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Revised Edition

Encyclopedia of General Science

FOR GENERAL COMPETITIONS

Based on NCERT Science Books

In-line with Analysis of Competitive Exams Papers

Explanation to Everyday Science Phenomena

Best 2000 Multiple Choice Questions

UPSC & State PSC Examinations, SSC, Railways & Other General Competitive Exams

Revised Edition

Encyclopedia of General Science

FOR GENERAL COMPETITIONS

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Preface

Analyzing the recent pattern of competitive exams like SSC, UPSC & State Level PSCs, etc, it is evident that general science has taken an important dimension. General Science has always been a problematic section for aspirants they find it difficult to prepare for this section because it has no prescribed syllabus and coverage area. Also there is a good number of students preparing for general competitions who are not from science background and they find it even more difficult.

So, the need arises for a book that can give the whole contents of General Science in an organized and in-complex manner which can be studied by all the students even by non-science background students too and can make them ready to face the questions on General Science.

The book **Encyclopedia of General Science** has been prepared keeping the importance of the subject in mind. It covers all the sections of General Science like Physics, Chemistry, Biology, Space Science, Agriculture & Animal Husbandry, Environment, Health , Computer & IT, etc.

In this book, we have tried to simplify the complexities of some of the topics so that the non-science students feel no difficulty while studying general science. As NCERT books are considered to be most important & foundation books for general competitions, so NCERT books have been kept as the base books for this book.

Some of the Special Features

- Only book based on NCERT Textbooks of Science
- In-line with Analysis of Competitive Exams' Papers
- Explanation to Everyday Science Phenomena
- Coverage of Previous years' Questions in Chapterwise manner (upto 2020)
- With Appendices covering; Glossary, Branches and other important information of each section

However, we have put our best efforts in preparing this book, but if any error or whatsoever has been skipped out, we will by heart welcome your suggestions.
The role of Arihant DTP Unit and Proof reading team is praiseworthy in the making of this book.

Best of Luck

Contents

1 Units, Measurements *and* Errors

Physical Quantities

Anything which can be expressed in numbers is called quantity. Different events in nature take place in accordance with some basic laws. Revealing these laws of nature from the observed events, we need some quantities which are known as physical quantities. ***e.g.,*** length, mass, temperature, time, force, speed, distance, acceleration, velocity, momentum, current, etc.

Types of Physical Quantities

I. *On the basis of units and their measurement*

(i) Fundamental or Base Quantities The physical quantities which do not depend on the other physical quantities are known as fundamental (or base) physical quantities. ***e.g.,*** length, mass, electric current, time, temperature, luminous intensity, amount of substance, etc.

(ii) Derived Quantities All the physical quantities which are not the fundamental physical quantities but are derived from it are known as derived physical quantities. ***e.g.,*** work, force, pressure, area, volume, energy, etc.

(iii) Supplementary Quantities There are also two physical quantities which are neither fundamental nor derived. These quantities are called supplementary quantities. These are plane angles and solid angles.

II. *On the basis of direction and their magnitude*

(i) Scalar Quantity A physical quantity which has only its magnitude but no direction is called a scalar quantity. ***e.g.,*** distance, energy, power, time, speed, volume, density, pressure, work, charge, electric current, temperature, specific heat, frequency, mass, etc.

(ii) Vector Quantity A physical quantity which has magnitude as well as direction is called a vector quantity. ***e.g.,*** displacement, velocity, torque, position, acceleration, force, weight, momentum, impulse, electric field, magnetic field, current density, angular velocity, etc.

Units

To measure a physical quantity, a standard value of same physical quantity is used, which indicates that, how many times the standard physical quantity is used to measure the whole physical quantity. This standard value of the physical quantity is known as its unit and when any given quantity is measured in the term of this unit, the process is called measurement.

e.g., F = 10 N

Here, 10 indicates the unit of force (1 N) is ten times used to measure the force of 10 N.

Units are also divided into the following parts

Fundamental Units or Base Units

The units of fundamental physical quantities are called fundamental units. There are seven fundamental units ***i.e.,*** **metre, kilogram, second, ampere, kelvin, candela** and **mole.**

These units are used as standards for the concerned physical quantity and are independent of each other.

Initially, only metre, kilogram and second were considered to be fundamental but later on units of ampere (electric current), kelvin (temperature), candela (luminous intensity) and mole (amount of substance) were added to fundamental units.

