure 4.24 (a). The force that keeps a planets in orbit around sun is centripetal force, which, in this case is the gravitational force". This center is exactly where the Sun is located. In the case of the Moon, the centripetal force acting on it directed towards the center of the Earth as shown in figure 4.24 (b).

Q.16: Identify different sources of centripetal force in real life examples.

Ans. Examples of centripetal force:

(i) Artificial and natural satellites. The necessary centripetal force is provided by the gravitational force.

(ii) Flywheel spinning on the shafts. The frictional force between fly wheel and shaft provides necessary centripetal force.

(iii) Nuclear particles in accelerators such as cyclotron and Betatron. The necessary centripetal force is supplied by coulomb's force.

(iv) The electron revolving around the nucleus. The necessary centripetal force is supplied by coulomb's force of attraction between electron and nucleus.

(v) The car taking a turn along a curved path. The necessary centripetal force is supplied by the frictional force between the ground and the tyres of the car.

(vi) When a stone is tied at one end of a string, rotated from the other end of string held in hand in horizontal circle, then the necessary centripetal force is supplied by the tension in the string.

(vii) The motion of the planet moving around the sun is a nearly circular orbit the centripetal force provided by the circular orbit is provided by the gravitational attraction between sun and the planet.

Q.17: Define Satellite, Differentiate between natural and artificial satellites. Define orbital velocity. Calculate the average orbital speed for a satellite rotation around the earth.

Ans. **Satellite:** *An orbit is a regular, repeating path that one object in space takes around another one. An object in an orbit is termed as a satellite.*

Types of Satellite:

(i) A satellite can be natural, like Earth or the moon. Objects orbit each other because of gravity. Many planets have moons that orbit them, and may stars have planets, comets, asteroids and other objects that orbit them.

(ii) A satellite can also be man-made, like the international space station. Such man-made satellites are termed as artificial satellites.

To put an artificial satellite in to orbit, first we move it to high altitude and then accelerate it to a required tangential speed using rockets, as shown in Figure. 4.25. If the speed is too high, the spacecraft either move in elliptical orbit or will escape, never to return. It the speed is too low, it will fall back to Earth. Satellites are typically put into circular (or nearly circular) orbits.

Average Orbital Speed of Satellite: The orbital speed of the body is the speed at which it orbits around the center of the system. This system is usually around a massive body.

The relationship between speed, distance and time is:

$$\text{Average speed} = \frac{\text{distance}}{\text{time}} \quad \text{\_\_\_\_\_\_\_\_\_\_} (1)$$

This means that in one orbit, a satellite travels a distance equal to the circumference of a circle (the shape of the orbit). This is equal to '$2\pi r$'

Where 'r' is the radius a circle, thus:

$$\text{Distance} = 2\pi r \quad \text{\_\_\_\_\_\_\_\_\_\_} (2)$$

The time it takes for an object to orbit around another object is called its orbital period 'T'. Earth completes its orbital period around the sun every 365 days. The further away a planet is from the sun, the longer its orbital period. The planet Neptune, for example, takes almost 165 years to orbit the sun.

$$\text{Time} = \text{Orbital period} = T \quad \text{\_\_\_\_\_\_\_\_\_\_} (3)$$

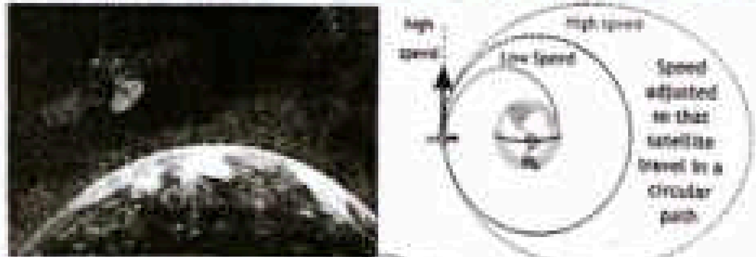
Putting equation 2 and equation 3 in equation 1, the average orbital speed 'V_{avg}' is

$$V_{avg} = \frac{2\pi r}{T} \quad \text{\_\_\_\_\_\_\_\_\_\_} (4)$$

Which means that for particular distance from the center of earth, all the satellite should have the same orbital speed irrespective of the size of satellite.

Scientists and engineers use the concept of orbital speed to determine the velocity required to launch satellites into specific orbits around the Earth. Factors such as the altitude of the orbit, gravitational force, desired orbital parameters, launch vehicle capabilities, and atmospheric drag influence the chosen speed and trajectory of satellite launched. By understanding these factors, scientists can design and deploy satellites that meet the requirements of their intended missions.

FIGURE 4.25: MOTION OF ARTIFICIAL SATELLITE



Q.18: Define a planet. Summarize the physical parameters of planets in solar system.

Ans. **Planet:** *An astronomical body orbiting a star or stellar remnant that is massive enough to be rounded by its gravity, is termed as planet.*

Explanation: There are more planets in our galaxy than stars. Our solar system consists of our star, the Sun, and everything bound to it by gravity – the planets Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune; dwarf planets such as Pluto 'dozens of moons; and millions of asteroids, comets, and meteoroids. Table 4.1, summarizes the physical parameters of the planets in solar system.

Table 4.1: Selected Data For the Solar System

Planet	Distance from Sun (Gm)	Mass (10_{24} kg)	G (N/kg)	Orbital Period (yr)	Density (kg/m³)	Average Surface temperature (°C)
Mercury	57.9	0.330	3.7	0.241	5429	167
Venus	108.2	4.87	8.9	0.615	5243	464
Earth	149.6	5.97	9.8	1	5514	15
Mars	228.0	0.642	3.7	1.88	3934	-65
Jupiter	778.5	1998	24.7	11.9	1326	-110
Saturn	1432.0	568	9.0	29.4	687	-140
Uranus	2867.0	86.8	8.7	83.8	1270	-195
Neptune	4515.0	102	11.0	164	1638	-200
Sun	5906.4	1,990,000	274	-	1408	5,600

For Your Information: Global Positioning System (GPS)

Many applications of satellite technology affect our lives. An increasingly important application is the network of 24 satellites called the Global Positioning System (GPS), which can be used to determine the position of an object. Figure illustrates how the system works, by locating position of enemy tank. A measurement using a single satellite locates the tank somewhere on a green circle, as Figure (a) shows, while a measurement using a second satellite locates the tank on another circle, The intersection of the circles reveals two possible positions for the tank, as in figure (b), with the aid of a third satellite, a third circle can be established, which intersect the other two and identifies the tank's exact position, as in Figure (c).

SHORTRESPONSE QUSTIONS

Q.1: Why long spanner is used to open or tight nuts of vehicle's tyre? While tightening a small nut, extra-long wrench is not suitable. Why?

Ans. From the relation of torque:

$$\tau = r \times F$$

When force is constant, the torque is directly proportional to moment arm. So, greater the moment arm, greater will be the torque and vice versa. A long spanner will have larger moment arm and will produce more torque. That's why long spanner is used to produce greater torque (turning effect) to open or tight nuts of vehicle's tyre rather than the short one. On the same principle, to open a small nut with the same wrench may damage or even break a small nut that's why it is advised not to open a small nut using large wrench.

Q.2: Why door knobs are fixed at the edge of door? What will happen if the door knob is at the middle of the door?

Ans. From the relation of torque: $\tau = r \times F$

When force is constant, the torque is directly proportional to moment arm. So, greater the moment arm, greater will be the torque and vice versa. That's why door knobs (handles) are fixed at the edge of door to increase the moment arm. In this way even a small force is sufficient to produce the required torque, which helps in the opening or closing of the door. If the door knob is at the middle of the door, the moment arm will become half and you will need a double force to open/close the door as compared to the edge knob.

Q.3: If you drop a feather and a bowling ball from the same height, which one will reach the terminal velocity first? Which one of them will hit the ground first?

Ans: The feather experiences a significant amount of air resistance due to its low mass and large surface area, which slows it down quickly. The bowling ball, being denser and having smaller surface area, experiences less air resistance. The feather will reach terminal velocity first, as it experiences a greater force of air resistance, which slows it down quickly and the bowling ball will hit the ground first, as it experiences less air resistance.

It must be noted down in the absence of air resistance both the feather and bowling ball would accelerate towards the ground at the same rate ($9.8\ m/s^2$) and hit the ground simultaneously because in the absence of air resistance, all object fall at the same rate regardless of their mass.

Q.4: Why do ice skates effortlessly slide on ice, while your shoes cause skidding?

Ans: Ice skates slide effortlessly on ice due to their thin sharp blades. These blades cut into the ice, reducing the friction between skate and surface, and allowing the smooth movement. Additionally, the pressure from skates can cause a thin layer of water to form on the ice, acting as lubricant further reducing friction. On the other hand, normal shoes are not designed for ice. These shoes typically have threads or patterns that provides grip on surface like pavement or flooring but can cause skidding on ice because they have more surface area in the contact with ice, creating friction reducing the ability to glide smoothing by using other footwear typically flats.

Q.5: Explain why it's easier to push a car on flat tyres than inflated ones. What happens to the frictional force between the tyres and the road?

Ans: When a car has flat tyres then frictional force between types and road increases due to availability of large contact path with larger surface area with the ground as a result of which co-efficient of friction increases and rolling resistance decreases so flat tyres provides more friction and less resistance, making it easier to push.

Q.6: When standing on a crowded school bus, which stance would provide better stability and prevent you from being pushed over: legs joined or legs spread apart?

Ans: The stability of a body depends upon two factors first lowering the centre of mass and secondly increasing the base area of support so when you are standing in a crowded school bus by joining your legs, it is more likely to fall because firstly, your centre of mass is comparatively high and secondly support area of legs is comparatively small. In comparison when you are standing with legs wide open, has lower centre of mass and higher support area. Hence it would be better to spreading your legs apart when you are standing in a crowded school bus to maintain stability and being pushed over.

Q.7: Why a moving bicycle is easier to balance? Relate this to the principles of rotational motion.

Ans: The rotating wheels of a bicycle possess angular momentum. In the absence of an external torque, neither the magnitude nor the direction of angular momentum change. The direction of angular momentum is along the axle of the wheel, so the bicycle does not get tilted.

Q.8: Why a pencil standing on its tip unstable, and what factors affect the stability of an object balanced on a point.

Ans. A pencil standing on tip is unstable due to:

i. **High centre of mass:** The centre of mass is high above the tip. Any small tilt moves the centre of mass away from the tip, causing the pencil to fall.

ii. **Small base of support:** The tip provides only tiny area of support, with such a small base, it is easy for the pencil to topple if there is any shift or tilt.

Factors affecting stability:

i. **Height of centre of mass:** The higher the centre of mass, the less stable the object is.

ii. **Base of support:** A large base makes an object more stable. A small base, like the pencil tip is less stable.

iii. **Distribution of mass:** Mass closer to the base helps keep the object stable.

iv. **External forces:** Things like wood or uneven surfaces can make the object less stable.

Hence pencils is unstable on its tip due to its high centre of mass and tiny base support.

Q.9: While driving what happens if the driver take the curve too fast? How does centripetal force play a role in keeping the car from skidding off the road?

Ans: i. When a driver takes a curve too fast while driving, the car tends to move in straight line due to inertia, following Newton's first law of motion.

ii. Centripetal force comes into play to keep the car from skidding off the road. This force acts towards the centre of curve and is responsible for changing the direction of motion of the car, allowing it to follow the curved path instead of continuing in a straight line.

iii. The centripetal force is provided by the friction between the tyres of car and road surface. This frictional force acts as the centripetal force, preventing the car from skidding off the road by providing the necessary inward force to keep the car moving in a curved path.

Q.10: Consider a situation where you swing a ball connected to a string in a circle. How does the tension in the string vary as the ball moves across different points in its circular path, and what forces are involved?

Ans: As the ball connected to string moves in a circular paths the tension in string varies as depending upon position of ball in circle.

i. The tension in the string is minimum at the top most point of circular path. This is because at this point, the centripetal force required to keep the ball moving in a circle is equal to the sum of tension in the string and weight of the ball i.e.

$$\left(\frac{mv^2}{r} = T + mg\right) \Rightarrow T = \frac{mv^2}{r} - mg$$

(At highest point weight and tension are acting vertically downward).

Tension is greater at the bottom of swing because it has to support both the centripetal force and weight of the ball, i.e. $T = \frac{mv^2}{r} + mg$.

The force involved are:

i. **Tension:** The force exerted by string on the ball directed toward centre of the ball.

ii. **Centripetal force:** The force required to keep the ball moving in a circle, also directed towards centre of circle.

iii. **Weight:** The force of gravity acting downward.

Q.11: Why is it important for communication satellites in geostationary orbit to maintain a specific speed?

Ans: i. Communication satellites in geostationary orbit must maintain a specific speed to ensure that they orbit the earth at the same rate as the rotation of earth. This allows the satellite to appear stationary relative to a fixed point on the surface of earth.

ii. If the satellite speed is too slow, it will fall out of geo stationary orbit and drift away from designated position above the earth.

iii. Conversely, if the satellite speed is too fast, it will move ahead of rotation of earth and will no longer appear stationary relative to earth's surface.

iv. Therefore, maintaining a specific speed is crucial for communication satellite in geostationary orbit to effectively provide continuous communication services.

Multiple Choice Questions.

Q.1: **A seesaw balances perfectly with two children of equal weight sitting at equal distances from the fulcrum. If one child moves closer to the fulcrum:**
(a) The seesaw remains balanced.
(b) The seesaw tips towards the child who moved closer.
(c) The seesaw tips towards the child who stayed farther away.
(d) The seesaw topples.

Q.2: **When line of action of the applied force passes through its pivot point then momnet of force acting on the body is:**
(a) maximum (b) minimum (c) zero (d) infinite

Q.3: **If a body is at rest or moving with uniform rotational velocity, then torque acting on the body will be:**
(a) maximum (b) minimum (c) zero (d) infinite

Q.4: **A body in equilibrium must not have:**
(a) speed (b) quantity of motion (c) velocity (d) acceleration

Q.5: **A uniformly rotating fan is said to be in:**
(a) static equilibrium only (b) dynamic equilibrium only
(c) both in static and dynamic equilibrium (d) not in equilibrium

Q.6: **You throw a weighted fishing net into a calm lake. As the net sinks, it opens fully underwater, spreading out its mesh evenly. Compared to the moment it left your hand, where is the net's center of mass now?**
(a) Higher in the water column. (b) Lower in the water column.
(c) At the same depth but slightly shifted horizontally.
(d) Unchanged from its position when thrown.

Q.7: **A tightrope walker is carrying a long pole while walking across a rope. The stability of the walker is affected if the pole is:**
(a) long and placed vertically (b) long and placed horizontally
(c) short and placed vertically (d) short and placed horizontally

Q.8: **It is more difficult to walk on a slippery surface than on a nonslippery one because of:**
(a) reduced friction (b) increased friction (c) high grip (d) lower weight

Q.9: **For an object moving with terminal velocity, its acceleration:**
(a) increases with time (b) decrease with time
(c) is zero (d) first increase then decreases

Q.10: **The correct order of comparison for the terminal speeds of a raindrop, snowflake, and hailstone is:**
(a) Raindrop > Snowflake > Hailstone (b) Hailstone > Raindrop > Snowflake
(c) Snowflake > Raindrop > Hailstone (d) Raindrop = Snowflake = Hailstone

Q.11: **You are trying to loosen a nut using a spanner, but it is not working. In order to open the nut, you need to:**
(a) insert a pipe to increase length of spanner (b) use a spanner of small length
(c) use plastic and soft spanner (d) tie a rope with spanner

Q.12: **The force that always changes direction of velocity and not its magnitude is called:**
(a) gravitational force (b) electrical force (c) centripetal force (d) friction

Q.13: **The reason that a car moving on a horizontal road gets thrown out of the road while taking a turn is:**
(a) the reaction of the ground (b) rolling friction between tyre and road
(c) gravitational force (d) lack of sufficient centripetal force

Q.14: **A car drives at steady speed around a perfectly circular track:**
(a) The car's acceleration is zero. (b) The net force on the car is zero.
(c) Both the acceleration and net force on the car point outward.
(d) Both the acceleration and net force on the car point inward.

Q.15: **A satellite of mass 'm' is revolving around the earth with an orbital speed 'v'. If mass of the satellite is doubled, its orbital speed will become:**
(a) double (b) half (c) one fourth (d) remain the same

Answer Key

1.	(b)	2.	(c)	3.	(c)	4.	(d)	5.	(c)
6.	(b)	7.	(b)	8.	(a)	9.	(c)	10.	(a)
11.	(a)	12.	(c)	13.	(d)	14.	(d)	15	(b)

Examples

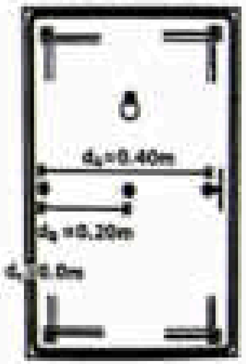
4.1: **A Physics teacher was explaining the role of moment arm in torque by performing an experiment. The teacher applied a force of 60 N to open a door. The force is applied at three different points perpendicularly and their distances from the axis of rotation are: (a) D_A = 40m (b) D_B = 0.20 m and (c) d_C = 0.0 m. Find the torque produced in each case.**

Ans. Given:

Force = 'F' = 60 N
Moment arm 'd_A' = 40 m
Moment arm 'd_B' = .20 m
Moment arm 'd_C' = 0.0 m

To find:

Torque 'τ_A' = ?
Torque 'τ_B' = ?
Torque 'τ_C' = ?



Solution:
In each case the moment arm is the perpendicular distance between the axis of rotation and the line of action of force.

(a). Using the definition of torque = $\tau_A = d_A \times F$
Putting values = $\tau_A = 0.40 \times 60$ N
= $\tau_A = 24.0$ N m **Answer**

(b). Using the definition of torque = $\tau_B = d_B \times F$
Putting values = $\tau_B = 0.20 \times 60$ N
= $\tau_A = 12.0$ N m **Answer**

(c). Using the definition of torque = $\tau_C = d_c \times F$
Putting values = $\tau_A = 0 \times 60$ N
= $\tau_A = 0$ N m **Answer**

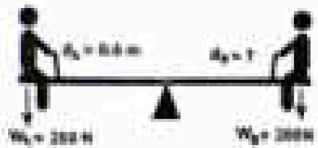
4.2: **Kamil and Bilal are sitting on a seesaw at F9 Park Islamabad. Kamil, weighing 250 N, is sitting at a distance of 0.6 m from the pivot. At what distance from the pivot should Bilal, weighing 200 N sit in order to balance the seesaw?**

Ans. Given:

Weight of Kamil = 'W_K' = 250 N
Moment arm of Kamil 'd_K' = 0.6 m
Weight of Bilal 'W_B' = 200 N

To find:

Moment arm of Bilal 'd_B' = ?



Solution:

Kamil's weight is producing anticlockwise moment, while Bilal's weight is producing clockwise moment, therefore, by principle of moments:

$$\tau_{anticlockwise} = \tau_{clockwise}$$

Hence $\quad d_K \times W_K = d_B \times W_B$

or $\quad d_B = \dfrac{d_K \times W_K}{W_B}$

Putting values $\quad d_B = \dfrac{0.6 \times 250}{200}$

Therefore $\quad = \quad$ **$d_B = 0.75$ m Answer**

4.3: Bilal is performing in hammer throw game as shown in the figure. Mass of the metal ball is 5 kg and length of the string is 1.5m. What centripetal force must Bilal apply to get a speed of 25 m/s?

Ans. Given:

Mass of metal ball = 'm' $=$ 5 kg
Radius 'r' $=$ 1.5 m
speed 'v' $=$ 25 m/s

To find:

Centripetal force 'F_C' $=$?

Solution:

The centripetal force acting on a body of mass 'm' is given by :

$$F_C = \frac{mv^2}{r}$$

Putting values $\quad F_C = \dfrac{5 \times 25 \times 25}{1.5}$

Therefore $\quad$ **$F_C = 2083.3$ N Answer**

4.4: Earth completes one revolution around the sun in 365.25 days. Find the orbital speed of Earth around the sun if it is 150 million km away from the sun.

Ans. Given:

Orbital period = 'T' = 365.25 days = 365.25 x 24 x 60 x 60 = 3.16 x 10^7 s

Radius 'r' = 150 million km = 150 x 10^6 x 10^3m = 1.5 10^{11} m

To find:

Orbital speed of Earth around sun 'v' $=$?

Solution:

The relation for average orbital speed is given by:

$$V_{ave} = \frac{2\pi r}{T}$$

Putting values $\quad V_{ave} = \dfrac{2 \times 3.14 \times 1.5 \times 10^{11}}{3.16 \times 10^7}$

Therefore $\quad$ **$v = 2.98 \times 10^4$ m/s Answer**

or $\quad v = 29.8$ km/s

or $\quad v = 107280$ km/h

Numerical Problems

Q.1: Calculate the torque acting on spanner of length 20 cm to loosen a nut by a force on 50 N. If the same nut is to be loosen up by force of 100 N, what should be length of spanner?

Ans. Given:

(i) moment arm 'd' $=$ 20 cm $= \dfrac{20}{100} = 0.2$ m
Force 'F' $=$ 50 N
Torque 'τ' $=$?

As we know

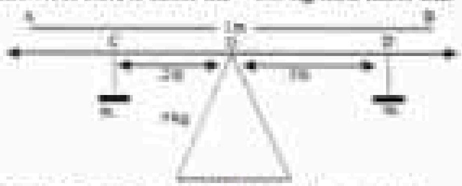
$\tau = Fd$
$\tau = 50 \times .2$
$\tau = 10$ N.m

(ii) Force 'F' $=$ 100 N
Torque 'τ' $=$ 10 N.m
Length of spanner 'd' $=$?

$\tau = Fd$
$10 = 100 \times d$
$d = \dfrac{10}{100}$
$d = 0.1$ m
$d = 0.1 \times 100$
$d = 10$ cm.

Q.2: A long uniform steel bar of length 1.0 m is balanced by a pivot at its middle. Two mass m_1 and m_2 are suspended at a distance of 0.2 m and 0.3 m respectively from the pivot. Ignoring mass of the steel bar, if mass m_1 = 0.6 kg find mass m_2.

Ans.



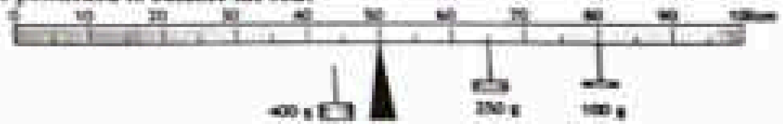
$m_1g \times OC = m_2g \times OD$ (Principle of moments)

$.6 \times .2 = .3 \times m_2$

or $\quad m_2 = \dfrac{0.12}{0.3}$

$m_2 = 0.4$ Kg

Q.3: Two masses, 250 g and 100 g, are hanging at positions 65 cm and 80 cm, respectively, on a uniform meter road, pivoted at 50 cm mark as shown. Where should a third mass of 400 g be positioned to balance the rod?



Ans: Mass m_1 = 250 g, $\quad$ Mass m_2 = 100 g, $\quad$ Mass m_3 = 400 g

Position of m_1 = 80 cm, $\quad$ Position of m_2 = 65 cm, $\quad$ Position of m_3 = ?

Moment arm of mass m_1, d_1 = 80 − 50 = 30cm

Moment arm of mass m_2, d_2 = 65 − 50 = 15cm

The mass m_1 will be positioned on left side of pivot to balance the meter rod.

Applying principle of moments

τ clockwise = τ anti clockwise

$d_3 \times F_3 = (d_1 \times F_1) + (d_2 \times F_2)$

$d_3 \times m_3 g = (d_1 \times m_1 g) + (d_2 \times m_2 g)$

$d_3 = \dfrac{(d_1 \times m_1) + d_2 \times m_2)}{m_3}$

Putting values, we have

$d_3 = \dfrac{(30 \times 100) + (15 \times 250)}{400} = \dfrac{3000 + 3750}{400}$

$d_3 = \dfrac{6750}{400} = 16.875\,cm$

Thus object should be placed in right side at 16.875 cm to balance the meter rode.

Q.4: A car weighing 1200 kg enters a roundabout with a diameter of 60 meters at a speed of 25 km/h. Calculate the centripetal force acting on the car as it navigates the curve.

Ans: Mass of car, m = 1200kg

Diameter of roundabout, d = 60m, $r = \dfrac{d}{2} = 30m$

Speed of car, v= 25km/h = $\dfrac{25 \times 1000}{60 \times 60} m/s$

$= 6.94\ m/s$

Centripetal Force F_c = ?

$F_c = \dfrac{mv^2}{r}$ (Equation)

$F_c = \dfrac{mv^2}{r}$

Putting values, we have

$F_c = \dfrac{1200 \times 6.94 \times 6.94}{30}$

$= 1923.54\ N$

Thus, Centripetal force acting on the car is 1926.54 N

Q.5: A geostationary satellite revolves around earth in an orbit of radius 42000 km. Find orbital speed of satellite at this height.

Ans. **Given Data:**

The radius of the orbit $r = 24000km = 42000 \times 10^3 m$

The orbital period T = 24hours = $24 \times 60 \times 60$ seconds

= 86400 seconds

Now we can calculate the orbital speed:

$\Rightarrow v = \dfrac{2\pi r}{T} = \dfrac{2\pi \times 42000 \times 10^3}{86400} = \dfrac{2\pi \times 42000}{86.4}$

$\Rightarrow v = \dfrac{2\pi r \times 420}{0.864} \quad \Rightarrow \quad v = \dfrac{840\pi}{0.864} \quad \Rightarrow \quad v \approx \dfrac{840 \times 3.14159}{0.864}$

$\Rightarrow v = \dfrac{2638.8364}{0.864} \approx 3055.368 ms^{-1} \quad \Rightarrow \quad v \approx 3.055 kms^{-1}$

The orbital speed of the geostationary satellite at this height is approximately $3.055 kms^{-1}$.

UNIT 05 Pressure and Deformation in solids

Q.1: Define elasticity and elastic limit. Show that a force may produce change in size and shape of solids.

Ans. **Elasticity:** '*The ability of a deformed body to return to its original shape and size when the deforming forces are removed is called elasticity*'.

Explanation: When a stretched spring is released, it comes back to its original form. When a tennis racket hits a tennis ball, the shape of the ball is distorted or deformed, but it regains its original shape when it bounces off the tennis ball. Similarly, when an archer shoots an arrow, she bends the bow which comes back to its original form after the arrow is released as shown in figure 5.3.

Not all materials return to their original shapes when a deforming force acting on it is removed. Materials that do not return to their original shapes after being distorted are said to be inelastic.

FIGURE 5.3 ELASTICITY

Examples of inelastic materials are plasticine, clay and dough.

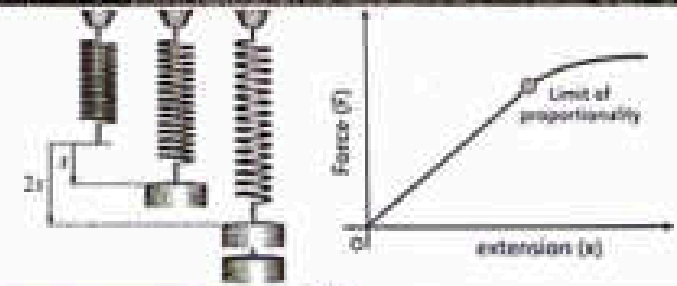
Elastic limit: Most materials are elastic up to a certain limit known as the elastic limit. Beyond the elastic limit a material will not return to its original dimensions when the deforming force is removed.

Q.2: What is Hook's law? Illustrate its application. Also, define and calculate spring constant.

Ans. **Hook' Law:** When a spring is stretched or compressed, the extension or compression is directly proportional to the applied force (figure 5.4). This relationship is known as Hooks' law which states that within elastic limits the extension (or compression) x is directly proportional to the restoring force F_{res} i. e.

Mathematically $\quad F_{res} \propto -x \quad$ or $\quad F_{res} = -kx$

FIGURE 5.4 HOOKS LAW



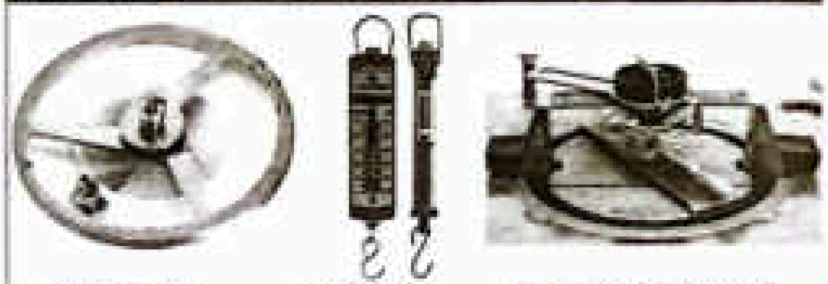
Therefore $k = \frac{F_{ex}}{x}$ __________ (5.1)

Where 'k' is the ratio of restoring force to the extension and is known as the spring constant having units Nm^{-1}. The negative sign show that force is directed against displacement. This relationship is also true for a wire under tension. Provided that the limit of proportionality is not exceeded, a graph of stretching force against extension is a straight line through the origin as shown in figure 5.4.

Explanation: The gradient of the line F/x is the spring constant 'k'. Hooke's law is obeyed up to the limit of proportionality. Beyond this point, stretching force and extension are no longer directly proportional and the graph begins to curve.

Applications: Hooke's law has many important practical applications, with one being the creation of a balance wheel, which made possible the creation of the mechanical clock, the portable timepiece. Hooke's law is also used as a fundamental principle behind spring scale. It is also used as the foundation for diving boards and car suspension systems, seismology, acoustics molecular mechanics and even in medical science.The spring is a marvel of human engineering and creativity, still in use in many modern day instruments.

FIGURE 5.5 AIR FILLING IN BICYCLE



(a) Balance wheel (b) Spring Scale (c) Hair spring in galvanometer

A. Balance wheel of the mechanical watches: A balance wheel is the timekeeping device used in mechanical watches. It is a weighted wheel that rotates back and forth, being returned toward its center position by a spiral torsion spring or hairspring as shown in figure 5.5 (a). It is driven by the escapement, which transforms the rotating motion of the watch gear train into impulses delivered to the balance wheel. Each swing of the wheel (called a 'tick' or 'beat') allows the gear train to advance a set amount, moving the hands of watch forward. The combination of the mass of the balance wheel and the elasticity of the spring keep the time between each oscillation or 'tick' very constant.

B. Spring Scale: A spring scale (spring balance) is a type of mechanical force measuring instrument that make use of spring. This device is mainly used to weigh items or objects by connecting them to a hook at it bottom as shown in figure 5.5 (b). Since by Hooke's law the force or weight that extends a spring is directly related to the distance that the spring is extended from its initial position. The spring scale converts this extension to measuring weight using an analog or digital gauge attached to the device.

C. Galvanometer: Galvanometer is a device used for detecting current or voltage. It make use of the hair spring which not only electrical connection to coil and restoring the pointer back but also make the deflection proportional to the force according to Hooke's law as shown in figure 5.5 (c). And since the force is proportional to the current, it permits us to draw an analogue scale under the pointer and measure the current.

Q.3: Draw and explain force-extension graph for elastic solids.

Ans. Stress and strain curves: Stress and strain curves are measured by stress tester, one such machine Rockwell hardness tester is shown in the **figure 5.6 (a)**. The applied stress is increased and the change in length is noted. The values are then printed on graph. A typical graph for metal is shown in the figure **5.6 (b)**

FIGURE 5.6 STRESS STRAIN CURVE

Here, Point, A is the limit of proportionality, the limit up to which Hooke, law is obeyed called proportional limit. Point, B, is the elastic limit, the limit up to which material shows elastic behavior, and point D, is the breaking point, where material breaks.

Q.4: Define pressure? What is its unit? Is it vector or scalar? What is effect of area on pressure acting on surface?

Ans. Pressure: Pressure is defined as force per unit area.

Mathematically; The pressure is given by

$$P = \frac{F}{A}$$

Where 'P' represents pressure, 'F' is Force and 'A' is area of surface.

The SI unit of pressure is Pascal (Pa) which equals newton per square meter (N/m^2).

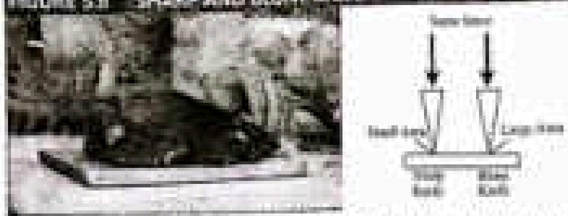
$$1Pa = \frac{1N}{1m^2}$$

Explanation: Pressure is increased if the force applied to a given area is increased, or if a given force is applied to a smaller area. Why does the balloon pop easily with a pin, but not with our hand? The pressure to rupture the balloon. That is why getting stepped on by heeled shoe hurts more than getting stepped by flat one. As the weight of the body is applied over a small area pencil heeled have you ever wondered why a blunt knife cannot cut meat easily? When you apply the same force on sharp and blunt knife, the sharp knife offers little surface area thereby increasing pressure, which help to cut meat easily as shown in figure. 5.8.

Note: Practical Application

The base of the dam is made wide to increases the strength of the dam so that it can withstand the enormous pressure of the stored water and this pressure increases with the depth of water. However, due to the wide base of the dam, the pressure exerted by the dam structure on the earth is greatly reduced.

FIGURE 5.8 SHARP AND BLUNT KNIFE



Q.5: Explain the term atmospheric pressure. With the help of an example, show that atmospheric pressure is applied equally in all directions?

Ans. **Atmospheric Pressure:** 'The pressure that atmospheric particles exert on the surface of earth and all over the surface of objects on the earth is called atmospheric pressure'.

Explanation: (i) Pressure is particularly useful for dealing with liquids and gases, as it exerts pressure in every direction. That's why during swimming we feel pressure on all parts of our body. Similarly we live at the bottom of the earth's atmosphere, which pushes inward on our bodies just like the water in a swimming pool.

(ii) The pressure of the air at a given place varies slightly according to the weather and height from sea level. At sea level, the pressure of the atmosphere on average is $1.013 \times 10^5\ Nm^{-2}$ (or 1.013×10^5 Pa). This value lets us define a commonly used unit of pressure, the atmosphere (abbreviated atm), such that

$$1\ atm = 1.013 \times 10^5\ Pa$$

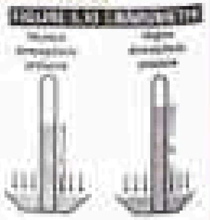
Another unit of pressure sometimes used (in meteorology and on weather maps) is the bar, which is defined as

$$1\ bar = 1.000 \times 10^5\ Pa.$$

How a suction cup gets its sticking force? Its is because of the atmospheric pressure. When we push the cup against a smooth wall, we actually force the air out of the cup, allowing atmospheric pressure to hold it to the wall. Another example of atmospheric pressure can be seen when we pump the air out of sealed can, atmospheric pressure produces an inward force that is unopposed, this results in the collapse of the can (figure 5.9).

FIGURE 5.9 SUCTION CUP AND AIR EVACUATED FROM SEALED CAN

Q.6: What is barometer? How a barometer is constructed?



Ans. **Barometer:** Mercury barometer is a device that is used to measure atmospheric pressure.

Construction: A long tube that is open at one end and closed at the other is filled with mercury and then inverted into a flat dish containing mercury. Once the tube is inverted, the mercury does not empty into the bowl completely. Instead the atmosphere exerts a pressure on the

surface of mercury. This atmospheric pressure pushes mercury in the tube to some height 'h' above the bowl as shown in the figure 5.10.

In this way force exerted on the bowl of mercury by the atmosphere is equal to the weight of mercury in the tube. Any change in the height 'h' of the column of mercury means that the atmosphere's pressure has changed. At sea level, the atmosphere will push down mercury and make it rise up in a tube to a height of approximately 760mm.

Q.7: What is effect on atmospheric pressure as we go up from the surface of Earth?

Ans. **Variation of atmospheric pressure with height:** The atmospheric pressure decreases as we go up from the surface of earth. on mountains the atmospheric pressure is lower than at sea level, — decreasing gradually to zero. The climbers at high altitudes encounter lower atmospheric pressure due to the thinner air. The thinner air causes breathing difficulties due to the lower level of oxygen. The graph in figure 5.11 shows that at Mount Everest (height of 8.8 km above sea level) the atmospheric pressure is only 33 kPa, and where Boeing 747 flies the atmospheric pressure is around 23 kPa.)

Q.8: What kind of weather change is indicated by variation in the atmospheric pressure?

Ans. **Weather change and atmospheric pressure:** Barometer that are kept in the same place at the same height above sea level show some variation in atmospheric pressure from day to day. These pressure variations are shown on weather maps (fig. 5.12) the lines in the map joining all those places with the same atmospheric pressure are called isobars. The unit for pressure used in weather maps is the millibar (mbar).

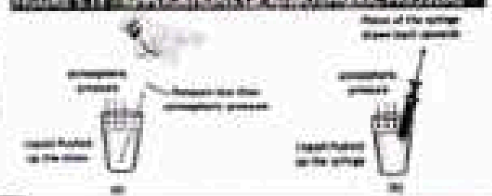
$$1\ bar = 100\ pa$$

FIGURE 5.12 PRESSURE MAP

Usually the range of atmospheric pressure varies from the very high pressure of 1040 mbar to as low as 950 mbar. Wind move from high pressure regions to low pressure regions. The strength of the wind is determined by the pressure difference. From the weather map, when the isobars are packed closely together, it indicates a high pressure difference.

Q.9: Give two applications of a atmospheric pressure.

Ans. **Applications of atmospheric pressure:** (A) DRINKING BY STRAW: The drinking through straw is possible by lowering the pressure in the he mouth below atmospheric pressure as shown in figure 5.13 (a). The action of sucking increases the volume of lungs, thereby reducing the air pressure in



the lungs and the mouth. The atmospheric pressure acting on the surface of the liquid will then be greater than the pressure in the mouth, thus forcing the liquid to rise up the straw into the mouth.

(B) DRAWING LIQUID BY SYRINGE: We can draw liquid up the syringe, as shown in Figure 5.13 (b), the piston of the syringe is drawn back upwards. This decreases the pressure within the cylinder. Atmospheric pressure acting on the surface of the liquid drives the liquid into the cylinder through the nozzle of the syringe.

Q.10: Show that liquid in a container exerts pressure equal to P =ρg h. What is effect of depth on pressure of liquid?

Ans. **Liquid Pressure:** Just like gases liquids also exert pressure. The pressure in liquid is due to its weight. We will determine that how pressure of incompressible liquid increases with depth.

Explanation: Consider a column of liquid of height 'h', base area 'A' at the bottom of a tank in liquid and density 'ρ' as shown in figure 5.14. The force acting on a base area is the weight of the cylindrical column of liquid of mass 'm' is,

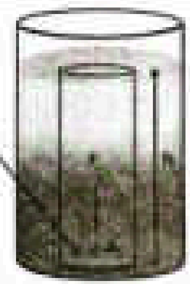
$$F = W = mg \quad \_\_\_\_\_\_ \quad (1)$$

The mass 'm' of the cylindrical liquid, in the terms of density 'ρ' is given by,

$$\rho = \frac{m}{V} \quad \text{or} \quad m = \rho V \quad \_\_\_\_\_\_ \quad (2)$$

Since the fluid forms a cylindrical volume V shown by dotted lines in the figure which has height h and area of cross section A, therefore

FIGURE 5.14 LIQUID PRESSURE



$$V = Ah \quad \_\_\_\_\_\_ \quad (3)$$

Putting equation 3 in equation 2, we get

$$m = \rho Ah \quad \_\_\_\_\_\_ \quad (4)$$

Putting equation 4 in equation 1, we get

$$F = \rho Agh \quad \_\_\_\_\_\_ \quad (5)$$

Since pressure is defined as

$$P = \frac{F}{A} \quad \_\_\_\_\_\_ \quad (6)$$

Putting equation 5 in equation 6, we get

$$P = \frac{\rho Ahg}{A}$$

Therefore

$$P = \rho hg \quad \_\_\_\_\_\_ \quad (5.3)$$

Form equation 5.3 we deduce that the pressure in a liquid depends on the depth and density of the liquid.

Q.11: What is manometer? Give its working and applications differentiate between manometer and barometer.

Ans. **Manometer:** A manometer can be defined as a device that is used to measure the pressure in a fluid using fluid dynamics. The fluid can be a gas or a liquid.

In other words, we can define it as a gauge that is used to measure pressure present in the fluid. Also, it is used in laboratory experiments to demonstrate the pressure of air on a liquid column or vice versa.

The formula of a manometer is as follows:

$$P = \rho gh$$

Where 'P' is the pressure of the fluid, 'ρ' is the density of the fluid, 'g' is the gravitational acceleration exerted by the earth, and 'h' is the height till which the fluid rises in a manometer.

Working Principle: The working principle of a manometer is that one end is connected to a seal-tight gas to measure the source of pressure. Whereas, its other end is left open to the atmospheric pressure of the earth. If the pressure present in it is greater than 1 atm then the fluid present in the column will be forced down by that pressure. However, it will cause an increase in equal amounts in the present column.

APPLICATION OF MANOMETER:

(i) It is used to measure the pressure of the fluids using mechanical properties of fluids.
(ii) It is also used to measure vacuum.
(iii) It is also used to measure the flow of the fluid.
(iv) It is used to measure the filter pressure drop of the fluids.
(v) It is also used for meter calibrations.
(vi) It is used to measure leak testing.
(vii) It is also used to measure the liquid level present in a tank.

	Difference between Manometer and Barometer	
	Manometer	**Barometer**
(1)	It is a device that is used to measure the pressure of the fluid but that of a liquid concerning the earth's atmospheric pressure.	It is a device that is used to measure fluid pressure but that of air as it can differ with distance when it's bellow or above sea level.
(2)	It comes in different forms.	It comes only in one basic design for all its types.
(3)	These are filled with mercury or any heavy liquid material but in some cases, they can be filled with a lighter liquid material.	In all its cases, these are only filled with mercury or any heavy liquid material.

Q.12: State and Explain Pascal's law? Describe working principle of hydraulic lift using Pascal's law? What do you mean by force multiplier? (OR) State Pascal's law and Explain its one application in detail.

FIGURE 5.16 AIR FILLING IN BICYCLE

Ans. When we pump a bicycle tire, we apply a force on the pump that in turn exerts a force on the air inside the tyre. The air responds by pushing not only against the pump but also against the walls of the tyre. As a result, the pressure increases by an equal amount throughout the tyre as shown in figure 5.16.

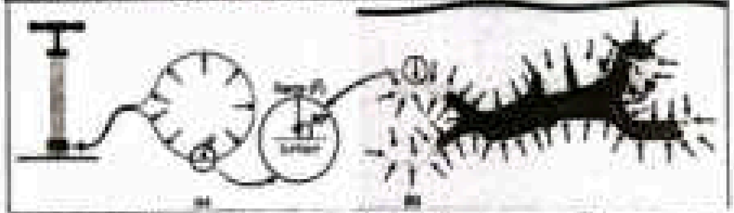
Pascal's Law: In general, if the pressure in a fluid is increased at any point in a container (such as at the valve of the tyre), the pressure increases at all points inside the container by exactly the same amount. Blaise Pascal (1623-1662_ noted this fact, what is now called Pascal's principle (or Pascal's law):

An external pressure applied to an enclosed fluid is transmitted unchanged to every point within the fluid.

Explanation: The relationship between pressure and force on a surface is described by Pascal's Principle, which explain how pressure at a surface produces a force in a direction perpendicular (at right angles) to the surface.

Since pressure is transmitted equally in all directions, the force generated ($F = P \times A$) is also distributed equally in all directions. The force acts perpendicular to the surface because the pressure is acting uniformly in all directions. If there were a component of force parallel to the surface, the object would exert force on the fluid parallel to it as a consequence of Newton's third law. This would result in an uneven distribution of forces, contradicting the principles of Pascal's Principle.

FIGURE 5.17 FORCE ACTS PERPENDICULARLY

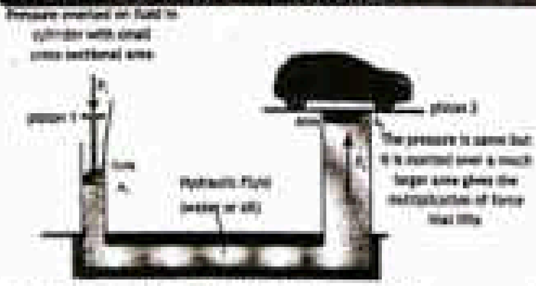


When you blow up a balloon, the pressure inside the balloon goes up. This pressure spreads out evenly in all directions. The force from the pressure pushes outward and goes straight across the surface of the balloon, making it get bigger as shown in figure 5.17 (a).

As you dive deeper underwater, the pressure increases due to the weight of the water above. The force exerted by this pressure is perpendicular to the surface of your body. This is why divers feel pressure on their ears, and it also explains why deep-sea divers need specialized suits to counteract the pressure as shown in figure 5.17 (b).

HYDRAULIC LIFT (application of Pascal's Law): Pascal's principle at work in hydraulic lift, which is shown schematically in Figure 5.18. Here we use two cylinders, one of cross-sectional area A_1 and the other of cross-sectional area A_2 (such that $A_2 > A_1$). The cylinders, each of which is fitted with a piston, are connected by a tube and filled with a Hydraulic fluid. Initially the pistons are at the same level and exposed to the atmosphere.

FIGURE 5.18 HYDRAULIC ELEVATOR OR LIFT



Now, suppose we push down on piston 1 with the force F_1. The pressure P_1 exerted by this piston is:

$$P_1 = \frac{F_1}{A_1}$$

Similarly, the pressure on the piston lifting vehicle is P_2, which can be written as

$$P_2 = \frac{F_2}{A_2}$$

By pascal's principle $P_2 = P_1$

Putting values from equation 1 and equation 2 in equation 3 and rearranging for F_2, we get

$$F_2 = \frac{A_2}{A_1} F_1 \quad \text{\_\_\_\_\_\_\_\_} \quad (5.4)$$

Equation 5.4 shows that depending on the ratio A_2/A_1 the force F_2 can be as large as possible. To be specific, let's assume that A_2 is 100 times greater than A_1. Then, by pushing down on piston 1 with a force F_1 we push upward on piston 2 with a force of $F_2 = 100\ F_1$. Our force has been magnified 100 times. Hence a relatively small effort can be used to overcome a much larger load so, it is called force multiplier also.

SHORT RESPONSE QUSTIONS

Q.1: While walking on a trampoline. Do you feel more pressure when you stand still or jump up and down? Why does pressure change with movement?

Ans: When you stand still on a trampoline, your weight is focused on a small area, making the pressure high (as $P = \frac{\text{Force}}{\text{Area}} = \frac{mg}{\text{Area}}$) when you jump up.

When you jump up or down your pressure decreases, because your weight is distributed over large area as you spread out.

The pressure changes with movement because pressure is defined as force per unit area. When you stand still, your weight the force applied over a small area, resulting in high pressure. When you jump up your weight is spread over larger area, decreasing the pressure. Essentially, the pressure is directly related to how much force is applied and the area over which it is distributed.

Q.2: How does the shape of a thumb pin help it penetrate surface easily?

Ans. The thumb pin penetrates surface easily due to its sharp pointed tip by concentrating the force applied to a small area.

Mathematically, $P = \frac{F}{A}$ relation shows that the sharp point reduces the area over which the force is distributed, making it easier to overcome the resistance of material being penetrated.

Q.3: If you blow up a balloon and then tie it closed, why does it stay inflated even though you stop blowing? How does pressure play a role here?

Ans: i. When you blow up a balloon, you increase pressure inside the balloon compared to the surrounding air pressure. This higher pressure inside the balloon pushes against the elastic walls of the balloon.

ii. When you tie the balloon closed, the air inside is trapped, and the elastic walls of balloon exert an inward force on air molecules, maintaining the pressure inside the balloon.

iii. The pressure inside the balloon remains higher than the external pressure, which prevents the balloon deflating.

Q.4: Why an inner airtight layer of a space suit is designed to maintain a constant pressure around the astronaut?

Ans: i. The inner airtight layer of a space suit is designed to maintain a constant pressure around the astronaut to ensure that astronaut's body is not exposed to vacuum of space.

ii. In the vacuum of space, there is no atmospheric pressure, which can lead to expansion of gases within the body, causing sever health issues such as decompression sickness.

iii. By maintaining a constant pressure around the astronaut, the inner airtight layer of the space suit prevents the gases within the body from expanding and helps maintains a stable environment for the astronauts to survive in space.

Q.5: If a liquid has density two times the density of mercury, what will be height of liquid column in barometer?

Ans. The atmospheric pressure can be calculated by using the given formula.

$$P = \rho g h$$

Let in the case of mercury barometer, the above expression can be written as:

$$P_1 = \rho g h_1 \quad \_\_\_\_\_\_\_\_ (1)$$

Now the mercury is replaced by a liquid whose density is two times the density of mercury.

Then:

$$P_2 = 2\rho g h_2 \quad \_\_\_\_\_\_\_\_ (2)$$

As the atmospheric pressure in both the cases is same, i.e. $P_1 = P_2$

$$\rho g h_1 = 2\rho g h_2 \Rightarrow h_2 = \frac{g h_1}{2g} \quad \Rightarrow h_2 = \frac{h_1}{2}$$

As the height of mercury column (h_1) is 76 cm.

Therefore $$h_2 = \frac{76\text{cm}}{2} = 38\text{cm}.$$

So, height of the new liquid column in barometer will be 38 cm (becomes half).

Q.6: How can we drink water from a glass with a straw? Can we drink water from a s straw on the moon?

Ans. When drinking with a straw, one has to suck the straw. This causes the pressure in the straw to decreases.

The external atmospheric pressure, which is greater, will then act on the surface of the water in the glass, causing it to rise through the straw.

No, we cannot sip water with straw on the moon, because there is no atmosphere and therefore, we cannot suck water.'

Q.7: How are we able to break a metal wire by bending it repeatedly?

Ans. Repeated bending of a metal wire causes dislocation in crystal lattice structure. (Cracks occur) until the wire breaks due to accumulated fatigue, leading to the formation and propagation of microscopic cracks. Over time, these cracks grow larger and eventually cause the wire to break. The repeated bending causes the metal's crystal structure to weaken and deform.

Q.8: A spring, having spring constant k when loaded with mass 'm', is cut into two equal parts. One of the pars is loaded with the same mass m again. What will be its spring constant now?

Ans.

$$\text{Spring constant (K)} \propto \frac{1}{\text{length of the spring}}$$

As length becomes half, spring constant K becomes twice i.e. 2K. So, when it is cut into two equal parts its length decreases to half and spring constant increases to 2K.

Q.9: Why do static fluids always exert a force perpendicular to the surface?

Ans. Static fluids exert force perpendicular to surface because the pressure from the weight of fluid above pushes equally in all directions, resulting in a balanced force perpendicular to any surface within the fluid.

Q.10: How can a small car lifter lift cars heavier than itself?

Ans. A small car lifter can lift heavier cars because of hydraulic systems. These systems use pressure to lift, applying a small force over a long area to lift a heavier object.

Multiple Choice QUESTIONS

Q.1: The most elastic material of the following is:
(a) Rubber (b) Wood (c) Glass (d) Steel

Q.2: Hooke's law hold good up to:
(a) Proportional unit (b) Yield limit (c) Elastic limit (d) Plastic

Q.3. A mass of 2 kg is hung by spring, which displaces it through 5 cm. the spring constant is:
(a) 400 N/m (b) 40 N/m (c) 4 N/m (d) 4000 N/m

Q.4: Materials which does not regain its original shape after removal of the load producing deformation are termed as:
(a) Elastic materials (b) Plastic materials (c) Rigid materials (d) Hooke's materials

Q.5: SI unit of pressure is:
(a) Pascal (b) Newton (c) Zero (d) Infinite

Q.6: Which will exert greater pressure?
(a) 3 g needle of tip area $1 mm^2$
(b) 4000 kg elephant of total feed area $0.5 m^2$
(c) A girl of mass 40 kg wearing high heel shoes of cross-sectional area $0.5 cm^2$
(d) A loaded ship of mass 2.2×10^7 kg having area $600 mm^2$.

Q.7: Pressure of 1000 m bars is equivalent to:
(a) 0.1 kPa (b) 1 kPa (c) 10 kPa (d) 100 kPa

Q.8: Pressure of 1 mm Hg is equal to:
(a) 1.316×10^{-3} atm (b) 1 atm (c) 133.29 atm (d) 1.316×10^{3} atm

Q.9: Atmospheric pressure is commonly measured using a:
(a) Hygrometer (b) Barometer (c) Monometer (d) Thermometer

Q.10: Pressure of liquid in a container increase with:
(a) Base (b) Volume (c) Depth (d) Mass

Q.11: The atmospheric pressure will be smaller at:
(a) Islamabad (b) Peshawar (c) Lahore (d) Murree

Q.12: A girl of mass 50 kg wears heels with an area of $2 cm^2$ in contact with the ground. The pressure she exerts on ground is:
(a) 4×10^{4} Pa (b) 245×10^{4} Pa (c) 4×10^{-4} Pa (d) 4×10^{5} Pa

Q.13: Divers wear special suites in order to protect them from:
(a) Low pressure (b) High pressure (c) Low temperature (d) High temperature

Q.14: In a stationary fluid, the local pressure of the fluid vary:
(a) With depth only
(b) Horizontally only
(c) Both with depth and along horizontal direction
(d) Neither with depth nor along horizontal direction

Q.15: The pressure exerted by a man on the surface of earth will be smaller when he:
(a) Stands on both feet
(b) Sits on the ground
(c) Stands on one leg
(d) Sleeps on the ground

Answer Key

1.	(d)	2.	(a)	3.	(a)	4.	(b)	5.	(d)
6.	(c)	7.	(d)	8.	(a)	9.	(b)	10.	(c)
11.	(d)	12.	(d)	13.	(b)	14.	(a)	15	(d)

Examples

5.1: Kamil sits on a spring chair as shown in the figure. If Kamil;s weight is 50 kg and compresses the spring by about 10 cm, when he sits on the chair, find the spring constant of this chair .