Derived Units

The units of all other physical quantities except fundamental physical quantities which are obtained with the help of fundamental units are called derived units. ***e.g.,*** units of area, volume, density, speed, power, work, force, energy, acceleration, momentum, etc.

Supplementary Units

The units used for the supplementary quantities are known as supplementary units. ***e.g.,*** units of plane angle and solid angle.

System of Units

A complete set of units having both the base units and derived units is known as the **system of units**.

The common systems of units are

(i) MKS System (Metre Kilogram Second) In this system, the units of length, mass and time are respectively metre, kilogram and second.

(ii) CGS System (Centimetre Gram Second) In this system, the units of length, mass and time are respectively centimetre, gram and second. It is also called **Gaussian system**.

- *The MKS and CGS system are called* ***metric*** *or* ***decimal system.***

(iii) FPS System (Foot Pound Second) In this system, the units of length, mass and time are respectively foot, pound and second. It is also called **British system.**

(iv) SI System (International System of Units) SI was adopted and accepted in the International Conference of Weights and Measures held at Geneva in 1960, on the basis of comprehensive consensus. SI system is extended and modified form of MKS system.

There are following seven fundamental units and two supplementary units in SI system.

Fundamental Units and their Symbols in SI System

Name of Quantity	Name of Unit	Symbol	Definition
Length	metre	m	The metre is the length of the path travelled by light in vacuum during a time interval of 1/299,792,458 of a second. (1983)
Mass	kilogram	kg	The kilogram is equal to the mass of international prototype of the kilogram (a platinum-iridium alloy cylinder) kept at International Bureau of Weights and Measures, at Sevres, near Paris, France. (1889)
Time	second	s	The second is the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom. (1967)
Electric current	ampere	A	The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length. (1948)
Thermodynamic temperature	kelvin	K	The kelvin, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water. (1967)
Amount of substance	mole	mol	The mole is the amount of substance of a system, which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon-12. (1917)
Luminous intensity	candela	cd	The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} Hz and that has a radiant intensity in that direction of 1/683 watt per steradian. (1979)

Supplementary Units and their Symbols in SI System

Name of Quantity	Name of Unit	Symbol	Definition
Plane angle	radian	rad	The radian is the plane angle subtended at the centre by an arc of a circle having a length equal to radius of the circle. All plane angles are measured in radian.
Solid angle	steradian	Sr	The steradian is the solid angle which has the vertex at the centre of the sphere, and cut off an area of the surface of sphere equal to that of square with sides of length equal to radius of sphere.

Important Formulae and Units of Derived Units

Physical Quantities	Formulae	SI Units
Area of rectangle	Length × Breadth ($l \times b$)	m^2
Area of square	$(\text{Side})^2$	m^2
Area of triangle	$\frac{1}{2}$ × Base × Height	m^2
Density	Mass/Volume	$kg\ m^{-3}$
Acceleration	Change in Velocity /Time	ms^{-2}
Pressure	Force/Area (F/A)	Nm^{-2} or pascal
Work or energy	Mass × Acceleration due to Gravity × Height (PE = mgh)	N-m or joule
Power	Work/Time	Js^{-1} or watt
Impulse	Force × Time	N-s
Volume of cuboid	Length × Breadth × Height ($l \times b \times h$)	m^3
Velocity	$\frac{\text{Displacement}}{\text{Time}}$	ms^{-1}
Force	Mass × Acceleration	$kg\ ms^{-2}$ or newton
Linear momentum	Mass × Velocity	$kg\ ms^{-1}$
Magnetic field	$\frac{\text{Force}}{\text{Electric Current} \times \text{Displacement}}$	$N\ amp^{-1}\ m^{-1}$ or tesla or weber $/m^2$
Frequency	$\frac{1}{\text{Time Period}}$	s^{-1} or hertz

Practical Units of Length, Mass and Time

Practical Units of Length

1 Angstrom (Å) $= 10^{-10}$ m
1 Nanometre (nm) $= 10^{-9}$ m
1 Micrometre (μm) $= 10^{-6}$ m
1 Millimetre (mm) $= 10^{-3}$ m
1 Centimetre (cm) $= 10^{-2}$ m
1 Kilometre (km) $= 10^{+3}$ m
1 Terametre $= 10^{+12}$ m
1 Light year = 9.46×10^{15} m or 10^{16} m
1 Astronomical unit (1AU) $= 1.5 \times 10^{11}$ m
1 Parsec = 3.26 light year $= 3.083 \times 10^{16}$ m
1 Mile = 1.6 km
1 Fermi $= 10^{-15}$ m