Ans. Given:-

Mass of Kamil 'm' = 50 kg
Extension in spring 'x' = 1000 kg/m³
Spring constant 'k' = ?

Solution:

The force stretching the spring is equal to weight of the body, given by:

$$W = F = mg = 50\,kg \times 9.8\,m/s^2 = 490\,N$$

Form Hook's Law: $F = kx$ or $k = \frac{F}{x}$

Putting values, we have $k = \frac{490\,N}{0.1\,m}$

So, the given chair spring has a spring constant of 4,900 N/m.

5.2: **Abdurrahman was standing at the stage of a hall for a speech. What pressure does he apply on the stage if his two feet cover an area of 400 cm2? (b). If for a while he stands on one foot, what will be the pressure under that foot? (Take his mass 500 kg).**

Ans. Given:-

Mass of Abdurrahman 'm'	=	50 kg
Area of two feet 'A_1'	=	$400\,cm^2 = 400 \times 10^{-4}\,m^2 = 0.04\,m^2$
Area of one feet 'A_2'	=	$A1/2 = 0.04\,m^2/2 = 0.02\,m^2$
Pressure with both feet 'P_1'	=	?
Pressure with both feet 'P_2'	=	?

Solution:

Weight of Abdurrahman will be given by: $W = mg = 50 \times 9.8\,m/s_2 = 490\,N$

$$P = \frac{F}{A} = \frac{W}{A} \quad \text{———} \quad (1)$$

(a) For both feet the equation 1 can be written as: $P_1 = \frac{W}{A_1}$

Putting values $P_1 = \frac{490}{0.04}$

Therefore $P_1 = 12{,}250\,N/m^2 = 12{,}250\,Pa = 12.25\,kPa$ (Answer)

(b) For one foot the above equation can be written as: $P_2 = \frac{W}{A_2}$

Putting values $P_2 = \frac{490}{0.02}$

Therefore = $P^2 = 24{,}500\,N/m^2 = 24{,}500\,Pa = 24.50\,kPa$ (Answer)

Thus, for the same force (or weight), If area is halved pressure become double.

5.3: **A submarine was moving in the Pacific Ocean (the largest and deepest ocean) at a depth of 8.5 km. How much pressure is exerted upon the submarine if density of water is 1000 kg/m³?**

Ans. Given:-

Depth = height = h	=	8.5 km = 8500 m
Density of water 'ρ'	=	$1000\,kg/m^3$
Acceleration due to gravity 'g'	=	$9.8\,m/s^2$
Pressure 'P'	=	?

Solution:

The pressure exerted on a body inside a liquid, can be given by: $P = \rho gh$

Putting values $P = (1000) \times (9.8) \times (8500)$

Therefore = $P = 8.33 \times 10^7\,N/m^2 = 8.33 \times 10^7\,Pa$. (Answer)

5.4: **A hydraulic lift has 0.002 m² narrow cylinder area while 0.9 m² wider area. How much force must be applied the narrow cylinder If a car weighing 1800 kg is to be lifted.**

Ans. Given:-

Area of narrow cylinder 'A_1'	=	$0.002\,m^2$
Area of wider cylinder 'A_2'	=	$0.09\,m^2$
Mass of car 'm'	=	1800 kg
Force at narrow cylinder F_1	=	?

Solution:

First we will find weight of the car as this will be the force applied on car:

$$W = mg = F_2 = 1800 \times 9.8 = 17{,}640\,N.$$

Form Pascal's principle $F_1 = \frac{A_1}{A_2} F_2$

Putting values, we have $F_1 = \frac{0.0002}{0.09} \times 17{,}640$

$$F_1 = 39.2\,N$$

That is why we use hydraulic lifts to lift heavy weights with much smaller force than their weight.

Numerical Problems.

Q.1: **Consider a spring with a spring constant of 8000 N/m. If a force of 500 N is applied to the spring, what will be the displacement of the spring?**

Ans. Given:-

Spring Constant	K	=	8000 N/m
Force	F	=	500 N
Displacement	x	=	?

As we know that $F = Kx \Rightarrow x = \frac{500}{8000} \Rightarrow 0.0625m$

Thus the displacement of the spring will be 0.0625 m.

Q.2: **In a force multiplier, small piston has diameter of 15 cm and large piston has diameter of 30 cm. If 250 N force is applied on the small piston then how much force will produce on large piston.**

Ans. Given:-

Diameter of small piston 'd_1'	=	15 cm
Diameter of large piston 'd_2'	=	30 cm
Applied force on small piston 'F_1'	=	250 N
Radius of small piston 'r_1'	=	7.5 cm
Radius of large piston 'r_2'	=	15 cm
Applied force on large piston 'F_2'	=	?

Solution:

From Pascal's Law $\frac{F_2}{F_1} = \frac{A_2}{A_1} = \frac{\pi r_2^2}{\pi r_1^2}$

$$\frac{F_2}{F_1} = \frac{r_2^2}{r_1^2} \Rightarrow F_2 = \frac{r_2^2}{r_1^2} F_1$$

Putting values, we have

$$F_2 = \frac{(15)^2}{(7.5)^2} = \frac{225}{556.25} \times 250$$

$$F_2 = 1000\ N$$

Q.3: A hydraulic car lifter lifts a car of mass 1000 kg when we apply force of 50N on small piston. Radius of its small piston is 20 cm. Find the radius of its large piston.

Ans. Given:-

Mass of car 'm'	=	1000 kg
Force on small piston 'F_1'	=	50 N
Radius of small piston 'r_1'	=	$20\ cm = \frac{20}{100} = 0.2\ m$
Radius of large piston 'r_2'	=	?

Solution:

First, we will find force on larger piston from the weight of car:

Force on large piston F_2 = weight of car $w = mg = 1000 \times 9.8 = 9800\ N$

From Pascal's Law
$$\frac{F_2}{F_1} = \frac{A_2}{A_1} = \frac{\pi r_2^2}{\pi r_1^2}$$

$$\frac{F_2}{F_1} = \frac{r_2^2}{r_1^2} \Rightarrow r_2 = \sqrt{\frac{F_2}{F_1} r_1^2}$$

$$r_2 = \sqrt{\frac{9800}{50}\ (0.20)^2}$$

$r_2 = 2.8\ m$ (The answer given in textbook is wrong).

Q.4: Water column in a beaker is 70 cm. Find the pressure of water in beaker. Take density of water as 1000 kg/m^3.

Ans. Given:-

Height	h	=	70 cm
Density	ρ	=	1000 kg/m^3
Pressure	P	=	?

As we know that $P = \rho gh$

Putting values, we have $P = 1000 \times 9.8 \times \frac{70}{100} = 6860\ Pa =$ **6.86 KPa**

Thus pressure of the water in the beaker will be 6.86 KPa.

Q.5: How much force should be applied on an area of 20 cm^2 to get a pressure of 4500 Pa?

Ans. Given:-

Area	A	=	20 cm^2
	A	=	$\frac{20}{100 \times 100}\ m^2$
	A	=	$20 \times 10^{-4}\ m^2$
Force	F	=	?

As we know that $P = \frac{F}{A}$ Or

$F = PA$

Putting values, we have
$F = 4500 \times 20 \times 10^{-4}$
$F = 90000 \times 10^{-4}$
$F = 9 \times 10^4 \times 10^{-4}$
$F = 9\ N$

UNIT 06 Work and Energy

Q.1: Define work and its S.I. units.

Ans. Work: *Work is said to be done when a force displaces a body in its own direction.*

Mathematically: When an object moves distance S in the direction of applied force F (figure 6.1), then work done W is given mathematically as:

Work done = Force × Displacement

$$W = F \times d \qquad (6.1)$$

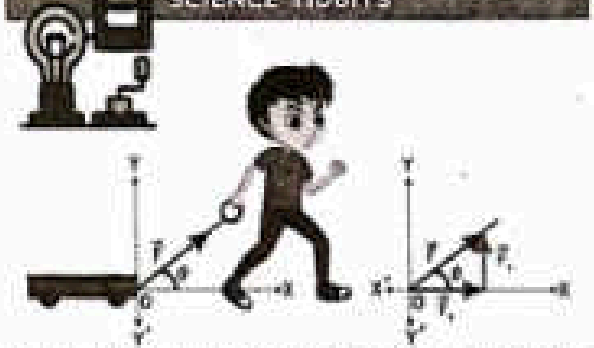
FIGURE 6.1 WORK DONE

Nature of Quantity: Work is a scalar quantity

Unit: In the international system of units (SI) Work is measured in joules (J). *One joule is equal to the work done by a one-newton (1 N) force acting over a one-meter (1m) distance.*

$$1\ J = 1\ N \times 1\ m$$

SCIENCE TIDBITS



Vector representation: Force is not always applied perfectly in the direction of motion. For example consider a toy car which is moving in horizontal direction and force 'F' is applied making certain angle 'θ' with the horizontal. In such situations the force is resolved into its rectangular components as shown in figure.

Q.2: Define and Explain Energy.

Ans. Energy: *The capacity of body to do work is called Energy.*

Examples:

(i) A boy is pushing a toy car. The boy exerts a force on the toy ca to move on floor. The work done on toy car is transfer of energy from boy to the sharpener.

(ii) A sharpening pencil by a child is due to energy transfer to the sharpener.

(iii) Riding a bicycle is possible due to transfer of energy to bicycle by a person.
So energy is defined as *'the capacity of a body to do work'*.

Types or Energy:
Energy has many different forms such as **(i)** Chemical energy **(ii)** Electromagnetic energy **(iii)** Electrical energy **(iv)** Sonic energy **(v)** Nuclear energy.

Unit of energy: The unit of energy is the same as that of work i.e. *joule (abbreviated J = Nm)*.

Q.3: Define mechanical energy? What are its different Types?

Ans. **Mechanical Energy:** All forms of energy (Heat, electrical, light, chemical, nuclear and sound) can be classified as one of two types, either potential energy (stored) or kinetic energy (due to motion) collectively termed as mechanical energy.

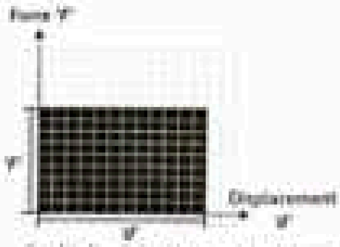
Table 6.1 Types of Energy

Type	Description	Example
Chemical Energy	The energy contained within the bonds between atoms.	These bonds can take many different forms, including energy derived from carbohydrates in food to energy stored in gasoline.
Electromagnetic Energy	Electromagnetic energy (or radiant energy) is energy from light or electromagnetic waves.	Electromagnetic energy from the sun supplies earth with all of the energy required to sustain life.
Electrical Energy	The energy The energy associated with charges.	Electrons moving from negatively to positively charged objects.
Sonic Energy	The energy of sound waves. Sound waves travel through the air or another medium.	Sound vibrations cause a person's eardrums to vibrate.
Nuclear Energy	Nuclear energy is energy resulting from changes in the atomic nuclei or from nuclear reactions.	Nuclear power stations use nuclear energy to generate electric energy.

Q.4: Define kinetic energy of a body. Derive its expression.

Ans. **Kinetic Energy;** *The energy possessed by a body due to its motion is called Kinetic energy.*
A moving bullet is able to do work by overcoming forces when it strikes something e.g. wood similarly kinetic energy to is felt during a collision.

FIGURE 6.2 F - D GRAPH



Graphical analysis of force and displacement

Explanation: A football is kicked by a boy it moves because it possess kinetic energy. Now think a tennis ball and a football moving with same speed. Which possess greater ability to do work? Of course it is the football with larger mass, which is difficult to stop. Similarly now two footballs are approaching you with different speeds, which can do more work? Again it is easy to answer as the football with greater speed is difficult to stop. Thus the object's mass and its speed contribute to its Kinetic energy. Like all energies Kinetic energy is also a scalar quantity.

Derivation: Consider a constant force "F" is acting on an object of mass 'm' and as a result the object moves on a frictionless surface. The kinetic energy of an object will be equal to work done.
The work done on force displacement graph can be calculated by finding area of figure under force -displacement graph as shown in figure 6.2.
Change in kinetic energy (E_k) = Work done = F.d
Work done = area under force displacement graph
Here the area under force displacement graph is the area of rectangle, thus;
Change in kinetic energy (E_k) = Area of rectangle = width x length = (F) (d)

or
$$E_k = (ma)(v_{av}t) \quad \_\_\_\_\_\_ (1)$$
Here;
$$V_{av} = \frac{v_i + v_f}{2}$$
As the speed is increasing from $v_i = 0$ to $v_f = v$, therefore the average speed v_{av} is therefore
$$V_{av} = \frac{0 + v}{2} = \frac{v}{2} \quad \_\_\_\_\_\_ (2)$$
And acceleration can also be written as:
$$a = \frac{v}{t} \quad \_\_\_\_\_\_ (3)$$
Putting equation 2 and equation 3 in equation 1, we get
$$E_k = m\frac{v}{t} \cdot \frac{1}{2}vt$$
$$E_k = \frac{1}{2}mv^2 \quad \_\_\_\_\_\_ (6.2)$$

FIGURE 6.3 KINETIC ENERGY

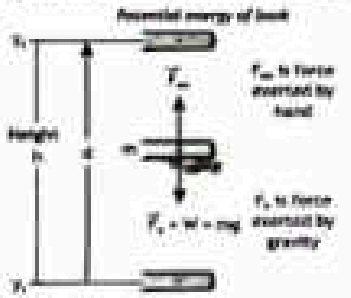
Kinetic energy of a moving cricket ball

By solving equation 6.2 kinetic energy for cricket ball can be found, For example, a 100g cricket ball moving with a speed of 2.0 m/s has a kinetic energy of 0.2 J as shown in figure 6.3.

Work kinetic energy theorem: work kinetic energy theorem states that the work done on an object is equal to change in energy. i.e W = ΔE, Where "W" is the work done and "ΔE" is the change in energy.

Q.5: Define potential energy? What are its different types? Define gravitational potential energy. Derive its expression.

FIGURE 6.4 STORED ENERGY



Ans. **Potential Energy:** *'The energy possessed by a body by virtue of its position (in a force field or in configuration) is called potential energy'.*

Types of potential energy:
(i) Gravitational potential energy.
(ii) Chemical potential energy.
(iii) Elastic potential energy.
We define each type separately,

(i) Gravitational potential energy: *The energy possessed by an object due to its height from the surface* *of Earth is called gravitational potential energy.*

Mathematically. Gravitational potential energy is the product of mass 'm', the acceleration due to gravity 'g' and the change in height 'h'.

$$E_{p.grav} = m\,g\,h$$

Like all energies potential energy is also a scale quantity. For example if we lift a stone of mass 5 kg from the ground to 20m high the work is done against the force of gravity, this work appears as 980J of potential energy.

Example: Consider the work you do on a book when you lift from the floor and place it on the top shelf. The work you did on your book is now stored in the book by virtue of its position. By doing work against the force of gravity, you have given your book a special form of potential energy called gravitational potential energy (figure 6.4). If you release book from the top shelf it will accelerate, gaining kinetic energy, thus gravitational potential energy can released and have the ability to do useful work.

(ii) Chemical potential energy: *The energy stored as a result of chemical process is called chemical potential energy.*

Examples: Chemical potential energy stored in the food you eat. A battery contains both chemical and electrical potential energy during working of battery. Similarly, in a capacitor, which consists of two conductive plates with opposite charges, electrostatic potential energy is stored in the electric field between the plates.

(iii) Elastic potential energy: *The energy stored in an object as a result of stretching and compressing the object is called elastic potential energy.*

Examples: For example, doing work on an elastic spring by stretching it stores elastic potential energy in elastic spring. (slingshot, shock absorber, winding spring in toys and watches are all example of elastic potential energy).

Derivation of Expression for gravitational potential energy: Consider an object of mass 'm' being lifted vertically by a force 'F' to 'h' as shown in figure 6.6. The work done by the force F is given by equation.

FIGURE 6.6 POTENTIAL ENERGY

$$W = E_{p.grav} = F\,S \quad \_\_\_\_\_\_ \quad (1)$$

Since the force in this case is equal to its weight

$$F = W = mg \quad \_\_\_\_\_\_ \quad (2)$$

Here the distance moved is the height 'h'

$$S = h \quad \_\_\_\_\_\_ \quad (3)$$

Putting equation 2 and 3 in equation 1, we get

$$E_{p.grav} = mg \times h = mgh \quad \_\_\_\_\_\_ \quad (6.3)$$

Q.6: State and Explain Law of conservation of Energy.

Ans. Statement: Energy cannot be destroyed or created it is only converted from one form to the other. The law of conservation of energy states that,

"Energy can neither be created nor destroyed in any process. It can be converted from one form to another, but the total amount of energy remains constant".

Think of a book lying on a shelf. The book has gravitational potential energy when it is on the shelf. What happens if the book falls off the shelf? Its potential energy changes into kinetic energy. This change in energy from one form to another is conversion of energy.

Explanation with Examples:

(i) Generation of electricity: Potential energy of water which is stored at a certain height is converted into kinetic energy by making it fall on turbine to produce electricity as shown in figure 6.7.

FIGURE 6.7 ENERGY CONVERSION

(ii) A cyclist going up to the top of a hill: Stored chemical energy in the body of cyclist allows him to do work against gravity (see figure 6.7). At the top of the hill, he will possess gravitational potential energy which will allow him to go down the hill with increasing kinetic energy even without pedaling.

When current passes through bulb, electrical energy is converted into light energy and thermal energy. In a car driven with petrol the chemical energy stored in the fuel is converted into kinetic energy of car. Engineers are concerned with the technologies associated with transformation from sources such as fossil fuels into conveniently used forms such as electrical energy and heating.

It must be noted that during this conversion process all the energy is not converted into useful forms. Scientists term this lost energy as dissipated energy. For example, in an automobile driven energy that moves the car. The remaining portion (80%) is lost to the environment as heat and other forms of energy. Electric cars are far more energy efficient than internal combustion engine cars.

FIGURE 6.9 ENERGY CONSERVATION

Mathematically: If the work done "W" is zero then, the change in energy 'ΔE' is also zero.

$$\Delta E = 0$$

If the total energy at final stage is E_{Tf} and the total energy at initial stage is E_{Ti}, then by conservation of energy principle

$$E_{T_f} - E_{T_i} = 0$$

$$E_{T_f} = E_{T_i} \quad \_\_\_\_\_\_ \quad (6.4)$$

Thus the initial energy of a system is equal to its final energy. However, some time this principle appears to be violated. For example, when electrical energy is provided to fan some of this energy is used in rotating the fan, the remaining energy is not lost or destroyed but converted into other forms of energy (such as thermal energy). In this way, the total energy remains constant.

In certain processes, both the total energy and the total mechanical energy are conserved, meaning they stay the same. An example of this can be seen in figure 6.9, where a ball is falling. The ball stats from a rest position and drops from a height 'h', above the ground. As the ball falls, its gravitational potential energy is converted into kinetic energy causing it to move faster. However, its mechanical energy remains constant. This can be expressed mathematically as:

$$E_{kf} + E_{P.gravf} = E_{ki} + E_{p.gravi} \quad \_\_\_\_\_\_ \quad (1)$$

As energy at initial point is totally because of gravitational potential energy '$E_{p.gravi}$' which is totally transformed into kinetic energy 'E_k' at final point, therefore equation 1 can be:

$$E_{kf} = E_{p.gravi} \quad \_\_\_\_\_\_ \quad (2)$$

When the frictional force such as air resistance acts between initial and final points, the gravitational potential energy '$E_{p(grav)}$' at initial point apart from converting into kinetic energy 'EK'. 'EK' is dissipated into work done against friction 'W_F'. Thus equation above can be written as:

$$E_{kf} + W_F = E_{p(grav)} \quad \_\_\_\_\_\_ (6.5)$$

Q.7: Explain renewable and non-renewable energy sources with examples. Write down advantages and disadvantages of each in reference to their availability and environmental impact.

Ans. Renewable and Non-renewable Sources of Energy: The progress in science and technology has propelled society from a time when human strength was the primary source of energy, to a time where various forms of energy are harnessed. However, in every conversion of energy, there is always a loss of useful energy. It is evident that society cannot persistently consume increasing amounts of energy without taking into account the needs of future generations. The forthcoming challenge lies in the development of energy sources and processes that are sustainable. A sustainable resource is one that does not diminish over time and does not harm the delicate biosphere of the Earth, while still meeting the energy requirements of society On this classification the energy resources are divided into two groups — renewable and nonrenewable.

Non-renewable energy resource is an energy resource that is limited and cannot be replaced naturally in short time. Most of the energy we use comes from non-renewable energy resources, for example fossil fuels like coal, natural gas and petroleum.

Renewable energy resource is an energy resource that is replaced rapidly by a natural process. Renewable energy resources capture their energy from an on-going natural processes, such as sunshine, wind, flowing water and biological processes. They are part of the planet's physical structure, which means they are constantly being renewed by natural means and cannot simply run out (technology not fuel). Apart from this advantage many renewable energy systems are better for the environment, compared to non-renewable energy sources.

Energy Converter:

Energy conversion involves transforming available energy resources into a useful form. These resources provide the raw materials or sources used to generate energy for various purposes, including electricity generation, transportation, heating, and industrial processes. Nowadays, many energy converters focus on converting energy into electrical form. This process is facilitated by various devices and systems known as energy converters.

Achieving a sustainable and reliable energy supply requires us to increase the use of renewable energy sources, enhance energy efficiency, and create new technologies to minimize environmental impacts. It is important to strike a balance between energy requirements and environmental and social concerns.

Environment Effect:

The impact on the environment caused by the electricity system is influenced by different factors such as the generation and distribution methods used. In general, the environmental effects can include:

- Emissions of greenhouse gases and other air pollutants, especially when a fuel is burned.
- Use of water resources to produce steam, provide cooling, and serve other functions.
- Discharges of pollution into water bodies, including thermal pollution (water that is hotter than the original temperature of the water body).
- Generation of solid waste, which may include hazardous waste, a land use for fuel production, power generation, and transmission and distribution lines.

- Effects on plants, animals, and ecosystems that result from the air, water, waste and land impacts.

Social Concerns due to use of energy resources:

The use of energy resources raises various social concerns that involve impacts on communities public health, and overall societal well-being. To tackle these social issues, it is important to take a holistic and inclusive approach. This involves involving the community, engaging stakeholders, and carefully considering the potential effects of energy projects. Policymakers, industry stakeholders, and communities need to collaborate in order to create sustainable and socially conscious energy solutions.

(i) FOSSIL FUELS: Fossil fuels are the remains of million year old plant life (now coal) or aquatic animal life (now gasoline and natural gas). Chemical energy stored in fossil fuels is obtained through a process called combustion. Fossil fuels, which include coal, oil, and natural gas, are rich in hydrocarbons – molecules made up of hydrogen and carbon atoms. When these hydrocarbons burn, they combine with oxygen from the air to create carbon dioxide, water, and energy.

The general chemical equation for the combustion of a hydrocarbon, such as methane (CH_4) found in natural gas, is as follows:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O + \text{Energy}$$

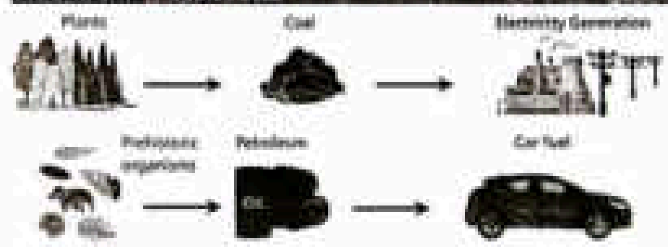
A. COAL: Coal, the most abundant fossil fuel globally, possesses an estimated reserve of one million metric tonnes. However, the combustion of coal leads to significant atmospheric pollution.

B. OIL: Crude oil undergoes refining processes to yield various energy products, including gasoline, jet fuel, and heating oil. Despite the limited global reserves of oil, it is favored over coal due to its higher energy output for the same quantity.

C. NATURAL GAS: Natural gas, often a byproduct of oil extraction, comprises a mixture of gases, primarily methane. One advantage of natural gas is its ease of transportation.

Fossil fuels are extracted from the Earth through various methods. Coal is usually mined whereas, oil and natural gas is often drilled and extracted from reservoirs. The extracted fossil fuel may undergo refining and processing to separate impurities and obtain usable forms of the fuel.

FIGURE 6.11 FOSSIL FUELS



To extract energy fossil fuel is burned in the presence of oxygen, typically in a combust on chamber or engine. This combustion reaction releases energy in the form of heat. The heat generated during combustion can be used to produce steam, drive turbines, or power engines in power plants, for instance, the heat produced is often used to generate steam, which in turn drives turbines connected to generators to produce electricity.

Fossil fuels serve as a significant energy resource due to their inherent value. The process of extracting them is relatively cost-effective. Furthermore, they possess the advantage of being easily stored, transported via pipelines, or shipped to any location across the globe. It is crucial to acknowledge that although fossil fuels play a significant role as an energy source, their combustion leads to the emission of carbon dioxide (CO_2) and other harmful substances into the atmosphere. This contributes to environmental problems like air pollution and climate change, consequently, there is an increasing focus on the advancement and implementation of cleaner and more sustainable energy alternatives.

(ii) NUCLEAR FUEL: Nuclear energy is often considered a nonrenewable energy source, even though nuclear energy itself is renewable. The material used in nuclear power plants, such as uranium, is not renewable. Nuclear power plants harness the energy in the nucleus of an atom through nuclear fission, where the atom's nucleus splits. These plants are complex machines that can control nuclear fission to generate electricity. While uranium is found in rocks worldwide, nuclear power plants typically use a rare type called U-235. Plutonium-239 is another material that can be used as nuclear fuel, it is often produced within nuclear reactors by irradiating U-238 which is common.

FIGURE 6.12 NUCLEAR FUEL

The process of nuclear fission involves splitting heavy atoms like uranium or plutonium, resulting in a significant amount of thermal energy. This heat is used to boil water, which then generates electricity.

Nuclear energy is a popular method for generating electricity globally because small amount of nuclear fuel can produce a large amount of energy and it doesn't pollute the air or emit greenhouse gases. These power plants can be constructed in rural or urban areas without harming the environment. Nevertheless, harnessing nuclear energy is challenging. Building and operating nuclear power plants is a complicated process that requires skilled scientists and engineers, which many communities lack.

However, nuclear energy produces radioactive waste, which is highly toxic and can cause severe health issues like burns, cancers, blood diseases, and bone decay.

(1) BIO MASS FUEL: Bio-mass refers to the material that provides bio-energy. The energy contained in biomass comes from the sun, as plants capture sunlight through photosynthesis and convert it into chemical energy specifically carbohydrates. Only green plants and photosynthetic algae with chlorophyll can utilize solar energy. The most basic way to harness this energy is through consumption. Whenever you eat a fruit, vegetable, or a processed form of either, you are benefiting from the energy stored as biomass.

FIGURE 6.13 BIO-MASS

Types of Bio-Mass:

Bio-mass has many types, this includes logs, branches, wood chips, sawdust, and other by products from forestry and wood processing. Agricultural residues such as straw, corn stalks, and rice husks can be used as biomass fuel. Certain crops, like switch grass and miscanthus, are grown specifically for energy production. Livestock waste, such as dung, can be used as a biomass fuel.

Methods to make best use of Bio-Mass energy:

There are many methods currently used around the world to make the best possible use of biomass energy. Biomass can be burned directly to produce heat or used in combustion processes to generate steam, which drives turbines connected to generators for electricity production. It can also be used as biochemical conversion which involves the use of microorganisms or enzymes to break down biomass into biofuels, such as ethanol and biodiesel. Apart from this, processes e pyrolysis and gasification can convert biomass into gases (syngas), bio-oil, or charcoal.

Production of biogas:

Bacteria decompose decaying plants, resulting in the production of biogas. A tonne of food waste can generate 85 m^3 of biogas, consisting of methane, carbon dioxide, and hydrogen sulfide gas. The biogas is mostly composed of 60% methane, with the remaining portion being primarily Carbon dioxide. This biogas serves as a great fuel source for heat and power plants. It is considered a CO_2 neutral fuel since the carbon dioxide released was recently extracted from the Atmosphere.

Biogas System:

Biogas is renewable energy System ideal for treating liquid manure and industrial wastes providing nutrient-rich fertilizers from the residues. Implementing biogas systems for farm manure helps decrease nitrate pollution and the risk of water contamination by E.-coli bacteria. However the effectiveness of biogas systems depends on the collaboration between regional farmers and industrial sites to support a centralized plant, which can be challenging to accomplish.

(2) HYDRO ELECTRIC RESOURCES: Hydroelectric generation is the process of using the gravitational potential energy of water to generate electric energy. The force of gravity pulls the water down, giving it a lot of kinetic energy. This kinetic energy is then converted into electric energy by large turbines.

FIGURE 6.14 HYDRO ELECTRIC RESOURCES

Sometimes, these large reservoirs flood a large area of farmland, thereby significantly changing the ecosystem, and we don't know what the consequences will be. In the past, engineers didn't have the technology to economically use smaller reservoirs for generating electricity. But now, with advancements in technology, smaller generation facilities are becoming more popular.

Hydroelectric power is renewable and efficient. Once the facilities are raised and running, they have minimal impact on the environment. However, generating power from water requires fast flowing water, and it often causes ecological damage when using large facilities.

(3) SOLAR RADIATION:

The energy from direct sun light can be used to produce electricity. Today, solar cells are used to power everything from calculators and watches to small cities.

Two different methods solar radiations in way of energy: Solar radiation is harnessed in two main ways for energy. The first method involves solar photovoltaic cells, also known as solar cells, which directly convert sunlight into electricity. These cells are made of semiconductor materials like silicon, which generate an electric current when exposed to sunlight. Solar panels are created by connecting multiple solar cells together to form a module. These panels can be installed on rooftops, solar farms, or other locations with access to sunlight.

The second method is through solar thermal systems, which utilize the heat from sunlight for various applications such as electricity generation, water heating, and space heating. Concentrated Solar Power (CSP) systems concentrate sunlight onto a small area using mirrors or lenses.

FIGURE 6.14 SOLAR SYSTEM

"The concentrated sunlight is then used to heat a fluid, like water or a heat transfer fluid, which in turn produces steam. This steam is used to drive a turbine connected to a generator for electricity production.

Explanation: The Sun is a completely free and renewable energy resource that is also very eco-friendly. Solar cells do not emit any greenhouse gases during operation, making them a clean energy option. Additionally, the main material used in solar energy conversion, silicon, is the second most abundant element in the Earth's crust. The use of solar energy helps reduce reliance on fossil fuels, decrease greenhouse gas emissions, and promote sustainable and renewable energy sources.

However, significant land area is required to produce significant amounts of electricity. Additionally solar energy is intermittent and variable because it depends on whether conditions and the time of day. Cloudy days and nighttime limit the availability of sunlight, requiring additional energy storage or backup systems to ensure a continuous power supply.

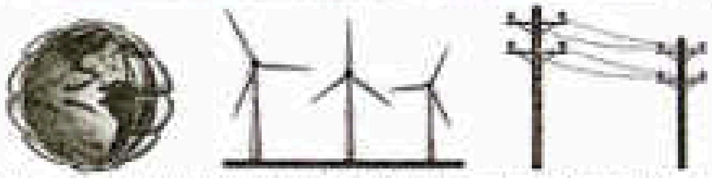
(4) GEOTHERMAL RESOURCES: Geothermal energy comes from the Earth's core and is formed by the trapped energy from billions of years ago and the heat produced by decaying radioactive elements. It is, in fact, not considered a renewable energy source because the heat is extracted faster than it is replenished. However, due to the immense size of the Earth, it would take thousands of years to deplete this energy source, making it practically renewable.

FIGURE 6.16 GEOTHERMAL ENERGY

Geothermal energy is abundant and does not produce greenhouse gas emissions. It is a reliable source of power that is not affected by weather conditions. Nonetheless, it is only economically viable in certain locations on Earth, and the discharge of hydrogen sulfide gas can be toxic and even deadly in high concentrations.

(5) WIND: The kinetic energy of the wind can be used to turn turbine which in turn produce electricity. Wind turbines are the main technology used to capture wind energy. They have big rotor blades connected to a hub, gearbox, and generator. The blades convert wind's kinetic energy into rotational energy. The design, length, and shape of the blades are important for the turbine's efficiency. Modern turbines usually have three blades that can be adjusted for better energy capture. Control systems are installed in wind turbines to adjust blade pitch or shut down the turbine in strong winds to prevent damage.

FIGURE 6.14 HYDRO ELECTRIC RESOURCES



The generator converts the rotational energy into electricity, usually alternating current (AC). Wind turbines are often grouped together in wind farms to maximize energy production. These farms are strategically located in areas with consistent and strong winds, like coastal regions plains, or mountain passes.

Generating electricity from wind is ecofriendly and renewable energy source with zero greenhouse gas emissions and a low risk of accidents.

However, the technology is still in its early stages of development. Challenges include the harsh marine environment, which requires extensive installation and maintenance, as well as the need for effective energy storage solutions for times when wave conditions are not optimal.

(6) Waves in the Sea: Wave energy, also called ocean wave energy, is obtained from the movement of surface waves on the ocean. Wave Energy converters (WECs) are devices created to capture the kinetic energy of these waves. There are different types of WECs, each with its own design and working principle.

FIGURE 6.18 WAVES IN SEA

One type is point absorbers, which move up and down with the waves. This vertical motion powers a system that converts the mechanical energy into electricity, such a as hydraulic pump or an electrical generator. Another type is attenuators, which are long floating structures that move with the waves. The relative motion between the segments of the attenuator is used to generate electricity.

Oscillating water columns utilize the rising and falling motion of waves to create air movement in a chamber. This moving air is then used to drive a turbine connected to a generator, producing electricity. In this way, the mechanical motion of the waves is converted into electrical energy.

(7) TIDES: The gravitational force exerted by the moon as it orbits the Earth leads to the formation of bulges in the oceans, both closest and farthest from the moon. These bulges, known as tides, occur twice a day as our planet completes one full rotation on its axis within a 24-hour period.

FIGURE 6.19 TIDES

Different Approaches: There are primarily two main approaches to harnessing energy from tides. The first method involves utilizing tidal stream systems, also referred to as tidal current systems, which harness the kinetic energy generated by the movement of water caused by tidal currents. Specifically designed underwater turbines are strategically placed in areas with strong tidal currents to capture the kinetic energy and convert it into electricity. On the other hand, tidal range systems make use of the difference in height between high tide and low tide, known as the tidal range. To generate electricity, a tidal barrage or a dam-like structure is constructed across the entrance of a tidal basin. Sluice gates within the barrage allow water to flow into the basin during high tide and release it during low tide, thereby producing electricity. Another method involves capturing high-tide waters and releasing them through turbines during low tide to generate a electrical power from the ocean.

Tidal energy systems, whether based on tidal streams or tidal ranges, are considered renewable sources of energy and possess the advantage of predictability due to the regular and cyclic nature of tides.

Physicists have calculated that the rise and fall of tides dissipate energy at a rate of two to three million megawatts. However, only a small fraction of this energy, approximately 23,000 MW worldwide, or about 1%, is currently recoverable. The deployment of tidal energy technologies is hindered by challenges related to environmental impact and the high costs associated with installation. Furthermore, the viability of tidal facilities is limited to only a few locations across the globe.

Q.8: Define power. What is its formula? Define its SI unit. What is its relation with horse pwer?

Ans. Power: Power is the rate at which work is done or the rate at which energy is consumed. **Mathematically:**

$$P = \frac{W}{t} = \frac{E}{t} \quad \text{\_\_\_\_\_\_ (6.6)}$$

Explanation: Like work power is a scalar quantity. The SI unit of power is watt (W). In honour of James Watt, a Scottish physicist who invented the first steam engine. From equation (6.6, the unit of power is given by

$$1 \text{ watt} = 1 \text{ joule/1second}$$

or $$1\,W = 1\,Js^{-1}$$

Power Rating: The power rating (sometimes called the "wattage") of a light bulb tells you how fast it will convert electric energy into heat and light. 100 W filament bulb and 40 W tube light are shown in the figure 6.20.

FIGURE 6.20 POWER RATING ON LIGHTING DEVICES

For practical purpose, a larger unit is often used, the horse power (hp) One horse power (hp) is defined as 550 ft. lb/s which equals 746 W.

$$1\,hp = 746\,W$$

Unit: A unit of energy (work) can now be defined in terms of the unit of power. One kilowatt hour (kWh) is the energy converted or consumed in 1h at the constant rate of 1 kW = 1000 J/s. The numerical value of 1kWh is,

$$1kWh = (10^3\,W)(3600s)$$

or $$1kWh = 3.6 \times 10^6\,J$$

The electricity bills that we pay are measured in terms of this unit i.e 1 unit = 1kWh.

Q.9: Define and Explain efficiency of a machine. Why efficiency of machines can never be unity or 100%?

Ans. Efficiency: The principle of conservation of Energy suggests that energy can neither be created nor destroyed. That is the total energy output of a machine must be equal to its energy input.

Explanation: A car engine is designed to convert chemical energy stored in the fuel into kinetic energy for the car. A light bulb is designed to convert electric energy into light energy. While the car engine and the light bulb are transforming some of the potential into the desired form of energy. Part of its energy is 'lost'.

The lost energy is converted into form that does not serve the intended purpose. Often the lost energy is transformed into heat. The efficiency 'η' of a machine or device describes the extent to which it concerts input energy or work into useful type of output energy or work.

Efficiency 'η' is the ratio of useful work output 'W_o' to the total work input 'W_i'.

$$\text{Efficiency} = \frac{\text{useful output work}}{\text{input work}} = \eta = \frac{W_o}{W_i} \quad \text{\_\_\_\_\_\_ (1)}$$

In terms of energy equation (1) can be written as:

$$\text{Efficiency} = \frac{\text{useful energy output}}{\text{energy work}} \text{ or } = \eta = \frac{E_o}{E_i} \quad \text{\_\_\_\_\_\_ (2)}$$

Efficiency has no unit as it is the ratio of same quantities and therefore units cancels. The efficiency of an energy transformation is sometimes given in percentage as follows

$$\eta = \frac{E_o}{E_i} \times 100\% \quad \text{\_\_\_\_\_\_ (3)}$$

Relation between power and efficiency: The correlation between power and efficiency becomes apparent when considering the output power of an energy conversion process. The output power 'P_{out}' of a given system is directly proportional to its input power 'P_{in}' through the efficiency 'η' factor.

$$P_{out} = \eta \times P_{in} \_\_\_\_\_\_ (4)$$

Equation (4) clearly demonstrates that the output power is a fraction of the input power, determined by the efficiency of the system. In the event that the system operates at 100% efficiency ($\eta = 1$), the output power will be equivalent to the input power. However, in practical applications, energy is often dissipated as waste heat or in other forms, resulting in efficiencies lower then 100%.

FIGURE 6.21 : EFFICIENCY OF INCANDESCENT BULB AND FLORESCENT LAMP

Explanation: Efficiency maximization plays a pivotal role in energy systems as it allows for optimal utilization or resources while minimizing energy wastage.

An incandescent light bulb is designed to provide light energy. Unfortunately, it also produces a lot of thermal energy while in use.

In fact, only about 5% of the electrical energy delivered to the bulb transforms to light energy, the rest becomes waste thermal energy. We say that the incandescent light bulb is only 5% efficient. A floresent lamp is about 20% efficient of converting electrical energy into light as shown in the figure 6.21. It is not possible to have a machine with 100% efficiency, because friction lowers the efficiency of a machine.

TABLE 6.3 : TYPICAL EFFICIENCIES OF ENERGY TRANSFORMATION TECHNOLOGIES

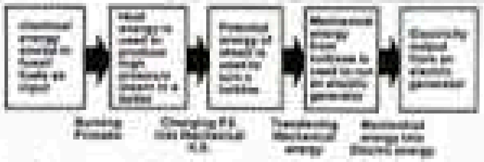
DEVICE	EFFICIENCY (%)
electric generator	98
hydroelectric power plant	90
large electric motor	90
home gas furnace	85
wind generator	55
fossil fuel power plant	40
automobile engine	25
fluorescent light	20
incandescent light	5

Work output is always less than work input, so an actual machine wasting some of input energy as heat (which is not required) cannot be 100% efficient. Typical efficiencies of energy transformation technologies are given in the table 6.3.

Q.10 Describe the process of electricity generation by drawing a block diagram of the process from fossil fuel input to electricity output.

Ans. We are using electricity in houses, offices, schools, business centers, factories and in farms.

We have different ways of generating electricity. Most of the electricity is obtained using fossil fuels such as oil, gas and coal. Fossil fuels are burnt in thermal power stations to produce electricity. Various energy conversion processes in producing electricity from coal are described in a block diagram as shown.



Several energy conversion processes are involved in producing electricity.

Q11. Explain flow diagram of an energy converter.

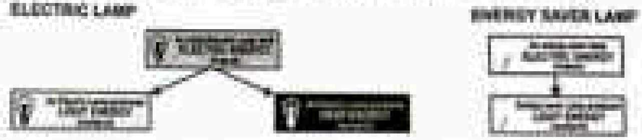
Ans. In an energy converter, a part of the energy taken (used up) by the system is converted into useful work. Remaining part of the energy is dissipated as heat energy, sound energy (noise) into the environment. Energy flow diagrams given below show the energy taken up by an energy

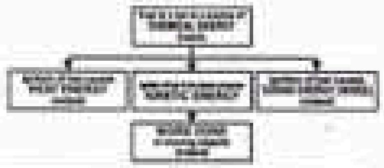
converter to transform it into other forms of energy.

ELECTRIC LAMP

(i) An incandescent Lamp uses electrical energy that is converted in to light energy and heat energy

(ii) Energy saver lamp uses electrical energy that is converted into light energy.





SHORTRESPONSSE QUSTIONS

Q.1: A car is moving with a constant speed along a straight road. Is there any work done on the car?

Ans. According to work energy principle, the work done by the car is zero. When a car moves at a constant speed, there is no change in its kinetic energy, and thus no net force acting on it in the direction of motion. Since, there is no force acting over a displacement, no work is done on the car. If there is friction then work done will be force into displacement. The gravity and the direction of the car are perpendicular to each other. i.e., $W = \vec{F}.\vec{S} = |\vec{F}||\vec{S}|\cos\theta$

$\Rightarrow$ θ is 90° degree's here and $\cos 90^{\circ}$ is zero.

Thus, work done on a car moving along a straight level road with constant speed is zero.

Q.2: Does the work done in raising a box up in a building depend upon how fast it is raised up?

Ans. The work done in raising up box in a building depends upon several factors, including how fast it is raised, the path taken and the height it is raised.

1)Speed: The faster the boxes raised, the more work is done, as this requires applying a greater force over a shorter time period. However, the increase in work due to speed is typically negligible compared to work required to lift the box against gravity.

2)Path: The work done depends on the path taken because work is product of force and displacement in the direction of force. For example if box is lifted straight up vertically, the work done is simply force exerted multiplied by the height lifted. However if path is not vertical, the force required to lift box may vary at different points along the path and work done would be the sum of work done against gravity at each point along the path.

3)Height: The work done is directly proportional the height of the box is raised lifting the box to greater height requires more work because it involves lifting the box against the force of gravity over a greater distance.

(OR)

The work done in raising a box up in a building does not depend on how fast it is raised up; it depends only on the height to which it is raised and the force required to lift it. The work done "W" can be calculated using the formula: $W = F.d.\cos\theta$

So, the work done in raising the box depends on the vertical height to which it is raised and the force exerted against gravity. The path taken while raising the box does not affect the work done, as long as the force is applied in the direction of the motion (vertical direction in this case).
Another way to approach this is through the concept of potential energy. The work done in raising the box is equal to the change in its gravitational potential energy, regardless of how quickly or slowly it is raised.
Mathematically, the work done "W" is given by the change in potential energy:

$$P.E = W = \Delta U = mgh$$

Q.3: Work done on the body either speeds it up, slows it down. Keeping in mind, tell how much work is done by centripetal force on the orbiting satellite?

Ans. Since centripetal force is always perpendicular to the direction of motion, thus no work is done on the satellite by centripetal force and the total energy (K.E + P.E) of the satellite will remain constant. Mathematically"

$$W = Fd\cos\theta \quad \_\_\_\_\_ (1)$$
$$\Rightarrow W = Fd\cos 90 \quad (\text{As } \cos 90^\circ = 0)$$
$$\Rightarrow W = Fd\cos(0) = 0$$

Thus, no work is done on the orbiting satellite by the centripetal force.

Q.4: A car has Kinetic energy 'E_k'. What will be the effect on its kinetic energy if its velocity is doubled?

Ans. The Kinetic energy of the car having mass 'm' moving with velocity 'v' is give by:

$$K = \frac{1}{2}mv^2 \quad \_\_\_\_\_ (1)$$

Let new velocity be $v_1 = 2v$, then new kinetic energy be K' will be given by:

$$K' = \frac{1}{2}m(2v)^2 \Rightarrow K' = \frac{1}{2}m4v^2 = 4(1/2\,mv^2) \Rightarrow K' = 4K$$

Using equation 1, we get:
Thus, kinetic energy will increases four times when velocity of the car is doubled.

Q.5: A bullet is fired from gun, bullet penetrates into sand wall and it stops. Where does its kinetic energy used?

Ans. When a bullet is penetrating into a target, (sand wall) its motion is opposed by the retarding force of the sand wall. Therefore, some part of the K.E is utilized in doing work against the retarding force of the sand in deforming the wall, while some part of K.E is converted into heat energy and sound energy.

Q.6: An LED light bulb has efficiency of 80%. Does it violate conservation of energy principle?

Ans: No, an LED light bulb with an efficiency of 80% does not violate the conservation of energy principle. Conservation of energy states that energy cannot be created or destroyed, only transformed from one from to another.
In the case of the LED light bulb, the efficiency of 80% means that 80% of the electrical energy supplied to the bulb is converted into light energy, while the remaining 20% is typically converted into heat energy.
Therefore, the total energy input (electrical energy) is transformed into light energy and heat energy, consistent with the principle of conservation of energy.

Q.7: How does using renewable energy sources contribute to reducing environmental impact compared to non-renewable sources?

Ans: **Using reducing greenhouse gas emission**

i. Major renewable energy such as solar, wind and hydroelectric power generate electricity without emission of greenhouse gases such as CO_2 and other pollutants.

ii. Renewable energy sources are naturally replenished and abundant in nature.
iii. Reducing water usage
They do not relay on water sources as non-renewable source relay.

iv. Reducing pollution
They produce electricity without emitting harmful pollutants such as SO_2, nitrogen oxide etc.
v. Improving of land degradation by reducing deforestation, improving soil health etc.

Q.8: Will we eventually rely entirely on renewable energy sources? Why or why not?

Ans: Relying on renewable energy is essential for:
i. Reducing carbon emission
ii. Improving air quality
iii. Creating jobs
iv. Achieving energy independence
Renewable are abundant and sustainable, unlike fossil fuels.
However, challenges include intermittent supply (like when there is no sun or wind) and the need for efficient energy storage. Despite high upfront costs, technological advances are making renewable more viable and likely to become the primary energy source.

Q.9: How can increasing the power of a machine impact its energy consumption?

Ans: Increasing the power of a machine generally leads to high-energy consumption, as more power requires more energy per unit of time. This can mean higher operational costs and increased environmental impact if energy sources are not managed efficiently. However, if a more powerful machine completes tasks faster or more efficiently, overall energy consumption might stay the same or even decrease, depending on the task and machine efficiency.

Q.10. A perpetual engine has an efficiency equal to 1. Why it will not work?

Ans. Perpetual motion is the motion of bodies that continues forever in an unperturbed system. A perpetual motion machine or engine is a hypothetical machine that can do work infinitely without an external energy source.
This kind of machine is impossible, as it would violate either the first or second law of thermodynamics, or both.

Multiple Choice Questions

Q.1: The unit of work or energy joule (J) is equal to __________.
(a) horsepower (b) watt metre (c) watt second (d) newton second

Q.2: A car, an elephant and a cricket ball have same kinetic energies. Which of these have greater speed?
(a) car (b) Elephant (c) Cricket ball (d) all have same speed

Q.3: A ball weighing 50 N is lifted to a height of 5 metre. The potential energy stored in it is:
(a) 10 J (b) 25 J (c) 45 J (d) 55 J

Q.4: What is the power utilized when 100 J of work is done in 5 s:
(a) 10 W (b) 20 W (c) 105 W (d) 500 W

Q.5: The SI unit of power
(a) "Joule (b) watt (c) newton (d) erg

Q.6. A 4 kg body is thrown vertically upward from the ground with a velocity of 5 ms^{-1}. If friction is neglected its kinetic energy just before hitting the ground is:
(a) 25 J (b) 50 J (c) 75 J (d) 100 J

Q.7. A ball is thrown downward with an initial velocity, its:
(a) E_k increases & E_p decreases (b) E_k decreases & E_p increases
(c) Both E_k & E_p increases (d) Both E_k & E_p decreases

Q.8: The type of energy derived from heated ground water is:
(a) tidal energy (b) geothermal energy
(c) hydroelectric energy (d) nuclear energy

Q.9: A weight lifter of power 1960 watt lifts a load of mass 'M' from the ground to a height of 2m in 3 second. 'M' is:
(a) 100 kg (b) 200 kg (c) 300 kg (d) 400 kg

Q.10: Which one is renewable source of:
(a) Coal (b) Natural gas (c) Sunlight (d) Uranium

Q.11: One unit of horsepower is equivalent to:
(a) 756 W (b) 716 W (c) 736 W (d) 746 W

Q.12: A practical engine cannot have an efficiency equal to:
(a) 0 (b) 0.5 (c) 0.8 (d) 1

Q.13: A heavy and a lighter object have same momenta. The object with greater kinetic energy is:
(a) lighter (b) heavy
(c) same kinetic energy (d) either (a) or (b)

Q.14: A force is acting on body but causes no displacement. The work down on the body is:
(a) positive (b) negative (c) zero (d) infinite

Q.15: A box is taken to the second floor of a building by doing some work. This work converts to:
(a) kinetic energy (b) potential energy (c) heat energy (d) sound energy

Answer Key

1.	(c)	2.	(c)	3.	(b)	4.	(b)	5.	(b)
6.	(b)	7.	(a)	8.	(b)	9.	(c)	10.	(c)
11.	(d)	12.	(d)	13.	(a)	14.	(c)	15	(b)

Examples

6.1: Muhammad Taaha was pushing a box with a force of 100 N on a flat frictionless surface. How much work he does on the box if he pushes it through a displacement of 200 m.

Ans. Given:-
Force 'F' = 100 N
Displacement 'd' = 200 m
Work done = ?

Solution:
As we know $W = Fd$
Putting Values $W = 100 \times 200 = 20000\ J = 20\ kJ$

6.2: Babar Azam hits a cover drive by giving kinetic energy of 50 J to the ball by his bat. At what speed will the ball go to the boundary if mass of the ball is 120 g?

Ans. Given:-
Mass of ball 'm' = 120 g = 0.12 kg
Kinetic energy of ball 'E_k' = 50 J
Speed of cricket ball 'v' = ?

Solution:
As we know $E_k = \frac{1}{2}mv^2$
For Velocity $v^2 = \frac{2E_k}{m}$
or $v = \sqrt{\frac{2E_k}{m}}$ Putt values $v = \sqrt{\frac{2(50)}{.12}}$
$v = 28.9\ m/s$

At this speed, the ball will touch the boundary line in just 2.5 seconds, which is about 72 m long.

6.3: At School sports gala, Kamil made a record in high jump at his school. He jumped 1.5 m high. What will be his potential energy if his mass is 60 kg? From where does this potential energy come?

Ans. Given:-
Mass 'm' = 60 kg
Acceleration due to gravity 'g' = 9.8 m/s^2
Potential Energy '$E_{P_{grav}}$' = ?

Solution:
Potential energy is given by:
$E_{P_{grav}} = mgh$
$E_{P_{grav}} = 60 \times 9.8 \times 1.5$
$E_{P_{grav}} = 882\ J$

This gravitational potential energy comes from pushing himself upward with kinetic energy of 882 J.

6.4: A player kicks the football of mass 450 g is thrown vertically upward at a speed of 22 ms^{-1}. (a) Neglecting air resistance how high would it reach. (b) If due to air friction the ball only rises to 20 m, what is the work done against air resistance?

Ans. Given:-
Mass 'm' = 450 g = 0.45 60 kg
Speed 'v' = 22 m/s
Acceleration due to gravity 'g' = 9.8 m/s^2
Height with air friction 'h_o' = 20 m
Height 'h' = ? (without friction)
Work done by friction 'W_b' = ?
Height with air friction 'h_o' = ?

Solution:
(a) without frictional loss:
$E_{KI} = E_{P_{grav}}$
$E_{KI} = \frac{1}{2}mv^2 = mgh$
or $h = \frac{v^2}{2g}$
$h = \frac{(22)^2}{2 \times 9.8}$
$h = 24.7\ m$

(b) Due to friction when the ball only raises to 20 m, then:
Loss in KE = gain in PE + work against friction
or $E_{KI} = E_{P_{grav}} + W_b$
or $W_b = E_{KI} - E_{P_{grav}}$
hence $W_b = \frac{1}{2}mv^2 - mgh_o$
Putting values $W_b = \frac{0.45 \times (22)^2}{2} - 0.45 \times 9.8 \times 20$
Therefore $W_b = 108.9 - 88.22 = 20.7\ J$

6.5: How powerful will be a Tesla Car's engine if it does 3×10^7 J of work in 1 minute? What will be its power in hp?

Ans. Given:-

work done 'W'	=	3×10^7 J
time 't'	=	1 minute = 60 s
Power 'P'	=	?
Power in hp 'h'	=	?

Solution:

Power is given by the relation:

$$P = \frac{W}{t}$$

$$P = \frac{3.69\times10^7}{60}$$

$$P = 6.15\times10^5\ W = 615\ kW$$

Since, $1hp = 746$ watt or $1\ watt = \frac{1}{746}$ hp

or $P = 6.15\times10^5\ \frac{1}{746}$ hp

Therefore $P = 825$ hp Answer

6.6: A petrol engine in-takes 400 J of fuel energy and does only 120 J of useful work. How efficient is this petrol engine.