Practical Units of Mass

1 Microgram (μg) $= 10^{-9}$ kg
1 Milligram (mg) $= 10^{-6}$ kg
1 Gram (g) $= 10^{-3}$ kg
1 Quintal $= 10^{2}$ kg
1 Metric tonne $= 10^{3}$ kg
1 Atomic mass unit $= 1.66 \times 10^{-27}$ kg
1 Pound = 0.4537 kg
1 Chandrashekhar limit = 1.4 × Mass of sun $= 2.8 \times 10^{30}$ kg
1 Slug = 14.59 kg

Practical Units of Time

1 Picosecond (ps) $= 10^{-12}$ s
1 Nanosecond (ns) $= 10^{-9}$ s
1 Microsecond (μs) $= 10^{-6}$ s
1 Millisecond (ms) $= 10^{-3}$ s
1 Minute = 60 s
1 Hour = 60 min = 3600 s
1 Day = 24 hours = 1440 min = 86400 s
1 Week = 7 days
1 Lunar month = 28 days = 4 weeks
1 Solar month = 30 or 31 days = 28 or 29 days (feb)
1 Year = $365\frac{1}{4}$ days
1 Moon month = 27.3 solar day
1 Solar day = 86400 s
1 Leap year = 366 day (There are 29 days in feb of leap year)
1 Shake $= 10^{-8}$ s

Conversions of Units

Some conversions of units are given below

Conversion of Mass

$$10 \text{ milligram (mg)} = 1 \text{ g} = 15.43 \text{ grains} = 10^{-3} \text{ kg}$$
$$1000\ (10^3) \text{ g} = 1 \text{ kilogram (kg)} = 2.205 \text{ pounds}$$
$$1000 \text{ kg} = 1 \text{ tonne}$$

Conversion of Length

$$10 \text{ millimetre (mm)} = 1 \text{ centimetre (cm)} = 0.394 \text{ inch}$$
$$100 \text{ centimetre} = 1 \text{ metre (m)} = 39.4 \text{ inch} = 1.094 \text{ yard}$$
$$1000\ (10^3) \text{ metre (m)} = 1 \text{ kilometre (km)} = 0.6214 \text{ mile}$$
$$1 \text{ foot} = 0.3048 \text{ m}$$

Conversion of Area

$$4046 \text{ square metre } (\text{m}^2) = 1 \text{ acre}$$
$$100 \text{ hectare} = 1 \text{ square kilometre } (\text{km}^2)$$

Conversion of Volume

$$10 \text{ millilitre (mL)} = 1 \text{ centilitre (cL)} = 0.018 \text{ pint (0.021 USpint)}$$
$$100\ (10^2) \text{ centilitre (cL)} = 1 \text{ litre} = 1.76 \text{ pint}$$
$$10 \text{ litre} = 1 \text{ decalitre (daL)} = 2.2 \text{ gallon (2.63 USgallon)}$$

Metric Prefixes for Power of 10

The physical quantities whose magnitude is either too large or too small can be expressed more compactly by the use of certain prefixes (in accordance with power of 10) are given in the table.

Prefix	Symbol	Power of 10
yotta	Y	10^{24}
zetta	Z	10^{21}
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
hecto	h	10^{2}
deca	da	10^{1}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}
zepto	z	10^{-21}
yocto	y	10^{-24}

Dimensions of Physical Quantities

The dimensions of a physical quantity are the powers to which the units of base quantities are raised to represent a derived unit of that quantity.

Use of square bracket [ ] around a quantity means that we are dealing with the dimensions of the quantity.

In dimensional representation, the magnitudes are not considered ***i.e.,*** dimension of both 10 m of length and 100 m of length will be [L].

Dimensional Representation of Physical Quantities

In mechanics, all the physical quantities can be written in terms of the dimensions of fundamental (or base) physical quantities such as

[M] for Mass, [L] for Length, [T] for Time, [A] for Electric current, [K] for Temperature

[cd] for Luminous intensity, [mol] for Amount of substance.

Dimensional Formula and Dimensional Equation

The expression which shows how and which of the base quantities represents a physical quantity is called the dimensional formula of the given physical quantity.

e.g., $[M\,L\,T^{-2}]$ is the **dimensional formula** of force. It reveals that unit of force depends on [M],[L] and [T].