Ans. Given:-

Input energy = Input work 'W_{in}'	=	400 J
Output energy = output work 'E_{out}'	=	120 J
Efficiency	=	?

Solution:

The efficiency of an engine is given by:

$$\eta = \frac{E_o}{E_i}$$

$$\eta = \frac{120}{400}$$

$$\eta = 0.3$$

In percentage $\eta = 0.3\times100 = 30 = \text{Efficiency} = 30\%$

Numerical Problems

Q.1: Calculate the work done in pushing a box with 150 N through distance of 5m.

Ans. Given:-

Force 'F'	=	150 N
Distance 'd'	=	5 m
W	=	?

Solution:

As we know $W = Fd$

Putting Values $W = 50\times5 = 750$ J

So work done in pushing box is 75 J.

Q.2: A boy weighting 75N jumps up and gains 300 J of gravitational potential energy. Find the height to which the boy will rise.

Ans. Given:-

weight = $W = mg = 75$ N, P.E = 300 J

P.E = 300 J

height = h = ?

Solution:

As we know $P.E = mgh$

Putting Value, we have $300 = 75h$

$$h = \frac{300}{75}$$

$h = 4$ m Ans.

Q.3: A 5 kg steel ball is dropped from the top of a 12 m high tower. What is kinetic energy of the ball on hitting the ground? With what velocity will it hit the ground? (Neglect air resistance).

Ans. Given:-

Mass of steel ball 'm'	= 5 kg
height 'h'	= 12 m
Kinetic energy 'K.E'	= ?
Velocity of steel ball 'v'	= ?

Solution:

(a) After dropping from that height, all the potential energy of the steel ball will convert into kinetic energy, given by:

$$K.E_{gain} = P.E_{loss} = mgh$$

Putting Value, we have $K.E_{gain} = 5\times9.8\times12$

$$K.E_{gain} = 588\ J$$

(b) velocity of the ball can be given from the relation of kinetic energy:

$$K.E = \frac{1}{2}mv^2$$

or

Putting Value, we have $V = \sqrt{\frac{2K.E}{m}}$

$$V = \sqrt{\frac{2\times588}{5}}$$

$$V = 15.34\ m/s$$

Q.4 A 2.0 kg rock is dropped from 20 m tall building. What is the kinetic and gravitational potential energy when the rock has fallen 15m.

Ans. Given:-

Mass = 'm'	= 2 kg
Acceleration = 'g'	= 9.8 m/s^2
Height = 'h'	= 20 m
Kinetic Energy= 'K.E'	= ?

Solution:

As we know $P.E = mgh$

Putting Values $P.E = 2\times9.8\times20 = 392$ J

Calculate velocity of rock when it has fallen 15 m

$$V_f^2 - V_i^2 = 2aS$$

Putting values $(V_f)^2 - (0)^2 = 2\times9.8\times15$

$(V_f)^2 = 19.6 \times 15$

$(V_f)^2 = 294$

$V^2 = 294$

$K.E = \frac{1}{2} mv^2$.

$K.E = \frac{1}{2} \times 2 \times 294$.

$K.E = 294\ J$.

Q.5: A rocket with a mass of 800 g is launched vertically upward with an initial speed of $30ms^{-1}$. (a) Assuring no air resistance, calculate the maximum height the rocket would reach, (b) If, due to air friction, the rocket only rises to 25 m, determine the work done against air resistance.

Ans: We are given: **Part (a)**

Mass of the rocket $m = 800\ g = 0.8\ kg$ (since 1000 g = 1 kg), Initial speed of the rocket, $v_0 = 30ms^{-1}$

Acceleration due to gravity, $g = 9.8ms^{-2}$

$\Rightarrow$ $h_{max} = ?$

Assuming no air resistance, we can use the conservation of energy to find the maximum height. The initial kinetic energy will be converted into gravitational potential energy at the maximum height. Initial kinetic energy ($KE_{initial}$) is given: $KE_{initial} = \frac{1}{2}mv_0^2$

At maximum height, the kinetic energy is zero and all the energy is potential energy (PE_{max}):

$$PE_{max} = mgh_{max}$$

Since no energy is lost, $KE_{initial} = PE_{max}$

$\Rightarrow$ $\frac{1}{2}mv_0^2 = mgh_{max}$

Solve for h_{max}: $h_{max} = \frac{v_0^2}{2g}$

Substitute the given values:

$\Rightarrow h_{max} = \frac{(30ms^{-1})^2}{2 \cdot 9.8ms^{-2}}$ $\Rightarrow h_{max} = \frac{900m^2s^{-2}}{19.6ms^{-2}}$ $\Rightarrow h_{max} = 45.92m$

So the maximum height the rocket would reach is approximately 45.92 m.

Part (b)

$W_{air\,resistance} = ?$

If due to air resistance the rocket only rises to h = 25 m.

The gravitational potential energy at 25 m is: P.E = mgh

$P.E = 0.8kg \times 9.8ms^{-2} \times 25 = 196J$

The work done against air resistance is the difference between the initial kinetic energy and potential energy at 25 m: $W_{air\,resistance} = K.E_{initial} - P.E$

We already calculated $K.E_{initial}$ in part as: $K.E_{initial} = \frac{1}{2}mv_0^2$

$\Rightarrow K.E_{initial} = \frac{1}{2} 0.8kg \times (30ms^{-1})^2$ $\Rightarrow K.E_{initial} = 0.4 \times 900J$ $K.E_{initial} = 360J$

Now, calculated W_{air}

$\Rightarrow W_{air\,resistance} = 360J - 196J$ $\Rightarrow W_{air\,resistance} = 164J$

Therefore, the work done against air resistance is - 164 J.

Q.6: A 2 hp electric motor gives energy to a system that lifts a load of 100 kg to height of 10 m in 1.5 s. Calculate.

Ans. Given:-

Power of motor 'P'	= 2hp = 2 × 746 = 1492 watts
Mass 'm'	= 100 kg
Height 'h'	= 10 m
time 't'	= 1.5 s

To find:

(a) input work 'W_{input}'	= ?
(b) Output work 'W_{output}'	= ?
(c) Efficiency	= ?

Solution:

(a) The input is the work done by the motor on pulley, given by:

$W_{input} = P \times t$

$W_{input} = 1492 \times 1.5$

$W_{input} = 2238J$

(b) The output is the work done by lifting the load by system, given by:

$W_{output} = mgh$

$W_{output} = 100 \times 9.8 \times 10$

$W_{output} = 9800$ or **9.8 kJ**

(c) Percentage efficiency is the ratio of output to input, multiplied by 100 and is given by:

$\%Efficiency = \frac{output}{input} \times 100\%$

$\%Efficiency = \frac{980}{2238} \times 100\%$

$\%Efficiency =$ **437.8%**

Q.7: What horsepower (hp) is required to pump up 2500 kg of water to 100 m height in 5 minutes?

Ans. Given:-

Mass 'm'	= 2500 kg
Height 'h'	= 100 m
Time 't'	= 5 min = 5 × 60sec = 300 sec
Power 'P'	= ?

Solution:

As we know $P = \frac{mgh}{t}$

Putting Value, we have $P = \frac{2500 \times 9.8 \times 100}{300}$

$P = \frac{2500 \times 9.8 \times 1\cancel{00}}{3\cancel{00}}$

$P = \frac{2500 \times 9.8 \times 1}{3}$

$P = 8166$ watt (as 1 h.p = 746 watts)

$P = \frac{8166}{746}$

$P = 11$ hp

UNIT 07 Density and Temperature

Q.1: Define density. Describe methods to determine densities of regular and irregular-shaped solids, liquids and gases.

Ans. **Density:** We define density of material as: "Mass per unit volume of the substance is called its density". **Mathematically:**

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Its symbol is as: $\rho = \frac{m}{V}$

Its S.I unit is kilogram per cubic meter ($kg\,m^{-3}$). Smaller unit to measure density is gram per cubic centimeter (g/cm^3). Density of liquids is usually measured in gram per milliliter (g/mL). It is a scalar quantity.

(i) Density of small amount of substance is the same as the density of its bulk because density is calculated by the amount of matter in its unit volume. Density of a material changes with the temperature.

(ii) Density of a material tells us how much matter a substance has in its unit volume. The substance, which has more closely packed atoms, has more matter in a fix volume. Therefore, it is denser substance. Solids like metals, rocks etc. are denser materials because they have closely packed atoms in the given volume. Substances in which atoms are far from each other, they have small amount of matter in a fix volume, so they are less dense. It is the reason why liquids and gases have less density than solids. Density of solids is greater than liquids and density of liquids is greater than gases.

Table 7.1 Densities

Material	Density (kg/m^3)
Iron	7900
Gold	19300
Ice	920
Plythene	900
Petrol	800
Pure water	1000
Mercury	13600
Air	1.3
Carbon Dioxide	2.0

Measuring Densities of Different Substances: To measure the densities of liquids, solids (regular shaped or irregular shape), we will follow some steps in each case, which we will explain below:

Density of liquids: To measure density of liquids, we need a graduated measuring cylinder to measure volume of liquid, a balance to measure mass of liquids. We will measure density of liquid using following steps:

1) Place the empty measuring cylinder on balance and measure its mass.
2) Add liquid in the measuring cylinder and measure its volume.

3) Subtract mass of empty cylinder from the mass of cylinder and liquid (measured in step-2).
Mass of liquid = Mass of measuring cylinder and liquid - Mass of empty cylinder.
4) Measure volume of liquid from the measuring cylinder.
5) To calculate the density of liquid, divide mass of liquid by its volume.

$$\text{Density of liquid} = \frac{\text{Mass of liquid}}{\text{Volume of liquid}}$$

Density of Regularly Shaped Solids: To find density of regularly shaped solids (like solid cubes, solid cuboids, solid sphere etc.), we will follow these steps:

1) Find mass of the solid regular shaped object using balance.
2) Calculate the volume of object using formula according to shape of the object.

For example, volume of cuboid = Length x width x Height

Volume of cube = $(\text{side length})^3$

$$\text{Volume of sphere} = \frac{4}{3}\pi r^3$$

$$\text{Density of solid} = \frac{\text{Mass of Solid}}{\text{Volume of Solid}}$$

Density of Irregular Shaped Object (Displacement Method): We can find the density of irregular shaped solid objects like stones which can sink in the water. We need graduated measuring cylinder to measure volume and balance to measure mass of object. We will follow these steps to find its density:

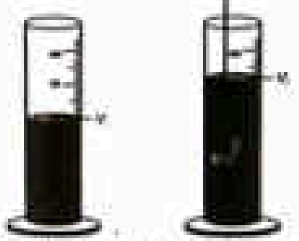
1) Find the mass of the irregular shaped stone.
2) Add some water in measuring cylinder and measure its initial volume (V_i).
3) Tie thread with the irregular shaped object e.g. stone and lower it in the measuring cylinder.
4. Water will rise (i.e. displace) in the measuring cylinder and measure final volume (V_f). This final volume reading is the sum of volume of water and volume of object.
5) Subtract initial volume (V_i) from final volume (V_f) to get volume of object.

$$\text{Volume of object} = V_f - V_i$$

6) To find density of objects divide mass of object with its volume.

$$\text{Density of solid} = \frac{\text{Mass of Solid}}{\text{Volume of Solid}}$$

FIGURE 7.3 FINDING VOLUME OF IRREGULAR SHAPED STONE



We can find this method to find volume and density of any insoluble irregular shaped object.

Q.2: How would you distinguish between solids, liquids, and gases on the basis of attractive force between particles and the motion of particles.

Ans. Matter exists in three fundamental states: solid, liquid and gas. Matter consists of particles (atoms and molecules). Gaps between these particles is the main reason that divides the matter in these states. Particles of matter apply an attractive force on each other. The difference in strength of this force is the reason for smaller or large gaps between particles. Therefore, their densities and patterns of particle motion are also impacted by varying strength of this attractive force. Now we will see properties of each of the three states:

FIGURE 7.4 MOTION OF PARTICLES IN DIFFERENT STATES

a) Particles vibration about their mean position in solids
b) Particles move freely relative to each other in liquid
c) Particles move freely and quickly in gases

Solids Liquids Gases

Properties of Solids:

1. Solids are made up of particles (atoms or molecules).
2. There is strong attractive force between particles.
3. Due to strong attractive force, particles of solids are closely packed and they have fixed lattice pattern.
4. Solid particles cannot freely move like gas particles or slide past one another like liquid particles due to their fixed location. Solids particles can only vibrate about their mean position.
5. Solids have fix shape.
6. Solids have high density.

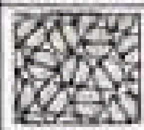
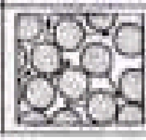
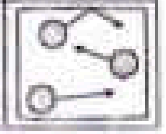
Properties of Liquids:

1. Liquid are also made up of particles (molecules).
2. The attractive force between particles is stronger than that of gases but weaker than that of solids.
3. The distance between particles in liquids is greater than that in solids due to an intermediate attractive force, yet they are still close together.
4. Liquid particles flow and glide over each other. Liquid particles keep changing their position.
5. Due to flowing particles, a liquid has no fix shape and can adopt the shape of the container.
6. A liquid has intermediate density (smaller than a solid and higher than a gas.

Properties of Gases:

1. Gas is also composed of particles (atoms and molecules).
2. There is negligibly weak attractive force between gas particles.
3. Due to weak attractive force, distance between particles is larger as compared to the size of the particles.
4. Particles are in constant random motion and they constantly colliding with each other and with the walls of the container.
5. Forces between molecules are negligible, except during collisions.
6. Gas has no fix shape and volume. Gas spread out in the container and fill it, therefore its volume is equal to the volume of the container.
7. Gases are less dense than liquids and solids.

TABLE 7.1 : STATES OF MATTER

State	Solid	Liquid	Gas
Density	High	Medium	Low
Arrangement of particles	Regular pattern	Randomly arranged	Randomly arranged
Movement of particles	Vibrate around a fixed position	Move around each other	Move quickly in all directions
Energy of particles	Low energy	Greater energy	Highest energy
2D diagram			

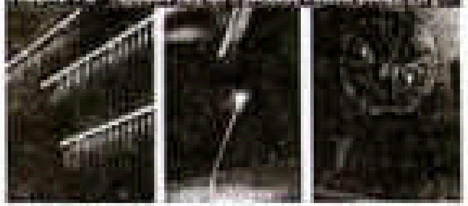
Q.3: Describe plasma as fourth state of matter briefly.

Ans. **Plasma:** Plasma consists of positive ions, free electrons (negatively charged particles) and neutral atoms in gaseous state.

Explanation:

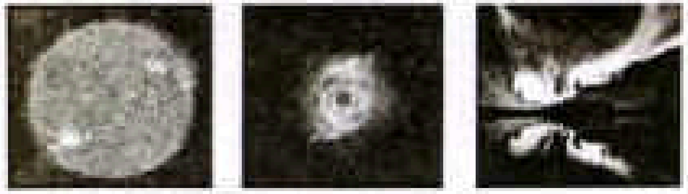
(i) Plasma exists at very high temperature: Usually, plasma exists at very high temperature or at high pressure or at both. By using a high electric and magnetic field, a substance can also be transformed into plasma.

FIGURE 7.6 EXAMPLES OF PLASMA FROM DAILY LIFE



(ii) Plasma in universe: There is lot of plasma in the universe. Plasma is gas that hot, bright and highly ionized. These characteristics together makes it different from the gas. 99% of visible universe is made up of plasma. That is why plasma is often called "the fourth state of matter," along with solid, liquid and gas.

FIGURE 7.7 EXAMPLES OF PLASMA IN NATURE

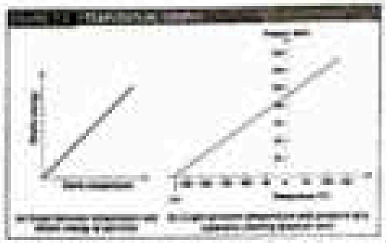


The Sun Nebula Aurora

(iii) Effect of temperature on K.E of gas: When a gas heated continuously K.E of gas molecules also continuously increases. Due to it, attractive molecules forces keep on decreasing as molecules go away from each other. The molecules and atoms start colliding with each other powerfully. Due to it, electrons of the atoms are removed and atoms become positive ion. This ionic state of matter is called plasma. It can highly conduct current because it has free electrons and moving ions.

Q.4: Discuss relationship between motion of particles and temperature of substance.

Ans. Motion of Particles and temperature of substance: Even though the water molecules in a pot are constantly moving, the movement is not powerful enough for us to notice it with our naked eyes. However, we observe water Currents, or water molecules in motion at a higher temperature, when we place this pot on a stove that is burning. There is certain relationship between motion of molecules of a material and its temperature. In this section, we will understand this relationship. When a material is heated, one of the two things may happen:



(i) Strength of attractive force between particles can decrease and bonds between particles may break (as it happens during melting and boiling processes of a material)

(ii) It can speed up the particles and hence increase K.E. of the particles. "The temperature of a substance is the measure of its hotness or coldness, and the temperature of a substance is directly proportional to the average K.E. of its particles." When we heat a substance (at room temperature), the speed and kinetic energy of its particles increase. That is why the temperature of the substance will also increase. Conversely, when we remove heat from a substance (for example, by placing hot water in ice or in a refrigerator), the speed and kinetic energy of the particles will become slower and slower. Therefore, the temperature of the substance will also decrease.

If we keep on removing the heat energy from a substance, its particles will keep on slowing down and hence keep on losing kinetic energy. By doing so, a stage will come when molecules will no longer be moving and they have least or no kinetic energy. Particles cannot collide with each other or with the container, therefore they cannot exert pressure (P=0 Pa). At this point, temperature of the substance is called absolute zero.

"Absolute zero is the lowest possible temperature of a substance at which its particles have least kinetic energy". Its value is zero kelvin (0K) while on the Celsius scale, it is -273.15°C. At absolute zero, there is no heat energy available to move the particles of the substance.

Q.5: Define and Explain internal Energy of a substance.

Ans. INTERNAL ENERGY AND TEMPERATURE OF A SUBSTANCE: Internal energy of a substance is the total energy possessed by the particles of the substance.

Explanation: internal energy is the total kinetic and potential energy of the particles of a substance. Potential energy of the particles of a substance is due to attractive force between them. These particles can have three forms of kinetic energies i.e. translational K.E., rotational K.E. and vibrational K.E. in case of ideal gas, it has only translational kinetic energy of particles. Therefore, its internal energy is only due to kinetic energy of particles. in the previous topic, we have studied that temperature is directly proportional to average Kinetic energy of the particles of a substance. When we heat a substance, it speeds up the particles and increases the kinetic energy of its particles. Hence, we can say that internal energy of the substance also increases. By increasing the temperature of a substance, its internal energy also increases. A change in internal energy gives important information about the substance. For

example, an increase in internal energy indicates an increase in temperature of the substance, which can be the result of energy given to particles by adding heat or by some other method.

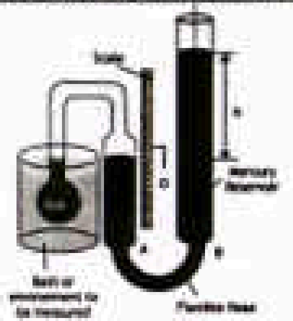
Q.6: Describe two different physical properties that vary with temperature and explain how these properties can be used to measure temperature.

FIGURE 7.9 THERMOMETER

Ans. Physical Properties: Now we know that when the temperature of a body increases, it increases the kinetic energy of its particles. These fast-moving particles can cause variations in different physical properties (volume, pressure, change in colour, electrical resistance etc.) in a predictable way. Variations in these physical properties may be used to measure the temperature of a body. These physical properties on the basis of which a thermometer works is called its thermometric property. Let us explain the concept in more detail.

Expansion of Liquids: Most liquid expand upon heating. Liquids that expand on heating uniformly can be used as thermometric materials. We use this property for liquid in glass thermometers, which use mercury or alcohol as thermometric materials. When this thermometer is touched by a hot body, it absorbs heat from the body and causes the mercury to expand. This uniform expansion of mercury varies linearly with temperature when absorbing heat. The positon of the mercury in the thermometer gives a reading of the temperature on the thermometer scale.

FIGURE 7.10 GAS THERMOMETER



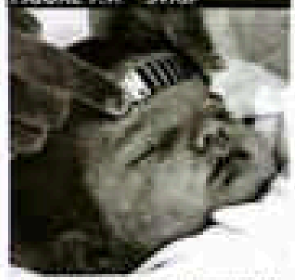
Variation of Volume and Pressure: When a gas is heated its volume as well as pressure may change these variations in volume an pressure are used in gas thermometers to measure temperature. There are two types of gas thermometers, constant pressure gas thermometer and constant volume gas thermometer.

A constant volume gas thermometer uses the principles that the pressure of a gas is directly proportional to the temperature, while the volume of the gas is kept constant (Gay-Lussac's law). We touch the thermometer bulb with the body whose temperature is to be measured. When the temperature of the thermometer bulb increases, the K.E. of gas particles increases.

They collide with each other and the walls of the container more vigorously. This causes an increase in pressure. This variation with in pressure is used to measure temperature.

A constant-pressure gas thermometer uses the principle that the volume of a gas is inversely proportional to the temperature, while the pressure of the gas is kept constant (Charles's law). In this thermometer, the gas in its bulb expands and pushes a piston according to the increase in volume of the gas. This change in volume of the gas is used to measure its temperature.

FIGURE 7.11 STRIP

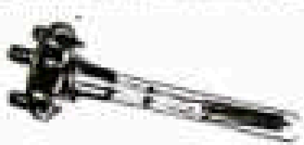


liquid crystal strip thermometer

Variation in Colour of Crystals: Liquid crystals are those materials that change colour with a change in temperature. Liquid crystals are packed inside a plastic strip. Liquid crystals are substances that change colour with a change in temperature. In these thermometers, a liquid crystal material is sealed in a plastic strip or patch. We touch it with the body who's temperature is to be measured. When its temperature changes, it also changes colour. By matching the colour to a temperature scale, we can determine the temperature of a body. These thermometers are often used as fever thermometers and for aquariums and baby bottles. There are also other thermometers for example resistance thermometers, bimetallic thermometers, thermocouple etc.

Q.7: Write brief note on (i) Resistance thermometers or thermistors. (ii) Bimetallic strip thermometers.

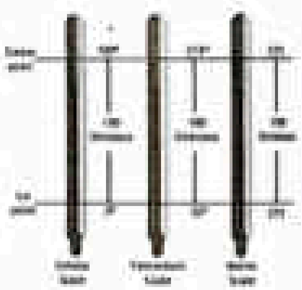
Ans. **Resistance Thermometers or Thermistors:** It can measure temperature due to change in its resistance (change in opposition to flow of current through it) it due to variation of its temperature.



Volume expansion of a gas	Constant pressure gas thermometer
Volume expansion of a liquid	Laboratory or clinical thermometer
Volume expansion of a solid	Bimetallic strip thermometer
Pressure change of a fixed mass of gas	Constant - volume gas thermometer
Changes in e.m.f	Thermocouple
Changes in electrical resistance	Resistance thermometer or thermistor

...ic strip thermometers: It can measure temperature by variation in volume expansion of thermocouple: It can measure temperature due to change in its emf produced due to variation in its temperature.

Discuss Fixed points in calibration of thermometer.



Fixed Points in calibration of Thermometer: When a thermometer is used to determine the temperature of a body, we measure its reading from the calibrated scale made on it. Without a temperature scale, a thermometer is valueless. We can measure the temperature accurately from thermometer, we need two fixed points. These two fixed points should be accessible and reproducible. These two fixed points are also called the reference points; lower reference points and upper reference points. Gap between these two points is divided into equal divisions. So, we cannot measure temperature accurately without deciding about these fixed points.

A fixed points is a standard degree of hotness or coldness. In general, we have three scales; Celsius scale, Fahrenheit scale and Kelvin scale.

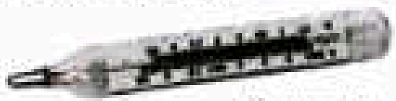
For these scales, lower reference point is a standard degree of coolness. Melting point of ice is taken as lower reference points for these scales which is 0°C on Celsius scale, 32°F on Fahrenheit scale and 273 K for kelvin scale. Similarly, upper reference point is standard degree of hotness. Boiling point of water is taken as their upper reference point which is 100°C on Celsius scale, 212°F on Fahrenheit scale and 373 K for Kelvin scale.

Number of divisions on temperature scale is calculated by taking the difference between upper reference point and lower reference point values on the scale. That's why, there are 100 divisions on Celsius and Kelvin scales while there are 180 divisions on Fahrenheit scale.

Q.9: Explain sensitivity, range and linearity of the thermometer in detail.

Ans. **SENSITIVITY OF A THERMOMETER:** It is ability of a thermometer to detect small changes in temperature. We can say that it is smallest variation in temperature which a thermometer can measure. For example, a thermometer with a sensitivity of 0.1°C can detect changes in temperature as small as 0.1°C.

FIGURE 7.15 RANGE



Thermometer

A thermometer with a sensitivity of 1°C can only detect changes in temperature as large as 1°C. It cannot measure change in temperature less than 1°C. We can say that sensitivity is analogous to least count of a measuring instrument. Mercury thermometer is a sensitive thermometer. To illustrate sensitivity of a thermometer, place it in a glass of water at room temperature and let it to set at room temperature. Then, add a few drops of hot water to the glass. We will see that mercury in thermometer will rise quickly to show change in temperature of water.

RANGE OF ATHERMOMETER: The range of a thermometer is the range of temperature that it can measure. It is measured by the lowest and highest temperatures that the thermometer can measure. For example, clinical mercury thermometer can measure the temperature from 35°C to 42°C on Celsius scale. So, this is its range on Celsius scale while its range on Fahrenheit scale its range is from 94°F to 108 °F.

Digital thermometers have a wide range and can measure temperatures from very cold to very hot. So, we use it to illustrate range of thermometer by measuring lowest and highest temperatures. For example, place a digital thermometer in a glass containing ice. It will accurately show melting point of ice (0°C). Then place the digital thermometer in a pot of boiling water. It will accurately show boiling point of water (100°C). This method can be used to measure range or thermometers.

LINEARITY OF A THERMOMETER: Linearity tells us how equally and uniformly a thermometer shows the temperature variations. Thermometers scales have equally spaced marks on its scale. If temperature changes and thermometer shows an increase of some divisions then it should same increase in divisions for same change in temperature at higher temperatures. For example, a linear thermometer will measure an increase in temperature from 0°C to 50°C with the same accuracy as an increase of temperature from 50°C temperature of 100°C. Bimetallic thermometers are linear thermometers and measure temperature equally accurately across their range. To illustrate this, place a bimetallic thermometer in a glass of water at room temperature, then, gradually heat the water. The bimetallic thermometer will gradually respond to the change in temperature and the pointer on the thermometer will move.

Q.10: Explain structure and function of liquid-in-glass thermocouple and thermometers.

Ans. Liquid-in-glass thermometers and thermocouple thermometers are two different types of thermometers that are used to measure temperature.