Further, if we represent force by [F], then $[F] = [M\,L\,T^{-2}]$, is called the **dimensional equation** of force.

For example,

(i) $\text{Speed} = \dfrac{\text{Distance}}{\text{Time}} = \dfrac{[L]}{[T]} = [LT^{-1}]$

(ii) $\text{Pressure} = \dfrac{\text{Force}}{\text{Area}} = \dfrac{\text{Mass} \times \text{Acceleration}}{\text{Area}}$

$$= \frac{[M]\times[LT^{-2}]}{[L^2]} = [ML^{-1}T^{-2}]$$

Some Physical Quantities and their Dimensional Formulae

Physical Quantity with Formula	Dimensional Formula
Area = Length × Breadth	$[L\times L] = [L^2] = [M^0L^2T^0]$
Volume = Length × Breadth × Height	$[L\times L\times L] = [L^3] = [M^0L^3T^0]$
Velocity = Displacement/Time	$\dfrac{[L]}{[T]} = [M^0LT^{-1}]$
Acceleration = Velocity/Time	$[LT^{-1}]/[T] = [M^0LT^{-2}]$
Force = Mass × Acceleration	$[M][LT^{-2}] = [MLT^{-2}]$
Work = Force × Displacement	$[MLT^{-2}][L] = [ML^2T^{-2}]$
Kinetic energy $= \dfrac{1}{2} \times$ Mass $\times$ (Speed)^2	$[M][LT^{-1}]^2 = [ML^2T^{-2}]$
Potential energy = Mass × Acceleration due to gravity × Height	$[M][LT^{-2}][L] = [ML^2T^{-2}]$

Dimensionless Quantities

The physical quantities which have zero dimensions are called dimensionless quantities. The dimensionless quantities are angle, solid angle, relative density, specific gravity, Poisson's ratio. A dimensionless quantity has same numeric value in all system of units.

Uses of Dimension

There are mainly three uses of dimension

(i) To check an equation whether it is homogeneous or not.
(ii) To establish the relation among the physical quantities.
(iii) To convert the units from one system to another system.

Important Scientific Instruments and their Use

Altimeter	It measures altitudes and is used in aircrafts.
Ammeter	It measures strength of electric current (in ampere).
Audiometer	It measures intensity of sound.
Barometer	It measures atmospheric pressure.
Binocular	It is used to view distant objects.
Burette	It is used to deliver any required volume of a liquid upto its maximum capacity.
Calorimeter	It measures quantity of heat.
Cardiogram	It traces movements of the heart, recorded on a cardiograph.
Cinematography	It is an instrument used in cinema making to throw on screen and enlarged image of photograph.
Dynamo	It converts mechanical energy into electrical energy.
Dynamometer	It measures electrical power.
Electrometer	It measures electricity.
Electroscope	It detects presence of an electric charge.
Endoscope	It examines internal parts of the body.
Electroencephalogram (ECG)	It is a test used to evaluate the electrical activity in the brain.
Fathometer	It measures the depth of the ocean.
Galvanometer	It measures the electric current of low magnitude.
Hydrometer	It measures the specific gravity of liquids.
Hygrometer	It measures humidity in air.
Hydrophone	It measures sound under water.
Lactometer	It determines the purity of milk.
Manometer	It measures the pressures of gases.
Mariner's compass	It is an instrument used by the sailors to determine the direction.
Microphone	It converts the sound waves into electrical vibration and to magnify the sound.
Microscope	It is used to obtain magnified view of small objects.
Odometer	An instrument by which the distance covered by wheeled vehicles is measured.
Phonograph	It is used for producing sound.
Photometer	It compares the luminous intensity of the source of light.
Periscope	It is used to view objects above sea level (used in sub marines).
Radar	It is used for detecting the direction and range of an approaching plane by means or radio microwaves.
Pyrometer	It is a remote - sensing radiation thermometer used to measure the high temperature of the surface.
Pyrheliometer	It is an instrument for measurement of direct beam solar irradiance.
Radiometer	It measures the emission of radiant energy.
Screw gauge	It is used to measure thickness of a thin glass plate and diameter of a thin wire or a small sphere.