LIQUID-IN-GLASS THERMOMETERS:

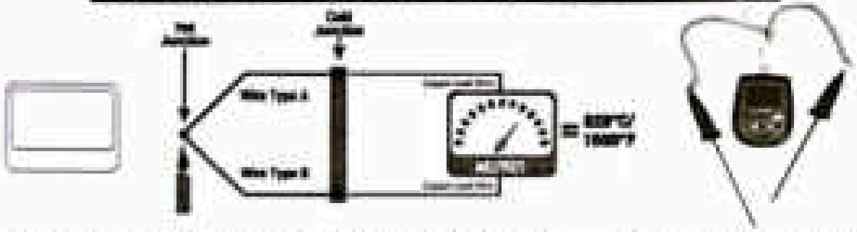
Construction: A glass thermometer usually has a long, thin glass tube with a bulb at the end. The bulb contains mercury or alcohol as a liquid. The liquid expands as it warms and contracts as it cools.

Working: Liquid-in-glass thermometers work by measuring the expansion and contraction of the liquid in the bulb. When the thermometer is placed in a warm atmosphere or touched with hot body, the liquid (mercury or alcohol) in the bulb expands and rises up the glass tube. When the thermometer is placed in a cold environment or touched with cold body, the liquid in the bulb contracts and falls down the glass tube. Reading of temperature on the thermometer scale is measured. The scale is calibrated so that a certain temperature is represented by the height or position of the liquid inside the thermometer tube.

Use: In homes, schools, and laboratories, liquid-in-glass thermometers are frequently used to measure temperature. They are also used in a few industrial applications.

THERMOCOUPLE THERMOMETERS: Thermocouple thermometers have two wires made of different metals that are joined at one end. This junction is called the hot junction. The other ends of the wires, called the cold junctions, are connected to a measuring device, such as a voltmeter.

FIGURE 7.16 THERMOCOUPLE THERMOMETERS



Thermocouple thermometers work by measuring the voltage difference between the hot junction and the cold junctions. When the hot junction is heated, it causes free electrons in metals to flow across the junction and it creates voltage between hot and cold junctions. If we keep on heating hot junction then voltage difference between the hot junction and the cold junction increases.

When the hot junction is cooled, the voltage difference between the hot junction and the cold junctions decreases. This shows the change in temperature in thermocouple is linearly proportional to change in voltage between hot and cold junctions. Thus, we can measure temperature by measuring this voltage. The voltmeter is calibrated so that the voltage difference between the hot junction and the cold junctions corresponds to a specific temperature. Thermocouple thermometers are used to measure the temperature of furnaces, kilns, engines, and other industrial equipment. These are also used in the agriculture industry to measure the temperature of soil and water.

Q.11: Analyze how the structure of a liquid-in-glass thermometer can be modified to improve its performance. Give a detailed answer.

Ans. **Effect of Structure of a Liquid-in Glass Thermometer On its Sensitivity, range and Linearity:** The structure of a liquid-in-glass thermometer affects its sensitivity, range, and linearity in the following ways:

Effect of Nature of Liquid used in Thermometer on its sensitivity: Liquid like mercury and alcohol expand more than others when heated as compared to liquid like water. Therefore, we can say that thermometers having mercury or alcohol are more sensitive.

Effect of Diameter of Tube on Sensitivity of Thermometer: Sensitivity of a thermometer is its ability to detect the smallest change in temperature. Liquid in glass thermometer has a long capillary tube of small diameter filled with liquid mercury or alcohol. The sensitivity of a liquid-in-glass thermometer is affected by the diameter of this tube. A thermometer with small diameter capillary tube can detect smaller change in temperature than the thermometer with

large diameter of the tube. Narrower diameter tube will have smaller volume of liquid in it. Which will react quickly to the absorbed heat and will rise quickly.

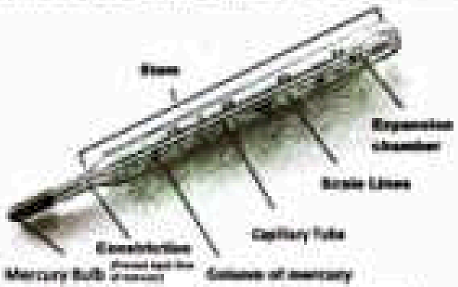
Effect of Nature of Liquid Used in Thermometer on Its Sensitivity: Liquid like mercury and alcohol expand more than others when heated as compared to liquids like water. Therefore, we can say that thermometers having mercury or alcohol are more sensitive.

Effect of Size of bulb of thermometer on its Range: The range of a liquid-in-glass thermometer is affected by the volume of the bulb. If bulb has large size then it will contain more amount of liquid in it. So, this thermometer has large amount of liquid available to expand. Therefore, it can cover large range.

Effect of Type of glass used in Thermometer on its Linearity: The nature of the glass used in a thermometer can impact its linearity by affecting its expansion and contraction with temperature change, transparency, chemical stability, uniformity, durability, and thermal conductivity.

Some types of glass, such as borosilicate glass, have a more linear expansion coefficient than others. Liquid-in-glass thermometer made with borosilicate glass will be more linear than a liquid-in-glass thermometer made with another type of glass, such as soda lime glass.

FIGURE 7.17 PARTS OF GLASS THERMOMETER



SHORTRESPONSE QUSTIONS

Q.1: Two liquids A and B, have densities 1 g/mL and 1.2 g/mL respectively. When both liquids are poured into a container, one liquid floats on top of the other. Which liquid is on top, and why?

Ans. The liquid with low density of 1 g/mL will float on the top of the liquid with a higher density of 1.2 g/mL, this is because object with higher density sink in liquids with lower densities. Since the density of second liquid is higher, it will sink to bottom of container, allowing the liquid with lower density to float on top.

Q.2: Write a method to find the volume and density of a human body?

Ans. 1) Measure the mass of the body (human body) using scale in Kilograms (Kg).

2) Submerge the body in a container filled with water, the volume of the water displaced by the body is equal to the volume of the body. Measure the volume of water displaced by using a graduated cylinder or by marking water level before and after the submerging the body.

3) Divide the mass of the body by its volume to calculate density.

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{m}{v}$$

Q.3: How is plasma the fourth state of matter? Give a reason.

Ans. Plasma is often referred as the fourth state of matter due to following reasons.

1) Ionization: Atoms lose or gain electrons, resulting in mixture of positively charged ions and free electrons. This process known as ionization unlike gases. Where atoms are neutral.

2) Electric conductivity: plasma can conduct electricity because of the Presence of free electrons of the property distinguishes it from gases which are typically insulations.

3) Response to electric and magnetic field: Plasma responds strongly to electric and magnetic field. There fields can influence the behavior and movement of charged particles within the plasma.

4) Occurrence in nature: Naturally occur in phenomenon such as lightning, aurora and stars and artificially generated in labs due to these above distinct characteristics and behavior, plasma is considered as separate state of matter.

Q.4: Why water is not used in liquid in glass thermometer?

Ans. Water is not used in the thermometer due to following reasons:

1) water has narrow freezing and boiling points.
2) water has significant vapour pressure.
3) thermal expansion of water is not linear and consistent as alcohol or Hg.
4) The density of water changes with temperature.
5) water can be corrosive to certain materials used in thermometer.

Q.5: Can we increase internal energy of a substance without increasing its temperature?

Ans. The internal energy can increase without a change in temperature through a processes such as compression or expansion in a closed system, chemical reactions or by adding or removing heat while the system is performing work.

Q.6: Why are fixed point scales required for thermometers? What difficulties are there when setting fixed points for thermometer scales?

Ans. Fixed points on thermometer scales are necessary for calibration and accurate temperature measurement. Difficulties arise when setting these fixed points due to:

1) uniformity 2) precision 3) standardization 4 Material properties.
5) Environment

Q.7: Mercury is replaced with alcohol in liquid in glass thermometer. Discuss the possible change in sensitivity and range of thermometer?

Ans. Alcohol typically expands more than mercury for some rise in temperature. Therefore, the sensitivity of the thermometer, defined as the change in length per unit temperature change would likely decrease when using alcohol instead of Hg. While sensitivity decreases, the increased expansion of alcohol may expanse the readability of then meter, ??? small temperature change more noticeable.

Q.8: Why -273. 15 °C temperature is called absolute zero? Can we achieve this temperature?

Ans. Absolute zero -273.15 °C the lowest possible temperature where molecular motion ceases entirely, theoretically it is impossible to achieve this temperature because it would require removing all energy from a system which is not feasible.

Q.9: Why thermocouple thermometer is suitable to measure high temperatures good for measuring high temperatures but a liquid in glass thermometer is not?

Ans. Thermocouple is suitable for high temperature due to following reasons:

1). Wide temperature range. 2) Fast response time. 3) durable 4) compact design

On the other hand liquid in glass thermometer is not suitable for high temperature because

i) limited temperature range. ii) Fragility iii) slow response time
iv) Risk of contamination

over all, thermocouple thermometers are preferred for high temperature, applications due to their which temperature range, durability, fast response time and suitability for harsh environment.

Q.10: Can we increase the sensitivity of a liquid-in-glass thermometer without changing its range?

Ans. The sensitivity of liquid-in-glass thermometer can be changed without altering its temperature range.

1) Bulb size: Increasing or decreasing bulb size can affect sensitivity. A long bulb will increase sensitivity because it contains more liquid, allowing for more expansions.

2) capillary tube diameter: A narrow tube will increase sensitivity because it requires less thermal energy to cause a noticeable expansion or contraction of liquid column.

3) liquid selection: using a different type of liquid with higher co-efficient of expansion. than Hg such as alcohol can increase sensitivity.

4) Calibration: Adjusting calibration of thermometer by changing the marking on the scale can effectively change the perceived sensitivity.

Q.11: One student claims to have constructed a more sensitive liquid in glass thermometer. How can her claim be verified?

Ans. To verify the claim of constructing a more sensitive thermometer, the following steps can be taken:

1) Review design and material 2) theoretical analysis: conduct a theoretical analysis of proposed thermometer design. Calculate the expected sensitivity based on factors such as

i) bulb size ii) capillary tube diameter iii) thermal expansion of liquid etc.

Multiple Choice Questions

Q.1: How many phases of mater are there?

(a) 1 (b) 2 (c) 3 (d) 4

Q.2: In which of the materials, particles have only vibrational motion?

(a) Solid (b) Liquids (c) Gas (d) Plasma

Q.3: Which amount of water has greater density at room temperature?

(a) 100g (b) 1 kg
(c) 1 ton (d) All have same density

Q.4: What is mass of a liquid of density 50 kg m^{-3} in a container of volume $5m^3$?

(a) 200 kg (b) 225 kg (c) 250 kg (d) 275 kg

Q.5: Gases and liquids are categorized as:

(a) Liquids (b) Gases (c) Fluids (d) Solids

Q.6. Which Statement describes the particles structure of gases?

(a) particles are tightly packed and have strong bonds
(b) particles have moderate kinetic energy and move randomly
(c) particles are arranged in a repeating pattern
(d) Particles have fixed positions and low kinetic energy

Q.7. Which state of matter has particles that are highly compressible and can fill any container?

(a) Solid (b) Liquid (c) Gas (d) Plasma

Q.8: What happens to the arrangement of particles when a solid is heated and turns into a liquid?

(a) Particles become more closely packed (b) Particles move farther apart
(c) particles start vibrating in fixed positions (d) Particles change their state from solid to gas

Q.9: Which of the following is not a form of internal energy?
(a) A Kinetic energy of the particles (b) Potential energy of the particles
(c) Chemical energy of the bonds between the particles
(d) Light energy

Q.10: When an ideal gas is expanded keeping its temperature constant, its internal energy
(a) Increases (b) Decreases (c) Remains the same (d) Cannot be determined

Which of the following physical properties is used in a mercury thermometer?
(a) Electrical resistance (b) Pressure
(c) Volume (d) Colour

Q.12: Which of the following can increase the sensitivity of liquid in glass thermometer?
(a) Use a bigger bulb which contains more amount of liquids
(b) Use a longer capillary tube
(c) Using long specific its
(d) Changes colour on temperature.

Q.13: Thermometer, which is most suitable for measuring rapid changing temperatures, is:
(a) Constant volume gas thermometer (b) Resistance thermometer
(c) Liquid in glass thermometer (d) thermocouple

Q.14: Mercury has uniform linear expansion in liquid in glass thermometers. A liquid in glass thermometer has a mercury level of 2cm at melting point of ce and a mercury level of 6cm at boiling point of water. What is the distance between every 1 oC division on Celsius scale of thermometer?
(a) 0.04 cm (b) 0.06 cm (c) 0.08 (d) 1.00 cm

Q.15: Which thermometer uses voltage to measure temperature of a hot body?
(a) Thermocouple (b) Resistance thermometer
(c) Liquid in glass thermometer (d) Gas thermometer

Answer Key

1.	(d)	2.	(a)	3.	(d)	4.	(c)	5.	(c)
6.	(b)	7.	(c)	8.	(b)	9.	(d)	10.	(c)
11.	(c)	12.	(b)	13.	(d)	14.	(a)	15	(a)

Examples:

7.1: You find a material in the shape of cube of side length 5 centimeter. Mass of this cube is 500 grams. Find the density of this material?

Ans. Given:-
Mass of the material m = 500 g
Side length of the cube of the given material = 5 cm^3
To Find
Density of the material ρ = ?
Solution:
Volume of a cubic shape object is given by: Volume = (side length)^3
Putting values, Volume = $(5)^3$ = **125 cm^3**
Now, we will find density of cube shaped object is:

$$\text{Density of cube shaped object} = \frac{\text{Mass of cube}}{\text{Volume of cube}}$$

Putting values, we have $\rho = \frac{500}{125} =$ **4 g/cm^3**
Therefore density of this material is 4 g/cm^3.

7.2: Mass of empty measuring Cylinder is 145 g. We add a 60 ml liquid in it. Now, its mass becomes 205g. Find density of the liquid?

Ans. Given:-
Mass of empty cylinder 'm' = 145 g
Mass of measuring Cylinder and added liquid = 205 g
Volume of liquid = 60 ml
To Find
Density of the liquid ρ = ?
Solution:
Mass of liquid is calculated
Mass of liquid = Mass of measuring cylinder and liquid − Mass of empty cylinder
Putting values, Mass of liquid = 205 − 145
Mass of liquid = 60 g

Density of liquid is calculated by: $\rho = \frac{\text{Mass of liquid}}{\text{Volume of liquid}}$

Density of liquid is calculated by: $\rho = \frac{60}{60} = 1$ g/ml.

Therefore density of liquid is 1 g/ml.
Density of liquid is 1 gram per milliliter. As this is the density of water (at 4°C). So, our liquid in the measuring cylinder is water.

7.3: Find the density of a solid brick of mass 3.30 kg as shown in the figure.

Ans. Given:-
Mass of brick 'm' = 3.30 kg
Length of brick = 21.6 cm = 0.216 m
Width of brick = 10.2 cm = 0.102 m
Height of brick = 6.35 cm = 0.0635 m
To Find
Density of the Solid object ρ = ?
Solution:

First, we calculate the volume of regular brick by:
Volume = Length × Width × Height
Volume = 0.216 × 0.102 × 0.0635 = 0.00140 m^3
Now, we will find density of the brick using formula:

$$\text{Density of brick} = \frac{\text{Mass of brick}}{\text{Volume of brick}}$$

Putting values, $\text{Density of brick} = \frac{3.3}{0.00140}$

Therefore density of brick is 2358.773 kg/m^3 = 2360 kg/m^3.

7.4: Mass of rock is 80.52 grams. It was immersed in a measuring cylinder containing water. From the figure, find the initial volumes of water. Use this data to find volume of water and density.

Ans. Given:-

Mass of rock 'm' = 80.52 g

Initial volume of water = 18 mL

Final volume of water = 46 mL

To Find

Volume of object V = ?

Solution:

Volume of object = 46 – 80.52

Volume of object = 28 mL = 28 cm^3

Density of irregular shaped stone is:

$$\text{density of object} = \frac{\text{Mass of object}}{\text{Volume of object}}$$

$$\text{density of object} = \frac{80.52}{25}$$

$$\text{density of object} = 3.22\ g/cm^3$$

Therefore density of object is 3.22 g/cm^3.

Numerical Problems

Q.1: Sarah has two objects, a wooden block and a metal ball, with the following properties:
a) The wooden block has a mass of 300 g and a volume of 150 cm^3.
b) The metal ball has a mass of 500 g and a volume of 50 cm^3.
Calculate the density of each object and determine which one is denser.

Ans. a) Given:-

Mass m = 300 g

Volume V = 150 cm^3

To Find Density ρ = ?

As we know that $\rho = \frac{m}{V}$

Putting values, we have $\rho = \frac{300}{150} =$ **2 g/mL**

b) Given:-

Mass m = 500 g

Volume V = 50 cm^3

To Find ρ = ?

As we know $\rho = \frac{m}{V}$

Putting values, we have $\rho = \frac{500}{15} =$ **10 g/mL**

The density of metal ball is high so it is denser.

Q.2: You have a container with 500 milliliters of cooking oil, and it has a mass of 450 grams. Calculate the density of the cooking oil in grams per milliliter (g/mL).

Ans. Given:-

Mass m = 500 g

Volume V = 450 cm^3

To Find ρ = ?

As we know $\rho = \frac{m}{V}$

Putting values, we have $\rho = \frac{500}{450} =$ **0.9 g/mL**

Q.3: A 70cm, 10cm 30cm plastic box has mass of 2500 g. Find the density of plastic.

Ans. Given:-

Mass m = 2500 g

Volume V = 70 x 10 x 30 = 21000 cm^3

To Find ρ = ?

As we know $\rho = \frac{m}{V}$

Putting values, we have $\rho = \frac{2500}{21000} = \frac{25}{210}$ **0.12 g/cm³**

Q.4: Aluminum has a density of 2700 kg/m³. Find the mass of a solid 25 cm diameter aluminum ball.

Ans. Given:-

Density ρ = 2700 g

Diameter d = 25 cm

Radius r $= \frac{d}{2} = \frac{25}{2}$ 12.5 cm

Volume of sphere = $V = \frac{4}{3}\pi r^3$

$V = \frac{4}{3} 3.14 \times (12.5)^3$

$V = 1.33 \times 3.14 \times 1953 \times 10^{-6}$

V = = 8156 cm^3

To Find m = ?

As we know $\rho = \frac{m}{V}$

or $m = \rho V$

Putting values, we have $m = 2700 \times 8156 \times 10^{-6} =$ **22 kg**

Q.5: A cube of iron has a side length of 10 cm. What is volume of this cube? Mass of this iron cube is half kilogram. This cube has cavity inside it. Find the volume of the cavity.

Ans. Given the side length of the iron cube: $= \ell = 10cm = \frac{10}{100} = 0.1m$

The volume V_{cube} of a cube with side length 'ℓ' is calculated by the formula:

$$V_{cube} = \ell^3$$

Substituting the given side length:

$V_{solid} = (0.1m)^3$

$V_{solid} = 0.001m^3$

Given the mass of the iron cube: $m = \frac{1}{2}\ kg = 0.5\ kg$

$\rho_{iron} = 7800kgm^{-3}$

$V_{actual} = \frac{m}{\rho_{iron}} = \frac{0.5}{7800} = 0.00006410m^3$

Volume of cavity $= V_{solid} - V_{actual}$

Volume of cavity $= 0.001 - 0.00006410 = 0.0009359m^3$

Volume in cubic meter (cm^3):

Vactual $= 0.0009359 \times 1000000cm^3$

$V_{actual} = 935.9cm^3$

Q.6: Mass of an irregular shaped stone is 200 grams (g). When it is lowered in a measuring cylinder, it rises the water level from 40 mL to 73 mL. Find volume and density of this stone.

Ans. Given:-

Mass	m	=	200 g
Initial volume	V_1	=	40 mL
Final volume	V_2	=	73 mL
To Find	ρ	=	?
To Find	V	=	?

As we know $V = V_2 - V_1$

$V = 73 - 40 = $ **33mL**

As we know $\rho = \frac{m}{V}$

Putting values, we have $\rho = \frac{200}{33} =$ **6.1 g/mL**

Thus volume of stone is **33mL** and its density is **6.1 g/mL**

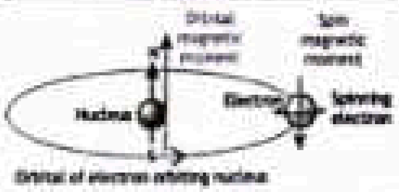
UNIT 08 Magnetism

Q.1: Define and explain the magnetism.

Ans. Magnetism: Magnetism finds its history to times back to the 600 BC, when the early loadstone, attracting the iron was found in the region of magnesia, from where it takes the name 'magnet'. Though it dates long ago but man began to understand magnetism in the twentieth century and started, developing technologies on this understanding. Magnetism arises due to motion of charge particles like electrons moving around the nucleus in the atoms and charges moving in the wires in the form of electric current. Now a day we have a lot of technological applications of magnets and magnetism.

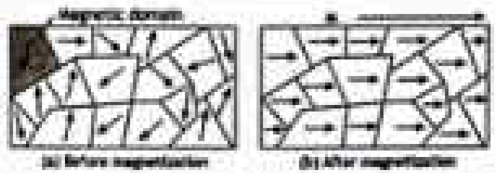
Q.2: What is the domain theory of magnetism? Explain.

FIGURE 8.1 MAGNETISM IN AN ATOM



Ans. Domain Theory: As we know everything around us is made up of atoms, having massive central body with positive charge known as nucleus and light particles with negative charge called electrons orbit around the nucleus. In late twentieth century we found that the basis of magnetism is the motion of charge particles. Electrons (charged particles) move around the nucleus in all atoms producing magnetism. So for a single atom each electron produces a small amount of magnetism as shown in figure 8.1. For a single electron loop a tiny magnet is produced which has two poles called the north-pole (N pole) and the south-pole (S pole). Spinning nucleus also produces some amount of magnetic field but that is negligibly small and the spin motion of electron also produces a tiny magnetism, hence we take the magnetic field of atoms only due to orbital motion of electrons. In some atoms electrons are so oriented that they may add up their magnetic field to make the atom with net non-zero magnetic field, which makes the whole material as magnetic material.

FIGURE 8.2 DOMAINS

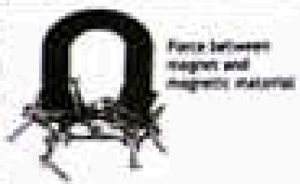


For your Information:

" A domain is the group of atoms in a material which have n-poles pointing in the same direction."

In a sizeable piece of a material a group of atoms having parallel magnetic field make a 'domain' (of roughly 1012 atoms and a size of few mm). In unmagnetized material the domains are randomly oriented while in a magnetized material (a material can be magnetized by placing it in external magnetic field) the domains are aligned as shown in figure 8.2.

FIGURE 8.3



Force between magnetic poles: As we seen above that a magnet, how small it may be, have an S-pole and N-pole. In magnets like poles repel each other while unlike poles attract each other. Similarly the materials which have magnetism are attracted by the opposite poles of a magnet. A magnetic material can also attract opposite poles of other magnetic materials as shown in figure 8.3.

Q.3: Explain magnetic field strength and magnetic shielding.

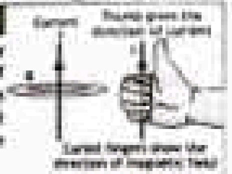
Ans. **Magnetic Field Strength:** Mono-pole never exist in magnets, magnets are always bipolar i.e. they have two poles N-pole and S-pole. Every magnet has a space around it where it has its influence on other magnets in the form of attraction or repulsion.

"The region or space around a magnet where it exerts a force on other magnetic poles is called magnetic field".

The intensity of magnetic field (B) at any point in the field can be measured in the unit called tesla (T). Graphically the magnetic field is represented by the field lines. The direction of the magnetic field of a material at any point can be found by the direction of force acting on the N-pole placed at that point. Magnetic field lines are curved in general, hence the direction of magnetic field on a point at such a curved line can be found by drawing a tangent at that point.

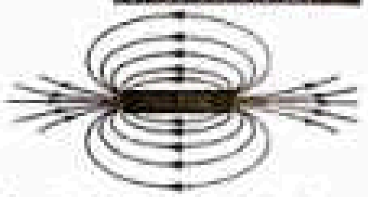
INFORMATION

Magnetic field (B) of a wire carrying a current (I) can be found by placing iron filing around the wire. We get the magnetic field of current carrying wire as the concentric circles having centers in the wire. The direction of such field can be found by using right hand rule. Hold the current carrying wire in your right hand, the fingers will curve in the direction of magnetic field.



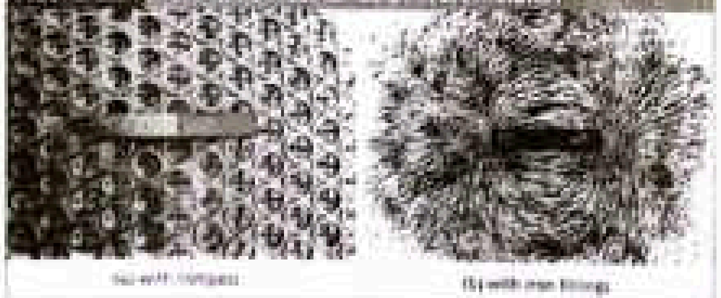
Magnetic Field of a Bar Magnet: A bar magnet is a rectangular part of a material which shows permanent magnetic properties. The magnetic field of a bar magnet can be found by placing the magnet on a plane sheet such that it has compass needles around it. You will notice that all the compass needles point in a particular manner, which shows the magnetic field pattern of the bar magnet as shown in figure 8.4.

FIGURE 8.4 MAGNETIC FIELD LINES OF A BAR MAGNET



The field lines originate from N-pole and terminate at S-pole, while within the body of magnet these lines travel from S-pole to N-pole. This pattern of magnetic field of a bar magnet can also be found by putting the iron fillings around a bar magnet instead of compass needles. The iron filling arrange them in the same pattern as that of compass needle as shown in figure 8.5 (a) and 8.5 (b).

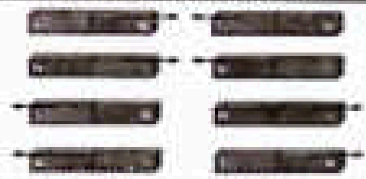
FIGURE 8.5 MAGNETIC FIELD LINES OF A BAR MAGNET



(a) with compass (b) with iron filings

Direction of magnetic Field at a point: The magnetic field is the map that we use to describe how the magnetic force is distributed in the space around a magnetic material or magnet and even within a magnetic material or magnet. To find the magnetic field at a point due to some magnet, is determined by placing a north-pole at that point, the force experienced by the north-pole will be the strength of magnetic field at that point. As when we put a test north-pole near the north-pole of material, it repels the test nor pole away from it showing the direction of north-pole of material as outward. The magnetic force is determined by the movement of test magnet as shown in figure 8.6.