Seismograph	It measures the intensity of earthquake shocks.
Salinometer	It determines salinity of solution.
Sonometer	To measure frequency of a tunning fork.
Spectrometer	It is an instrument for measuring the energy distribution of a particular type of radiation.
Speedometer	It is an instrument placed in a vehicle to record its speed.
Sphygmomanometer	It measures blood pressure.
Spherometer	It measures the curvatures of surfaces.
Stereoscope	It is used to view two dimensional pictures.
Stethoscope	An instrument which is used by the doctors to hear and analyse the heart and lung sounds.
Straboscope	It is used to view rapidly moving objects.
Tachometer	An instrument used in measuring speeds of aeroplanes and motor boats.
Telescope	It views distant objects in space.
Thermometer	This instrument is used for the measurement of temperatures.
Thermostat	It regulates the temperature at a particular point.
Voltmeter	It measures the electric potential difference between two points.
Vernier callipers	To measure lengths accurately.

Error in Measurement

The difference between true value and measured value of a quantity is called error of measurement. The error cannot be eliminated totally, however it can be minimise.

Resolution It is the least count of output of an instrument.

Accuracy An instrument is said to be accurate, if the physical quantity measured by it resembles very closely to its true value.

Precision An instrument is said to have high degree of precision, if the measured value remains unchanged, howsoever large number of times it may have been repeated.

Classification of Errors

I. *On the basis of nature of errors*

1. Systematic Errors

The systematic errors are those errors that tend to be in one direction, either positive or negative. The causes of these errors are known, so these can be minimised.

Some of the sources of systematic errors are

(i) **Instrumental Errors** These errors arise due to defect in the manufacturing or in design of the measuring instrument.

(ii) Imperfection in experimental technique or procedure.

(iii) **Personal Errors** These errors arise due to inexperience of the observer.

2. Random Errors

The random errors are those errors, which occur irregularly and hence are random with respect to sign and size. Errors due to external causes arise due to external factors such as temperature, pressure, wind, humidity, etc.

3. Least Count Errors

The smallest value that can be measured by the measuring instrument is called its least count errors. All the readings or values measured by any measuring instrument are good only upto its least count. This error is associated with the resolution of the instrument.

This type of error can be minimised by using the instruments of higher resolution and by improving experimental techniques.

- *The errors as a whole is termed as gross error.*

II. *On the basis of mathematical calculations of measurement*

1. Absolute Error

In the measurement of a physical quantity, the difference between true value and an individually measured value of the quantity is known as absolute error.

2. Mean Absolute Error

The arithmetic mean of absolute errors in all the measurement of the quantity is known as mean absolute error.

$$\text{Mean absolute error} = \frac{\text{Sum of absolute errors in each observation}}{\text{Number of observations}}$$

3. Relative Error

The ratio of mean absolute error to the mean value of the quantity is called relative error or fractional error.

If this ratio is expressed as percentage, then the error is called **percentage error.**

Significant Figures

The digits that are known reliably plus the first uncertain digit are known as significant digits or significant figures.

e.g., suppose a measured distance is 574.5 m. It has four significant figures 5, 7, 4 and 5. The digits 5, 7 and 4 are certain and reliable while the digit 5 is uncertain.

Common Rules for Counting Significant Figures

(i) All non-zero digits are significant.

(ii) All zeroes occurring between two non-zero digits are significant no matter, where the decimal point is, if at all.

(iii) If the number is less than one, the zero(s) on the right of decimal point and to the left of the first non-zero digit are not significant.

(iv) In a number without a decimal point, the terminal or trailing zeroes are not significant.

(v) In a number with a decimal point, the trailing zeroes are significant.

(vi) Change of unit does not change the number of significant figures.

(vii) The digit 0 conventionally, but on the left of a decimal for a number less than 1 is never significant.

Arithmetic Operation with Significant Numbers

(i) **Addition and Subtraction** In both addition and subtraction, the final result should retain as many decimal places as are there in the number with the least decimal places.

(ii) **Multiplication and Division** In multiplication and division, the final result should retain as many significant figures as are there in the original number with least significant figures.

Assessment

1. Identify the unit of measuring intensity of sound **[SSC CGL 2018]**
(a) Knots (b) Ampere
(c) Candela (d) Decibel

2. What is the unit of the physical quantity, Momentum? **[SSC (10 + 2) 2017]**
(a) Newton second (b) Joule second
(c) Erg second (d) Pascal second

3. Frequency is measured in **[BPSC (Pre) 2018]**
(a) hertz (b) metre/second
(c) radian (d) watt

4. What is measured in hertz? **[BPSC (Pre) 2019]**
(a) Frequency (b) Energy
(c) Heat (d) Quality

5. Which one of the following physical quantities has the same unit as that of pressure? **[NDA 2017]**
(a) Angular momentum
(b) Stress
(c) Strain
(d) Work

6. Angstrom is a unit of **[BPCS (Pre) 2018]**
(a) wavelength (b) energy
(c) frequency (d) velocity

7. What is the unit of pressure? **[BPCS (Pre) 2018]**
(a) Newton/sq metre
(b) Newton-metre
(c) Newton
(d) Newton/metre

8. The unit of pressure is **[BPSC (Pre) 2019]**
(a) kg/cm^2 (b) kg/cm
(c) kg/mm (d) None of these

9. Which one of the following quantities does not have unit? **[BPSC (Pre) 2019]**
(a) Stress (b) Force
(c) Strain (d) Pressure

10. Which one of the following is not the unit of heat? **[UPRO/ARO (Pre) 2017]**
(a) Centigrade (b) Calorie
(c) Erg (d) Joule

11. Which of the following is the SI unit of temperature? **[SSC (10 + 2) 2019]**
(a) Kelvin (b) Reaumur scale
(c) Candela (d) Ampere

12. Which one of the following is the unit of force? **[SSC (10 + 2) 2019]**
(a) Pascal (b) Watt
(c) Joule (d) Newton

13. Light year is a unit for measurement of **[NDA 2019]**
(a) very large distances.
(b) time interval in years.
(c) amount of light received on earth in a year.
(d) mass of atoms.

14. Light year is the unit of .... **[RRB 2019]**
(a) length (b) mass
(c) time (d) area

15. The unit of momentum is **[RRB 2018]**
(a) $kgms^2$ (b) $kgms^{-1}$
(c) kgms (d) $kgms^{-2}$

16. Which of the following quantities does not have any unit? **[SSC 2017]**
(a) Speed (b) Density
(c) Relative density (d) Acceleration

17. Maxwell is the unit of which one of the following? **[SSC 2017]**
(a) Magnetic flux
(b) Permeability
(c) Magnetic susceptibility
(d) Intensity of magnetisation

18. The SI unit of radioactivity is .... **[SSC (10 + 2)2019]**
(a) Ampere (b) Becquerel
(c) Decibel (d) Cobolt

19. The SI unit of weight is **[RRB 2018]**
(a) kilogram (b) newton
(c) gram (d) dyne

20. Hertz is the SI unit of **[SSC 2019]**
(a) frequency (b) force
(c) pressure (d) energy

21. The SI unit for electrical resistivity is **[RRB 2019]**
(a) ampere/metre (b) volt/metre
(c) tesla (d) ohm metre

22. Which of the following quantities have its SI unit named after Blaise Pascal? **[SSC 2019]**
(a) Energy
(b) Pressure
(c) Work
(d) Power

23. Newton-metre (N-m) is the SI unit of which of the following physical quantity? **[SSC 2017]**

(a) Acceleration (b) Torque
(c) Power (d) Force

24. Match the following. **[SSC 2017]**

	Quanity		SI Unit
A.	Frequency	1.	Ohm
B.	Force	2.	Hertz
C.	Resistance	3.	Newton

Codes

	A B C		A B C
(a)	2 3 1	(b)	1 3 2
(c)	3 2 1	(d)	2 1 3

25. Light year is **[WBCS 2019]**

(a) light emitted by Sun in one year.
(b) time taken by light to travel from Sun to Earth.
(c) the distance travelled by light in free space in one year.
(d) time taken by Earth to go once around the Sun.

26. A nautical mile is equal to ……… . **[SSC CGL 2019]**

(a) 2000 metres (b) 1852 metres
(c) 1672 metres (d) 2450 metres

27. Which one of the following is the value of 1 nanometre? **[CDS 2018]**

(a) 10^{-7} cm (b) 10^{-6} cm
(c) 10^{-4} cm (d) 10^{-3} cm

28. 1 dyne (a unit of force in CGS system) equals to **[NDA/NA 2019]**

(a) 10^3 g-cm/s^2 (b) 10^{-3} g-cm/s^2
(c) 10^5 kg-cm/s^2 (d) 10^{-5} kg-m/s^2

29. Match the List I with List II and select the correct answer using the codes given below:

	List I		List II
A.	Acceleration	1.	Joule
B.	Force	2.	Newton-second
C.	Work done	3.	Newton
D.	Impulse	4.	Metre per second^2