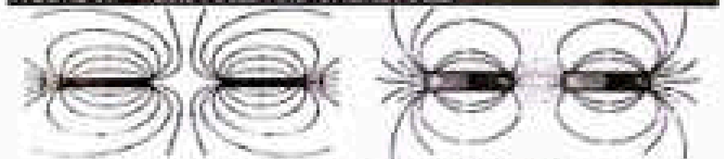
FIGURE 8.6 DIRECTION OF MAGNETIC FIELD



Relative Strength of Magnetic Field: The strength of magnetic field at any point due to a magnetic pole can be found by the field lines.

"The relative strength The field is stronger where the field lines are closer, of a magnetic field is while the field is weaker where the field lines are the degree of closeness farther apart.

FIGURE 8.7 LIKE POLES AND UNLIKE POLES



Neutral zone between like poles and strong field between unlike poles

Hence magnetic field lines give the direction and the strength of magnetic field. The relative strength of magnetic field due to like poles and unlike poles is shown in figure 8.7. By placing two N-poles close to each other we can decrease the field similarly by placing N-pole near an S-pole we can make magnetic field strengthen.

Magnetic Shielding: There may be different orientation of magnetic field by suitably adjusting the magnets. We can find a field free region called 'neutral zone' by placing two N-poles side by side, such that their field lines seem to repel each other by making a field free region, this phenomenon is called shielding of magnetic field. In daily life we deal with a lot of devices which have to work in strong magnetic environment but this external magnetic field can alter the functioning of the device So we have to shield the device from external magnetic field.

Science Tidbits: Materials used for magnetic shielding are called shields. These materials are used for protecting sensitive circuits from unwanted parasitic magnetic fields including power inverters, magnetic immunity, magnetic sensors and EMI. The commonly used materials as shield are Iron, Nickel and cobalt. Shields are usually made rounded corners because it is difficult for magnetic field lines to turn an angle of 90°.

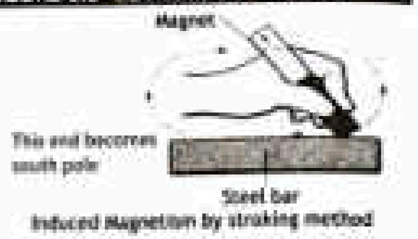
Q.4: Define induced magnetism. Also explain some of the methods for induced magnetism.

Ans. **INDUCED MAGNETISM:** A material which is not a magnet in normal condition can be made a magnet with the help of some techniques and is called induced magnet and this phenomenon is called induced magnetism. Similarly a magnetic material can lose its magnetization.

There are many ways to make an object an induced magnet or a magnet to lose its magnetization like, by stroking the material with a magnet, by hammering the material in a magnetic field, by heating or by putting the material inside a coil from which direct current is flowing.

STROKING METHOD: This is the way of aligning the poles of a material by a process called stroking for induced magnetism. A permanent magnet et is stroked in this process from one end of a bar of some metal to the other end to magnetize it. After rubbing one pole of the magnet on the bar of material from one end to the other then lift the magnet as shown in figure 8.8.

FIGURE 8.8 STROKING METHOD



Induced Magnetism by stroking method

HAMMRING METHOD: In this method a bar of metal is placed inside a strong magnetic field and hammered gently. The domains will begin to line up in the direction of applied magnetic field and hence metal bar becomes magnetized. This method is mainly used for magnetization of steel. Th e magnetization can be increased by heating the metal bar slightly before hammering. This method is shown in figure 8.9.

FIGURE 8.9 HAMMERING METHOD

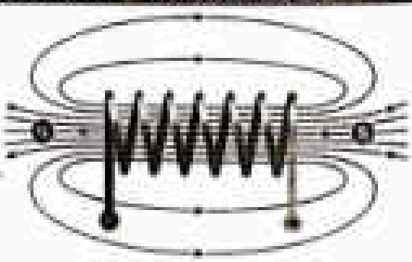
Induced Magnetism by hammering method

HEATING METHOD: This method is usually used to demagnetize a material, as heat speeds up the movements of already aligned domains which results in misalignment of domains and hence material loses its magnetization. However in recent past scientists have provided the evidences of generating magnetic field by the process of heating. This phenomenon is referred to as the 'magnetic See beck effect' or 'thermo-magnetism'.

FIGURE 8.10 SOLENOID

SOLENOID: This is the most common method used for the magnetization of metals. A solenoid is a coil of wire wrapped around a cylindrical coil as shown in figure 8.10. The magnetic field of the solenoid resembles with the field of a bar magnet. When we wrap a conducting wire (say a copper wire) around a metal with insulation the domains of the metal get aligned. In this process when a current flows through the wire it generates a magnetic

FIGURE 8.11 SOLENOID FIELD



Magnetic field of a solenoid

field which behaves as external field to the domains of metal placed inside, which aligns the domains. The coil of wire acts as a magnet as long as the current is flowing through it.

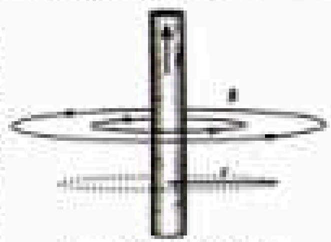
When current stops it no longer behaves as a magnet. For direct current (DC) the polarity of coil remains the same and hence it magnetizes the material in one direction.

For alternating current the polarity of solenoid changes after every half cycle and hence in first half cycle it magnetizes the material in one direction then demagnetizes it. In second half cycle it magnetizes the material in opposite direction and then demagnetizes it. Materials which easily magnetize and demagnetize are called soft magnetic materials (like soft iron), on the other hand materials which cannot magnetize and demagnetize easily are called hard magnetic materials (like steel).

For your Information:

Electric motors used in hand-held hair dryers, electric razors, hair trimmers and many more such devices, work with the help of magnetic force. An electric motor generates magnetic field with electric current through the coil. The magnetic force then causes the movement or spinning that runs the motor.

FIGURE 8.12 WIRE FIELD



Magnetic field around a wire

The magnetic field of a solenoid can mathematically be given as:

$$B = \mu_o n I \quad \text{\_\_\_\_\_\_\_\_} \quad (8.1)$$

Here 'B' is the strength of magnetic field having unit tesla (T) which is also equal to newton per ampere per meter ($N\ A^{-1}\ m^{-1}$), while μ_o is the permeability of the material (Permeability is the property of a material to its response towards a magnetic field, i.e. how much a material permits magnetic field to pass through it), 'I' is the current flowing through the solenoid and 'n' is the number of turns of the solenoid per unit length given by the relation as,

$$n = \frac{N}{L} \quad \text{\_\_\_\_\_\_\_\_} \quad (8.2)$$

Here 'N' is the total number of turns of the solenoid and L is the length of solenoid. The value of the permeability for vacuum 'μ_o' is given as:

$$\mu_o = 4\pi \times 10^{-7}\ N\ A^{-2}$$

Similarly the magnetic field due to a wire carrying current can be given as:

$$B = \frac{\mu_o I}{2\pi r} \quad \text{\_\_\_\_\_\_\_\_} \quad (8.3)$$

Here 'r' is the distance from the center of the wire and 'I' is the magnitude of current flowing through the as shown if figure 8.12.

Q.5: Differentiate between permanent and temporary magnets.

Ans. The solenoid as stated earlier behaves like a magnet as long as a current flows through it, just after removal of current it loses its magnetic field, hence it is a temporary magnet. It is also called as electromagnet. Electromagnet is type of magnet in which the magnetic field is produced due to an electric current. Examples of temporary magnetics include iron nails, screws, metal bolts, kitchen utensils etc.

Examples of permanent magnetic materials include iron ore, cobalt, nickel and Alnico.

Temporary of permanent magnetic are shown in figure 8.13. Some of the differences are listed below.

	PERMANENT MAGNET	ELECTROMAGNET
	Permanently magnetized	Temporarily magnetized
	Made of hard magnetic materials	Made of soft magnetic materials
	Magnetism does not vary in strength	Magnetism can be varied in strength according to need
	Magnets 'poles cannot be altered	Magnets' poles can be changed

Q.6: Explain some uses of electromagnets and temporary magnets.

Ans. **USES OF PERMANENT MAGNETS AND ELECTROMAGNETS:** Magnets are used in many fields, depending upon the need we can use permanent or electromagnets. A permanent magnet is made from a material which is magnetized once and does not lose its magnetization by itself and has its own magnetic field. As we know that permanent magnet does not require a continuous supply of electric energy for maintaining its magnetic field. Hence it is used in those applications where continuous supply of electricity is not available or cannot be maintain for long. Although magnetic field strength of permanent magnets are lower than those of electromagnets but they can have magnetic field even in the absence of electricity. Permanent magnets are used in induction cooker, MRI machines, particle accelerators, transformers etc. and in automotive, aerospace, medical, semiconductor and energy industries. Electromagnets are kind of magnets in which the magnetic field is created by an electric current. Electromagnets can be considered as temporary magnets that function only with the flow of electric current, when the current is turned off it loses its magnetization at once.

Electromagnets have a wide range of daily life applications like in electromechanical and electronics devices. Most of the home appliances use electromagnetism as the basic working principle, like electric fan, electric motors and door bells. In medical fields electromagnets are used in MRI scan. Electromagnets are also used in communication devices and power circuits.

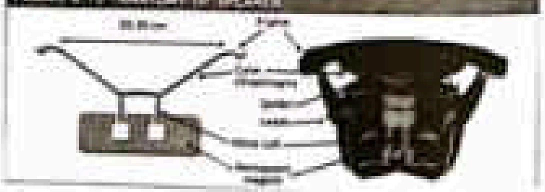
APPLICATIONS OF MAGNETS:

FIGURE 8.14 PROCESS OF MAGNETIC RECORDING

A. MAGNETIC RECORDING is a method of Saving sounds, pictures and data in the form of electrical signals by the process of selective magnetization of some portion of a magnetic material. For writing the data a magnetic tape head is moved onto the tape which is in motion the magnetic field of the tape head aligns the pattern of magnetic domains according to the applied current flowing through the tape head as shown in figure 8.14.

Similarly the reverse process is done for reading the data from the aligned pattern of tape. For magnetic recording the materials commonly used are iron-oxide, cobalt, chromium oxide and pure iron. The main recording media may be a magnetic tape or disk recorders which are used to store and reproduce audio, video signals and computer data. Some other magnetic recording devices are magnetic drum, core and bubble units used for computer storage units.

FIGURE 8.15 ANATOMY OF SPEAKER



B. SPEAKERS use magnets in their functioning. To produce sound the speaker need to create some vibrations in the air. This can be done with the help of two magnets one permanent magnet of strong magnetization and the other is electromagnet. The permanent magnet is fixed in the centre of cone (diaphragm), which is a conical structure made up of some flexible material to produce vibrations.

An electromagnet is attached at the centre of permanent magnet which can move to and fro. When the sound single in the form of electric current flows through the coil of electromagnet it produces alternating magnetic field which due to interaction with field of permanent magnet vibrates it. As the cone is attached to the electromagnet, with the to and fro motion of electromagnet it vibrates and produces sound. With larger permanent magnet we can produce louder sound. The commonly used material as permanent magnet in speakers is neodymium. The structure of speaker is shown in figure 8.15. Microphones also use magnets in their functioning, but in reverse order. In microphones the cone (diaphragm) vibrates due to sound and hence producing movement in the electromagnet within the magnetic field of permanent magnet. This produces an electric current which acts as the signal for the speaker.

FIGURE 8.16 MAGNETIC DOOR LOCK

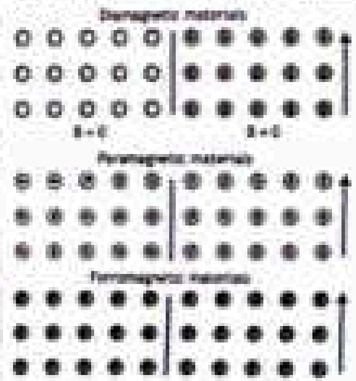
C. DOOR LOCKS also use magnets in their working. They have an electromagnet fixed at the door frame and a metal plate fixed with the door, in such a way that when the door is closed the metal plate connects with the electromagnet.

When the current passes through the electromagnet it attracts the metal plate with huge force, so that to open door is difficult. When we have to open the door we disconnect the current flowing through electromagnet which releases the metal plate. As this door requires electricity for its functioning it is mainly used for emergency exits at hotels, offices and residential buildings.)

Q.7: Explain three types of magnetic materials.

Ans. **TYPES OF MAGNETIC MATERIALS:** On the base of behavior of materials to the applied external magnetic field, they are classified into three types, i.e, diamagnetic, paramagnetic and ferromagnetic materials,

FIGURE 8.17 MAGNETIC MATERIALS



A, DIAMAGNETIC MATERIALS: Materials in which the spin and orbital motions of electrons are so oriented that they cancel each other's effect and the net magnetic field at a single atom level becomes zero, such materials are called diamagnetic materials. They are slightly repelled by a magnetic field and do not retain the magnetic properties when the external field is removed. Their magnetic field intensity is very small and opposite to the external magnetic field, as shown in figure 8.17, Examples of diamagnetic materials are cooper, zinc, bismuth, silver, gold, marble, water, glass and wood etc. Such materials which have zero magnetic field ($B=0$) in the absence of external field are called non magnetic or diamagnetic material,

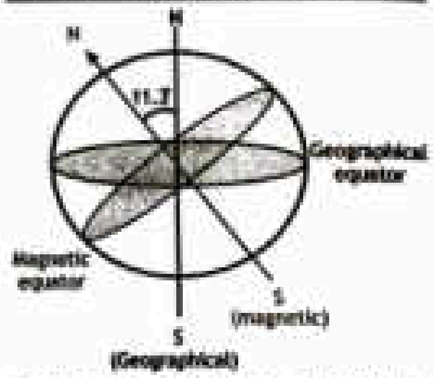
B. PARAMAGNETIC MATERIALS: Materials which have electrons, whose spin and orbital axis cannot completely cancel each other, in spite of it they add up their magnetic field, are called paramagnetic materials. On the application of external magnetic field they align themselves in the direction of applied field and hence the material is feebly magnetized, as shown in figure 8.17. They experience weak attraction to magnets. Their magnetic field intensity is small and along the direction of external magnetic field. Examples of paramagnetic materials are tungsten, aluminum, lithium and sodium etc. Such materials which have non-zero magnetic field (B 0) in the absence of external field are called magnetic material.

C. FERROMAGNETIC MATERIALS: Materials which have a net magnetism at the atomic level, even in the absence of external magnetic field, are called ferromagnetic materials. When placed in external field these materials are strongly magnetized in a direction parallel to the applied field and hence they are strongly attracted to a magnet. They retain their magnetization even after removal of applied magnetic field, as shown in figure 8.17. Their magnetic field intensity is very large and along the direction of external magnetic field. Examples of these materials include iron, cobalt, nickel and some metallic alloys.

Q.8: Explain the Earth's magnetic field. Also relate Earth's geographical and magnetic poles.

Ans. **8.5 EARTH'S MAGNETIC FIELD:** Life exists on our Earth, which is due to many factors, among them the magnetic field is the one. Our Earth is a big magnet and has a magnetic field which is essential for survival of life on it. Do you know from where the Earth gets its magnetic property? As we know that the core of Earth is mainly consists of molten iron, electrical currents flowing in the slowly moving molten iron generate the magnetic field of Earth, called "dynamo effect".

FIGURE 8.20 EARTH'S POLES



Earth's magnetic and geographical poles

Earth's field (is also known as geomagnetic field. The presence of a magnetic field acts like a protective shield around the Earth, which saves life on Earth from harmful cosmic rays coming from the outer space and the charge particles and radiations coming from the Sun. The Earth's magnetic field extends millions of kilometers into the space but have very small magnetic field strength.

Earth's magnetic field resembles with the field of a bar magnet and is shown in figure 8.18, where from the Sun side the field is pushed a little inside due to continuous striking solar winds consists of radiations and charged particles. The opposite side of the Earth to the Sun, the field is extended several millions of kilometers.

GEOGRAPHICAL AND MAGNETIC POLES OF THE EARTH: If we look at the map of our Earth we see the poles on it, the north-pole is shown at Arctic and the south-pole is at Antarctic. But these poles on map are the geographical poles of the Earth not magnetic poles of Earth. Our Earth spins about its geographical axis (The line joining the geographical poles of the Earth). The magnetic poles of Earth are inclined at an angle of 11.3° to the geographical poles.

Hence the compass needle does not point towards the north-pole shown on maps instead it points 11.3° away towards the magnetic pole.

BIO-MAGNETISM: Magnetism plays a vital role in the survival of life on Earth. It also plays a main role in the behavior of many species living on the planet. Like human's heart and brain produce some magnetic fields for their working, without these fields these organs are of

no use. These magnetic fields produced by brain and heart are also used for diagnostic techniques.

Q.9: Explain how birds and other migrating animal use Earth's magnetic field to navigate.

Ans. In ancient times people use to send messages through pigeons. How they locate their destination to deliver the messages?

Iron crystals are found in the beaks of pigeons. These crystals give the bird a sense for north. Pigeons can sense Earth's magnetic field. With the help of this magnetic navigation pigeons locate their molecule in their eyes, which is sensitive to the magnetism.

Q.10: Differentiate between magnetic and non-magnetic materials.

Ans. Materials are classified as magnetic and non-magnetic on the basis of their response to an applied magnetic field. These differences are summarized in table below.

Difference Between Magnetic and Non-Magnetic Materials	
Magnetic Materials	Non-magnetic Materials
Materials which are attracted to a magnet are known as magnetic materials	Materials which are not attracted to a magnet are known as non-magnetic materials
The atomic states of a magnetic material are aligned	The atomic states of a non-magnetic material are in random
They respond to a magnetic filed	They do not respond to a magnetic field.
Magnetic materials have field (magnetic field) around them	Non-magnetic materials do not have field (magnetic field) around them
Magnetic materials can attract and repel other magnetic materials.	Non-magnetic cannot attract or repel any magnetic material.
Examples of magnetic materials are: Nickel, Cobalt, Steel and Iron	Examples of non-magnetic materiel are: Rubber, Plastic, Wood and Cooper

SHORTRESPONSE QUSTIONS

Q.1: Can two magnetic field lines intersect each other? Justify your answer.

Ans. According to laws of Electromagnetism, two magnetic field lines cannot intersect each other if they were to intersect, it would imply that magnetic field would have two different directions at that point, which is not possible.

Q.2: A freely suspended magnet always points along north-south direction. Why?

Ans. A freely suspended magnet aligns itself with earth's magnetic field, pointing along the north-south direction. This alignment occurs because the magnet's north pole is attracted to the Earth's magnetic south pole, and its south pole is attracted to the Earth's magnetic north pole. This phenomenon is due to Earth's magnetic field, which acts as a reference for magnet's orientation.

Q.3: What is the neutral zone or field free region of the magnetic field?

Ans. The neutral zone, also known as field-free region, refers to the area where the magnetic field strength is effectively zero. In this region, the magnetic sources cancel each other out, resulting in no net magnetic field. This can occur between two magnets of opposite polarity or in certain configuration of magnetic materials. In practical terms, the neutral zone is a region where magnetic interactions are minimized or negligible.

Q.4: Is there any material which does not have any magnetic behavior? Justify your answer.

Ans. Yes, there are materials that do not exhibit any magnetic behavior these materials are called diamagnetic materials. Unlike ferromagnetic or paramagnetic materials which are attracted to or repelled by magnets, diamagnetic materials are weekly repelled by magnetic fields. This means they have no magnetic moments when placed in a magnetic field and are essentially unaffected by it. Examples of diamagnetic materials include copper, gold, silver, and most organic compounds.

Q.5: A proton is also a charged particle and spins like an electron. Why its effect is neglected in study of magnetism?

Ans. The effect of proton spin in magnetism is usually neglected because protons have greater mass and their spins cancel out within the nucleus's where as electrons, with their smaller mass, contribute significantly to magnetic properties due to their orbital and spin magnetism.

Q.6: What is the geomagnetic reversal phenomenon? Explain.

Ans. geomagnetic reversal is when Earth's magnetic field flips its polarity, causing the magnetic north and south poles to switch places. This natural phenomenon has occurred multiple times in Earth's history, with the magnetic field weaking, becoming disorganized, and then re-establishing with opposite polarity over thousands of years.

Q.7: Why the Earth spins about its geographical axis instead of its magnetic axis? Explain.

Ans. The Earth spins around its geographical axis because of its physical shape and gravitational forces, not its magnetic axis.

Q.8: Why the Earth's geographical and magnetic axis are not coincident? Explain.

Ans. The Earth's geographical and magnetic axis are not coincident because the Earth's magnetic field is generated by movement within its liquid outer core. This movement, driven by the convection currents of molten iron and nickel, creates the magnetic field, which is not perfectly aligned with the planet's rotational axis. This misalignment results in variation between the geographical and magnetic pole.

Q.9: What is the difference between paramagnetic field of an electromagnet materials?

Ans. Long Question

Q.10: On what factors the strength of the magnetic field of an electromagnet depends?

Ans. The strength of magnetic field of an electromagnet depends upon several factors

1) Number of turns: increasing the number of turns of wire in coil increases the strength of magnetic field.

2) current flowing through the coil: Increasing the current flowing through the coil increases the strength of magnetic field.

3) Material of the coil: using the core made of ferromagnetic material (like iron) increases the strength of magnetic field compared to using a non-magnetic or less magnetic material.

4) Length of the core: Increasing length of core can increase the strength of magnetic field.

5) Cross-sectional area of the core: increasing cross-sectional area of core can increase the strength of the magnetic field.

By optimizing these factors, the strength of magnetic field generated by an electromagnet can be maximized for given application.

Q.11: Draw magnetic field lines of two solenoids placed near each other (i) facing same poles to each other. (ii) facing opposite poles to each other.

Ans. When two solenoids face each other with the same poles, They repel each other.
The magnetic field lines will emerge from one solenoid's north pole and connect to the other solenoid's north pole, forming a loop between them.

Similarly magnetic field lines will emerge. From one solenoid's south pole and connect to other solenoid's south pole forming a loop between them.
When two solenoids are facing each other with opposite pole they attract each other.
The magnetic field lines will emerge from are solenoid's north pole and connect to other solenoid's south pole, forming a continuous loop between them.

Magnetic Field Lines

Opposite Poles Attract Like Poles Repel

Multiple Choice Questions.

Q.1: If a bar magnet is cut in half it will become:
(a) a monopole (b) magnetized (c) the same magnet (d) magnet of less strength

Q.2: Which one is the quickest method to magnetize a material?
(a) strike with hammer (b) moving into magnetic field
(c) stroking the opposite pole (d) putting inside a current carrying coil

Q.3: Earth's magnetic field intensity is:
(a) constant every ware (b) very high at equator
(c) very low at poles (d) varies place to place

Q.4: The cause of the Earth's magnetic field is:
(a) rotational motion of Earth (b) spinning of Earth
(c) pull of the sun (d) motion of ions in the core

Q.5: Material which is the best one for making a permanent magnet:
(a) soft iron (b) nickel (c) cobalt (d) steel

Q.6. Material which is the best one for making an electromagnet:
(a) soft iron (b) nickel (c) cobalt (d) steel

Q.7. A sensitive magnetic material is to shielded by the external magnetic field. It should be kept inside a box of:
(a) wood (b) plastic (c) steel (d) soft iron

Q8: Magnetic field lines:
(a) are farthest at poles (b) intersect each other
(c) are closed (d) do not pass in vacuum

Q.9: When two current carrying wires in the same direction are placed parallel near each other, due to magnetic field produced by each wire they:
(a) repel each other (b) attract each other (c) have no effect on each other
(d) stop moving the current through them

Q.10: Which of the following material is ferromagnetic?
(a) silver (b) copper (c) aluminum (d) nickel

Answer Key

1.	(a)	2.	(d)	3.	(d)	4.	(d)	5.	(d)
6.	(a)	7.	(d)	8.	(c)	9.	(b)	10.	(d)

Example

8.1: A student takes a long straight copper wire (with insulation on it) from his physics lab, he wraps the wire on an iron rod of 50 cm, to make it solenoid of 50 turns. He connects the ends of copper wire with the battery, which provides 1.2 A current. Find the magnetic field he produces in solenoid by doing so.

Ans. Given:-

Length 'L'	=	50 cm = 0.5 m
Number of turns 'N'	=	50
current 'I'	=	1.2 A
Permeability 'μ_o'	=	$4\pi \times 10^{-7}$ N/A^2
Magnetic Field Strength 'B'	=	?

Solution:

To find magnetic field strength we have to find number of turns per unit length first by using equation

$$N = \frac{N}{L} = \frac{50}{0.5} = 100\ m^{-1}$$

Now using equation

$$B = \mu_o n I$$

$$B = (4\pi \times 10^{-7})(100)(1.2)$$

Therefore $B = 1.5 \times 10^{-4}$ T ____________ Answer

So magnetic field at a distance of 10cm from the wire carrying 1.3 A Current is 1.5×10^{-4} T.

Numerical Problems

Q.1: Find the magnetic field due to a wire at 10cm, If 1.3 A current is passing through the wire.

Ans. Given:-

current I = 1.3 A

r = 10 cm

$$B = \frac{\mu_o I}{2\pi r}$$ (Magnetic field produced by current carrying wire

$$= \frac{(4\pi \times 10^{-7} m / A)1.3A}{2\pi \times 0.1m}$$

$$B = 2.6 \times 10^{-6}\ T$$

So magnetic field at a distance of 10cm from the wire carrying 1.3 A Current is 2.6×10^{-6} T.

UNIT 09 Nature of Science and Physics

Q.1: Discuss the importance of Physics in our daily life.

Ans. **Importance OF PHYSICS:** Physics plays a vital role in all parts of our lives.

(i) Physics and surrounding:

Physics discuss everything in our surrounding: from atom (which is small enough that can't be seen even with electron microscope) to galaxies. Everything either natural (such as, the sky, stars, planets, moons, seas and birds etc.) or artificial (such as, submarines, heavy ships, vehicles, satellites, laptops and cellular phones etc.), all involve the laws of physics.

For example, a cell phone, which become the most common component of our life in today's technological world, can be used to facilitate us in many ways (see the figure 9.1). It helps us to locate the position of any person, the car that we have booked or to follow the map by using GPS satellite (see cover picture of this chapter). Aero planes and ships also use signal from GPS to follow their path towards the right destination and stay connected with the control office.

(ii) Flight of Aero plane:

Aero plane runs on the runway to create a pressure difference above and below its wings before it takes off. Similarly, birds use the difference in air pressures above and below their wings to keep themselves high up. Feathers of birds give good thermal insulation especially when fluffed up during winter (see figure 9.2). The sky seems blue when sunlight strikes and scatters off by the gas molecules in our atmosphere. The presence of large water reservoirs such as lakes and seas keep the climates of nearby land moderate due to the large heat capacity of water. Vehicles use the principles of mechanics and thermodynamics to transfer stored chemical energy in fuel to kinetic energy in rotating wheels. Submarines and heavy ships work on the principle of floatation. Cellular phones use electronic components and the principles of electromagnetic waves to transfer energy and information from one cellular phone to another. These are just a few examples that involve physics.

(iii) Understanding of Physical World:

The objective of physics is to offer an understanding of the physical world by developing theories based on observations and experiments. A scientist who specializes in the field of physics is termed as 'physicist'. Physicists engage in theoretical and experimental research to explore and explain the fundamental laws of nature. Physicists express everyday happenings in mathematical formulas. These mathematical formulas are then used by all physicists and engineers to guess results of their experiments. For example, Isaac Newton (1642-1727) found the laws behind the motion of bodies, which we now used to design rockets that travel in outer space (to the moon and other planets). Physicists also improve the laws of physics from time to time according to experimental results. For example, Isaac Newton established the laws of motion working at normal speeds, but these laws fail for object's moving with high speed that approaches the speed of light. Albert Einstein (1879-1955) solved this issue by giving the theory of relativity. Theory of relativity gives the same result as Newton's laws of motion at slow speeds, but is more accurate as speeds approaches the speed of light. Hence science is a collaborative field that requires interdisciplinary researchers working together to share knowledge and critique ideas.)

Q.2: Describe Different Branch of Physics.

Ans. **FIELDS OF PHYSICS:** Physics is considered to be the most fundamental of all sciences. Physics has many sub-fields, and in today's world it involves interdisciplinary fields. In order to study biology, chemistry, or any other natural science, one should have a firm understanding of the principles of physics. For example, biology uses the physics principles of fluid movement to understand how the blood flows through the heart, arteries, and veins. Chemistry relies on the physics of subatomic particles to understand why chemical reactions take place. Geology uses the physics of seismic waves and energy transfer to determine the magnitude and location of earthquakes. Astronomy and cosmology rely on the laws of physics such as theory of relativity to describe the workings of the universe. Some fields of physics are given below.

(i) BIOPHYSICS: Biophysics is the study of various characteristics and systems of living body. Fluid dynamics of blood flow and respiration, radiation in diagnostics and treatment etc. are studied in biophysics.

(ii) ASTRONOMY: Astronomy is the study of everything in the universe beyond Earth's atmosphere. It deals with celestial objects (such as the Sun, the Moon, the planets, and the stars), space and the physical universe as a whole. To study astronomy, astronomers have to stay up late at night to see the celestial objects with the help of a powerful telescope.

(iii) ASTROPHYSICS: Astrophysics is the study of physical nature of stars and other celestial bodies, and the application of the laws and theories of physics to the interpretation of astronomical observations.

An Astrophysicist investigate the astronomical events such as formation of stars, planets and galaxies, to learn more about the universe.

(iv) COSMOLOGY: Cosmology is the study of the origin, development, structure, history, and future of the entire universe. cosmology spans the entire universe from birth to death, with a wealth of mysteries at every stage.

(v) THERMAL PHYSICS: Thermal physics is the collective study of statistical mechanics, thermodynamics and kinetic theory of gases.

(vi) OPTICS: Optics is the branch of physics that studies the nature and properties of light, its interactions with matter and the construction of instruments that use or detect it.

Nuclear Physics: Nuclear physics is the study of the structure, properties and behaviour of atomic nuclei, the radiation from unstable nuclei.

(vii) PARTICLE PHYSICS: Particle physics (or high energy physics) is the study of fundamental particles and forces that create matter and radiation.

(viii) ELECTROMAGNETISM: Electromagnetism is a branch of physics in which we study the — electromagnetic forces between electrically charged particles.

(ix) ACOUSTICS: Acoustics is the branch of physics that deals with the production, transmission, control, reception, and effects of sound.

(x) COMPUTATIONAL PHYSICS: Computational physics is the study and implementation of numerical analysis to solve complex problems in physics.

(xi) GEOPHYSICS: Geophysics is the branch of physics in which we study about the structure of the Earth, physical processes and phenomena occurring especially in the earth and in its vicinity.

(xii) CLIMATE PHYSICS: Climate Physics is the branch of physics that deals with the study of the Earth's climate. CLASSICAL MECHANICS: Classical mechanics is the branch of physics in which we study the motion of macroscopic objects under the action of forces.

(xiii) QUANTUM MECHANICS: Quantum mechanics is the branch of physics in which we study the mathematical description of motion and behavior of microscopic particles under different situations.

(xiv) RELATIVISTIC MECHANICS: Relativistic mechanics is the branch of physics in which we study the system of bodies whose relative velocities approaches to the speed of light c, or whose kinetic energies are comparable with the product of their masses (m) and the square of the velocity of light (c).

A physicist is a scientist who specializes in any field of physics, which covers the interactions of matter and energy at all length and time scales in the physical universe. A Physicists conduct in depth research on different topics.

Q.3: Explain the terms, hypothesis, theory and law with examples.

Ans- HYPOTHESIS, THEORY AND LAW:

When reading research articles, you will likely to go across the terms HYPOTHESIS, THEORY and LAW. These words have specific meanings in the science. The scientific method of research includes formulating hypotheses and testing them to see if they hold up to the realities of the natural world. Successfully verified hypotheses can lead to either theories or laws.

HYPOTHESIS: A hypothesis is a tentative assumption or explanation made before any research that can be verified by further investigation. It is made so that it can be verified to see if it might be true or false.

THEORY: In order to put a hypothesis into a proven theory, researchers design experiments to challenge their ideas under the conditions of the natural world. By following to the scientific method and working carefully, scientists can finally accumulate enough evidence to prove their hypothesis, thus making it a theory with predictive and extrapolative power. A scientific theory is a description of the nature that scientists have verified through rigorous testing. A theory explains how nature behaves under specific conditions. Theories tend to be as broad as their supporting scientific evidence will permit. A theory is a well-supported explanation of some aspect of the natural world of observations.

Some examples of famous scientific theories that have shaped our understanding of the natural world, are listed below.

- Kinetic Molecular Theory.
- Theory of General Relativity.

LAW: A law is a statement that summarizes an observed regularity or pattern in nature and gives the relationship between variables. Like theories, laws describe phenomena that the scientists have found to be provably true. Laws develop from discoveries and rigorously tested hypotheses, and new theories generally uphold and expand laws.

Examples of some famous laws include:

- Newton's Law of Universal Gravitation.
- Newton's Laws of Motion.
- Boyle's Law.
- Laws of Thermodynamics.

Both scientific laws and theories are considered as fact. However, theories and laws can be disproven when new evidence appears. For example, certain accepted truths of Newtonian physics were partially disproven by Albert Einstein's theory of relativity. The work of Louis Pasteur disproved prior theories of disease in animals. If through scientific research upends a previously held belief, scientists must find new hypotheses that better describe how nature works. DIFFERENCE BETWEEN THEORY AND LAW.

Scientific laws differ from theories in sense that laws tend to describe a narrower set of conditions. A scientific law might explain the relationship between two specific forces or between two changing substances in a chemical reaction. Theories are normally more expansive and they focus on the how and why of natural phenomena.

Q.4: Differentiate the terms 'science', "technology, and engineering' with suitable examples.

Ans. SCIENCE, TECHNOLOGY AND ENGINEERING:

Science and technology are quite different. Science is a system of knowledge that is concerned with establishing accurate conclusions about the behavior of everything in the universe. It is a field in which hypotheses are made, information is gathered, and experiments are performed to determine how something in our natural world works or behaves. Technology, on the other hand, is a field that uses scientific knowledge to develop material products or processes that satisfy human needs and desires.

Science is the pursuit of knowledge and understanding through systematic study, experimentation, and observation. It is the pursuit and application of knowledge and understanding of the natural and social world.

For example in physics, scientists study the principles of motion and energy to understand the behavior of objects. This may include conducting experiments to establish the laws of motion or formulating theories to clarify the forces of gravity.

Technology is the application of scientific knowledge for practical purposes, resulting in the development of tools, machines, and systems. It involves the creation and use of tools, machines, systems, and techniques to solve problems, achieve goals, or perform specific functions.

The development of smartphones for instance is a technological advancement. It involves the application of scientific principles in physics, materials science, and engineering to create a device that combines communication, computation, and various other functions.

Engineering is the practical use of scientific and mathematical principles to create and construct structures, devices, and processes. It requires the application of knowledge to solve real-world problems in a creative and organized manner.

For instance, civil engineering focuses on designing and building infrastructure like bridges, roads, and buildings. Civil engineers utilize scientific principles, such as materials science and structural mechanics, to ensure the development of secure and effective structures.

While these fields are distinct, they are interconnected. Advances in science often lead to technological innovations, and engineers use scientific knowledge to create new technologies that, in turn, drive further scientific exploration.

SHORTRESPONSE QUSTIONS.

Q.1: Define the following branches of physics: Biophysics, Astrophysics, Optics, Relativistic Mechanics, Nuclear Physics, Acoustics, Computational Physics

Define the terms theory and law. Also give two examples of each.

Ans. Discussed in Long Question 2.

Q.2: Define Hypothesis?

Ans. Discussed in Long Question 4.

Q.3: What is the difference between classical mechanics and quantum mechanics?

Ans. Discussed in Long Question 2.

Q.4: What determines the validity of a theory?

Ans. Validity of a theory depends on whether it can explain things well, match up with what we see in real world, make sense logically, and holds up when tested with experiments and observation.

Q.5: Which part of the study is not handled by the classical study of Physics?

Ans. The classical physics cannot explain quantum behavior of particles at smallest scale such as particle-wave duality and uncertainty principle.

Multiple Choice Questions.

Q.1: What is the best definition of the term "theory," as it as used in science?
(a) A theory is a guess or hunch about something that has occurred in nature
(b) A theory is a comprehensive set of ideas explaining a phenomenon in nature
(c) A theory is based on verifiable laws and can be proven true
(d) A theory is a hypothesis that uses laws and observation to make an assumption

Q.2: Which Statement below correctly identifies the difference between laws and theories?
(a) Laws describe phenomena, while theories explain why phenomena exist
(b) Laws are a statement of fact, while theories are statement of opinion
(c) Laws explain why phenomena exist, while theories explain how
(d) Laws are a prediction of phenomena, while theories are an explanation

Q.3: Why do scientists develop a hypothesis before conducting research?
(a) It give them direction on how to interpret the results of their research
(b) It helps to predict outcomes and define the parameters of the research
(c) Hypotheses give the researcher an outcome to shape their work around
(d) Hypotheses help a researcher decide which observations to record and which to ignore

Q.4: The Branch of Physics that is most important when studying how glasses help people see:
(a) Thermodynamics (b) Electromagnetism (c) Mechanics (d) Optics

Q.5: When studying how air conditioners cool your house, then it is:
(a) Thermodynamic (b) Electromagnetism (c) Nuclear Physics (d) Optics

Q.6. The branch of Physics that deals with the particles such as neutrons and protons:
(a) Solid State Physics (b) Plasma Physics
(c) Electricity (d) Nuclear Physics

Q.7. Which branch of science plays an important role in engineering?
(a) biology (b) Chemistry (c) Physics (d) Life science

Q.8: Physics is one of the branches of:
(a) Physical sciences (b) Biological sciences
(c) Social science (d) Life science

Answer Key

1.	(b)	2.	(a)	3.	(b)	4.	(d)	5.	(a)
6.	(d)	7.	(c)	8.	(a)				

Model Paper Federal Board

Paper: Physics	**Model Paper w.e.f 2025**	**Class: 9**
Time allowed: 20 Minutes	(Objective Type)	**Max. Marks: 12**
Name:		

PHYSICS SSC-I

SECTION – A (Marks 12)

Note: Section – A is compulsory. All parts of this section are to be answered on this page and handed over to the Centre Superintendent. Deleting/ overwriting is not allowed. *Do not use lead pencil.*

Q1. Fill the relevant bubble against each question according to curriculum. Each part carries one mark.

Sr	Question	(A)	(B)	(C)	(D)
1.	When a body moves in a circular path, its velocity is:	Constant	Variable	Zero	Increasing
2.	the force which opposes the relative motion between two surfaces in contact is known as:	Friction	Gravitational force	Electrostatic force	Nuclear force
3.	a train is traveling at 20 m/s and comes to a stop in 40 seconds. What is the magnitude of deceleration of the train?	$0.5\ m/s^2$	$2\ m/s^2$	$0.05\ m/s^2$	$0.2\ m/s^2$
4.	If two objects, one heavy and one light, are dropped from the same height, neglecting air resistance, which object will hit the ground first?	They heavy object	The light object	Both objects will hit the ground at the same time	It depends on the shape of the objects
5.	Sub branch of Physics in which we study the motion of object along with causes and effects is called:	Kinematics	Dynamics	Astro Physics	Optics
6.	Which of the followings is a magnetic material?	Plastic	Wood	Copper	Cobalt
7.	Which of the followings is a greatest prefix?	Deca	Deci	Milli	Nano
8.	Joule (J) is the unit of work which is equal to:	Newton	$kgms^{-2}$	Watt second	Newton second
9.	A car, an elephant and a cricket ball have same kinetic energies. Which of these have greater speed?	Car	Elephant	Cricket	All have same speed
10.	Magnetic field lines:	Are farthest at poles	Intersect each other	Never intersect each other	Do not pass in vacuum
11.	The Branch of Physics that is most important when studying how glasses help people see:	Thermodynamics	Electromagnetism	Mechanics	Optics
12.	Which term describes a thoroughly tested idea in Physics?	Idea	Hypothesis	Theory	Law

Model Paper Federal Board

Paper: Physics	**Model Paper w.e.f 2025**	**Class: 9th**
Time: 2.45 Hours	Subjective Type	**Max. Marks: 53**
Name:		

Note: Answer all parts from section 'B' and all questions from Section 'C' on the E-sheet. Write your answers on the allotted/given spaces.

Section – B (Marks 33)

Q.2 Answers the following questions briefly. **(11 x 3 = 33)**

(i)	Differentiate between precision and accuracy	03	OR	Differentiate between center of gravity and centre of mass.	03
(ii)	Draw the speed time graph for uniform acceleration. Use this graph to show that gradient of speed time graph gives acceleration.	03	OR	Which will have greater spring constant, steel spring or rubber spring?	03
(iii)	Differentiate between strong nuclear force and electromagnetic force.	03	OR	Define astrophysics, biophysics and optics.	03
(iv)	Define impulse. Write its formula and SI unit.	03	OR	How a vector is represented graphically and symbolically?	03
(v)	Provide justification that pressure exerts perpendicular force on a surface?	03	OR	Suggest changes in design of liquid in glass thermometer to increase its sensitivity and range?	03
(vi)	Differentiate between paramagnetic materials and diamagnetic materials.	03	OR	Why plasma is called fourth state of matter?	03
(vii)	State Pascal law. List any two its applications	2+1	OR	What are domains? Show alignment of domains in figures for magnetized and un magnetized materials.	2+1
(viii)	How manometer is used to measure the gas pressure?	03	OR	What is average speed of a car if it completes a circle of radius 200m in 5minutes?	03
(ix)	Cutting edge of knife is made sharper. How does it cut vegetables easily?	03	OR	If radius of the orbit is doubled then what will be effect on its orbital velocity of a satellite?	03
(x)	What steps would you take to minimize random error from measurement?	03	OR	How magnetic field is used to record sound on magnetic tapes or on hard discs?	03
(xi)	Differentiate between hypothesis and theory.	03	OR	Give three differences between vectors and scalars.	03

Section – C (Marks 20)

Note: Attempt all questions. Marks of each question are given along with each question. (4 × 5 = 20)

Q.3	What are different types of motion? Give two examples of each.	05	OR	What are soft magnetic materials? Discuss magnetic shielding effect of soft magnetic materials.	1+4
Q.4	State and prove Newton's second law of motion.	1+4	OR	Define kinetic energy and derive its formula.	1+4
Q.5	A long uniform steel bar of length of 100 cm is balanced on a wedge at its middle. Two weights W1 and W2 are suspended at distance of 0.2 m and 0.4 m respectively from the wedge. If weight W1 is 70 N then find weight W2.	05	OR	A hydraulic press lifts mass of 500 kg when we apply force of 10 N on small piston. Radius of its small piston is 15 cm, find the radius of its large piston.	05
Q.6	Discuss the structure and working of thermo-couple thermometer.	05	OR	Define centripetal force. Write its formula. Give three examples from daily life in which centripetal force plays an important role.	1+1+3

Past Papers of Federal Board 2024 (Local Area)

PHYSICS 9th	Local area Paper 2024	[illegible]
Paper -I (Objective Type)		[illegible]
Time Allowed: 15 Minutes		[illegible]
Maximum Marks: 12		12 [illegible]

[illegible]

Note: You have four choices for each objective type question as A, B, C and D. The choice which you think is correct, fill that circle in front of that question number. Use marker or pen to fill the circles. Cutting or filling two or more circles will result in zero mark in that question.

SECTION - A (Marks 12)

No.	Question	A	B	C	D
1	The SI unit for measuring temperature is:	Archimedes principle	Fahrenheit	Kelvin	Celsius
2	Which is the most suitable instrument to measure the depth of a test tube?	Vernier callipers	Screw gauge	Meter rod	Measuring tape
3	A ball is thrown straight up, what is its acceleration at the top of its path?	Zero	$10\ m\ s^{-2}$	$20\ m\ s^{-2}$	$5\ m\ s^{-2}$
4	1 Newton = ______	1 kg $m s^{2}$	1 kg m s	1 kg $m s^{-2}$	1 kg m s
5	If the velocity of the body becomes double, then centripetal force will be:	Double	Three times	Four times	Half
6	An example of neutral equilibrium is:	Table	Book on table	Paratrooper	Foot ball
7	A force of 10N is acting along x-axis, what will be its horizontal component:	0 N	5 N	10 N	15 N
8	The value of "g" at the centre of earth is:	∞	$9.8\ m\ s^{-2}$	$1.6\ m\ s^{-2}$	$0\ m\ s^{-2}$
9	Kilowatt-hour is the unit of:	Energy	Force	Power	Torque
10	Density of a substance can be calculated by using:	Archimedes principle	Pascal's Law	Hook's Law	Newton's Law
11	Best reflector of heat is:	Dull black surface	Coloured surface	White surface	Shining surface
12	Temperature of a substance is equal to:	K.E. of each molecule	Average K.E. of molecules	P.E. of each molecule	Average P.E. of molecule

PHYSICS 9th	Local area Paper 2024	[illegible]
Paper -II (Subjective Type)		[illegible]
Time Allowed: 2.45 Minutes		2.45 [illegible]
Maximum Marks: 53		53 [illegible]

SECTION - B (Marks 28)

Q.2 Attempt the following questions. (11×4=44) [illegible]

No.	Question	Marks		Question	Marks
(i)	What are base quantities? construct a table showing any four base quantities along with their units and symbols.	1+2	OR	How does heat transfer occur through the windows and vents of a room? Explain briefly.	03
(ii)	Express 200 micrometers in millimeters and kilometers.	1.5 + 1.5	OR	Prove that 4PC = 4.09	03
(iii)	Differentiate between rotatory motion and circular motion. Give examples for each.	03	OR	What changes are expected in weather if the barometer shows increase in atmospheric pressure?	1.5 + 1.5
(iv)	In case of a fall, how a helmet protects the motor cyclist? Explain in context of $F = \Delta P / \Delta t$	1.5 + 1.5	OR	prove that 1kWh = 3.6MJ	03
(v)	State conditions of equilibrium and also give their mathematical forms.		OR	Calculate the value of 'g' at the height of 2000 km above the surface of earth.	03
(vi)	A screw gauge has smallest division on main scale 0.5mm and circular scale has 100 divisions. What will be the pitch and least count of this screw gauge?	1.5 + 1.5	OR	A force is acting on a body making an angle of 30° with x-axis. The vertical component of force is 20N. Find the force.	03
(vii)	Calculate mass of earth by using law of gravitation.	03	OR	Differentiate between stable and unstable equilibrium.	1.5+1.5
(viii)	How much energy can be obtained from 20g of uranium?	03	OR	Why is the outer edge of the road kept higher at circular turn?	03
(ix)	State Hook's law. Briefly explain the term elastic limit.	1.5 + 1.5	OR	Differentiate positive and negative acceleration. Show these quantities graphically.	1.5 + 1.5
(x)	Briefly explain that the gravitational forces are consistent with Newton's third law of motion.	03	OR	Vernier callipers or Screw gauge which instrument gives more precise measurement? Give scientific reason for your choice.	1+2
(xi)	What is meant by radiation? Enlist the factors on which radiations emitted from a body depend.	1+2	OR	What is meant by moment of force (Torque)? On which factors it depends? Explain briefly.	1+2

SECTION - C (Marks 20)

Note: Attempt the following questions. (4x5=20) [illegible]

Q.3	Derive $S = v_i t + \frac{1}{2}at^2$ using speed time graph for uniformly accelerated body. [illegible]	[illegible]	OR	What is meant by rate of flow of heat through conductor (Thermal conductivity)? On what factors does it depend? Derive its formula. [illegible]	05
Q.4	What is meant by the terms 'Kinetic Energy' and 'Potential Energy'? Prove that $KE = \frac{1}{2}mv^2$ [illegible] $KE = \frac{1}{2}mv^2$ [illegible]	1.5 + 1.5	OR	Explain thermal expansion of liquids in detail. [illegible]	05
Q.5	Explain that liquids exert pressure. Show that liquid pressure depends on depth and density. [illegible]	05	OR	Explain Newton's second law of motion. Also derive unit of force from this law. [illegible]	1.5 + 1.5
Q.6	How much heat energy is required to change 0.5kg of ice at -10°C? [illegible]	1.5 + 1.5	OR	A car slows down from 100 km/h with a uniform retardation of 2m/s². How long it will take to attain a speed of 20km/h? [illegible]	05

Past Papers of Federal Board 2024 (hard Area)

PHYSICS 9th	Hard area Paper 2024	[illegible]
Paper -I (Objective Type)		[illegible]
Time Allowed: 15 Minutes		[illegible]
Maximum Marks: 12		12 [illegible]

[illegible]

Note: You have four choices for each objective type question as A, B, C and D. The choice which you think is correct; fill that circle in front of that question number. Use marker or pen to fill the circles. Cutting or filling two or more circles will result in zero mark in that question.

SECTION - A (Marks 12)

No.	Question	A	B	C	D
1	The gliders remain in air for longer time due to: [illegible]	Force [illegible]	Conduction [illegible]	Radiation [illegible]	Convection [illegible]
2	[illegible] = [illegible]	[illegible]	[illegible]	$0^{\circ}C$	$100^{\circ}C$
3	A rock weighs 25.7 N in air and 21.6 N in water. What is buoyant force of water? [illegible]	4.1 N	3.9 N	4.6 N	1.28 N
4	Boiling takes place at at ______ of liquid [illegible]	Surface only [illegible]	Bottom only [illegible]	Center only [illegible]	Every location [illegible]
5	The unit of young's modulus is: [illegible]	Nm^{-2}	$Kg\,m^{-3}$	m^{-2}	m/s
6	1Å is = [illegible]	1000 nm	0.01 nm	.001 nm	1 nm
7	slope of distance time graph represents: [illegible]	Displacement [illegible]	Speed [illegible]	Acceleration [illegible]	Momentum [illegible]
8	Centripetal force always acts ______ to the motion of body. [illegible]	Opposite [illegible]	Parallel [illegible]	Perpendicular [illegible]	Antiparallel [illegible]
9	When centre of gravity of a body is at heighest point, then the body will be: [illegible]	Neutral Equilibrium [illegible]	Stable Equilibrium [illegible]	unstable Equilibrium [illegible]	Dynamic Equilibrium [illegible]
10	Orbital speed of a satellite independent of ___ body. [illegible]	Mass of Earth [illegible]	Mass of Satellite [illegible]	R [illegible]	G [illegible]
11	The value of 'g' at the centre of Earth is: [illegible]	0	11	$1.6\ m/s^2$	$9.8\ m/s^2$
12	Work done will be zero if the between force and displacement is: [illegible]	0	30°	60°	90°

Past Papers of Federal Board 2024 (Hard Area)

PHYSICS 9th	Hard area Paper 2024	(فزکس)
Paper -II (subjective Type)		پرچہ II (انشائیہ طرز)
Time Allowed: 2.45 Minutes		وقت: 2.45
Maximum Marks: 53		کل نمبر: 53

SECTION - B (Marks 20)

Q.2 Attempt the following questions. (11x2=33) [illegible]

(i)	What is meant by limitation of measuring instrument? Discuss the limitation of Vernier caliper. [illegible]	1+1	OR	What is meant by moment of force (Torque)? [illegible]	02
(ii)	Is the measurement taken by Screw gauge more precise than by Vernier caliper? Give scientific reason of your answer. [illegible]	1.5 + 1.5	OR	State condition of equilibrium, give their mathematical expression. [illegible]	02
(iii)	Express the following quantities using suitable prefixes. [illegible] a) 4.0x10⁵ b) 4.0x10⁶ c) 4.0x10⁸	02	OR	Differentiate between rotatory motion and circular motion with examples. [illegible]	1.5 + 1.5
(iv)	Demonstrate that rolling friction is much lesser than sliding friction. [illegible]	1.5 + 1.5	OR	Why is outer edge of road kept higher on circular turn? [illegible]	02
(v)	A car starts its motion and acceleration at $2m/s^{-2}$. Find its velocity after covering distance of 1 km. [illegible]		OR	Calculate the value of g at the height of 1500 km above the surface of earth. [illegible]	02
(vi)	The masses of earth and moon are $6.0x10^{24}$kg and $7.4x10^{22}$ respectively. The distance of them. [illegible]	1.5 + 1.5	OR	Explain the situation when A car is moving forwards north but its acceleration is towards south. [illegible]	02
(vii)	How much energy can be obtained from 4kg of Uranium? [illegible]	02	OR	Why a system cannot have an efficiency of 100%? Explain in briefly. [illegible]	1+1
(viii)	Can a body be in equilibrium under the action of a single force? Give reason. [illegible]	02	OR	Why is mercury considered most suitable thermometric material? [illegible]	02
(ix)	What changes are expected in weather if the barometer shows increase in atmospheric pressure? [illegible]	1.5 + 1.5	OR	Birds fluff their feathers in winters. Explain in context of heat transfer. [illegible]	1.5 + 1.5
(x)	Briefly explain the following [illegible] a) Heat b) Temperature c) Internal energy	03	OR	Why are metals good conductors of heat? Explain in briefly. [illegible]	1+2
(xi)	What is conduction of heat? Why are gases poorest conductors? Explain briefly. [illegible]	1+1	OR	Which material is more elastic, Steel or rubber? Give reason. [illegible]	1+2

SECTION - C (Marks 20)

Note: Attempt the following questions. (4x5=20) [illegible]

Q.3	What is meant by resultant force? How is resultant force determined by usage head to tail rule? Explain with diagram. [illegible]	1+4	OR	What is meant by thermal expansion in solid? Derive expression for linear thermal expansion in solids? [illegible]	05
Q.4	What is meant by Force and momentum? What is the relation between Force and momentum? Explain in detail. [illegible]	1.5 + 3.5	OR	What is orbital velocity? Derive and expression for it also calculate value of orbital velocity of a satellite close to the earth. [illegible]	05
Q.5	State Archimedes principle. How Archimedes principle is helpful to find the density of an object. [illegible]	05	OR	Derive expression for acceleration and tension in string using Atwood machine. [illegible]	2.5 + 2.5
Q.6	A ball of mass 3kg is thrown upward with velocity of 12 ms-1, Find (a) maximum hight (b) Potential Energy at maximum height [illegible]	2.5 + 2.5	OR	Derive third equation of motion by using speed-time graph. [illegible]	05

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