[UPPCS 2005]

Codes

	A B C D		A B C D
(a)	1 2 3 4	(b)	2 3 4 1
(c)	4 3 1 2	(d)	3 4 1 2

30. If a physical quantity has the units- ampere meters per second squared, then what are it's dimensions? **[SSC (10+2) 2018]**

(a) [I LT^{-2}] (b) [ALT^{-2}]
(c) [I MS^{-2}] (d) [AMS^{-2}]

31. Which instrument is used to measure humidity? **[BPCS 2018]**

(a) Hydrometer (b) Hygrometer
(c) Pyrometer (d) Lactometer

32. Electroencephalogram (ECG) is used in monitoring **[BPCS 2018]**

(a) heart (b) liver
(c) pancreas (d) brain

33. Which one of the following thermometers is known as pyrometer? **[UPPCS 2016]**

(a) Thermo - electric thermometers
(b) Radiation thermometers
(c) Gas thermometers
(d) Liquid thermometers

34. Which one of the following devices is used to measure extremely high temperature? **[UPPCS 2016]**

(a) Pyrometer (b) Photometer
(c) Phonometer (d) Pycnometer

35. Pyrheliometer is used for measuring **[UPPCS 2015]**

(a) sun spots
(b) solar radiation
(c) air temperature
(d) temperature of plants

36. The density of milk is measured by **[MPPCS 2015]**

(a) loctometer
(b) hydrometer
(c) barometer
(d) hygrometer

37. A student measures certain lengths using a meter scale having least count equal to 1 mm. **[NDA/NA 2019]**

Which one of the following measurement is more precise?

(a) 0.50 mm (b) 29.07 mm
(c) 0.925 mm (d) 910 mm

1. (d)	**2.** (a)	**3.** (a)	**4.** (a)	**5.** (b)	**6.** (a)	**7.** (a)	**8.** (d)	**9.** (a)	**10.** (a)
11. (a)	**12.** (d)	**13.** (a)	**14.** (a)	**15.** (b)	**16.** (c)	**17.** (a)	**18.** (b)	**19.** (a)	**20.** (a)
21. (d)	**22.** (b)	**23.** (b)	**24.** (a)	**25.** (c)	**26.** (d)	**27.** (a)	**28.** (d)	**29.** (b)	**30.** (a)
31. (b)	**32.** (d)	**33.** (b)	**34.** (a)	**35.** (b)	**36.** (a)	**37.** (a)			

2

Motion

In our daily life we see some objects in motion ***e.g.,*** walking men, moving cars, running trains, and some objects at rest ***e.g.,*** furnitures, houses, trees, etc. In both the cases, we see that in motion, the position of objects change with time while at rest, the position of objects do not change with time.

Rest

If an object does not change its position with respect to its surroundings with time, then it is called at rest. ***e.g.,*** a book lying on a desk is at rest, because its position with respect to the desk does not change with time.

Motion

If an object changes its position with respect to its surroundings with time, then it is called in motion. ***e.g.,*** fish swims in water, car or bus moves on a road, train moves on the track, bird flying in air, etc.

- *Rest and motion are relative terms i.e., an object in one situation can be at rest but in other situation same object can be in motion.*
  e.g., if two cars are going side by side with the same velocity, then with respect to each other, they are in a state of rest, but with respect to trees and persons going on the road, they are in a state of motion.

Types of Motion of a Body

Generally, the motion of a body can be of the following three types

(i) Rectilinear and Translatory Motion The motion in which a particle moves along a straight line, is called rectilinear motion. If a body (or a particle) moves along a straight line, then the motion is called translatory motion.

e.g. Motion of sliding body on an inclined plane.

(ii) Circular and Rotatory Motion The motion in which a particle moves along a circular path, is called circular motion. e.g. A string whirled in a circular loop.

If a body rotates about a line (axis) passing through it then the motion is called rotatory motion or rotational motion. e.g. Fan moving in the house.

(iii) Oscillatory and Vibratory Motion The motion in which a body moves to and fro or back and forth repeatedly about a fixed point, is called oscillatory motion (the extent to which the body moves on either side of the fixed point is called the amplitude). If in oscillatory motion, the amplitude is very small, then the motion is said to be vibratory motion. e.g. Simple pendulum.

One, Two and Three Dimensional Motion

One-Dimensional Motion When the position of the object changes only in one direction, then the motion of an object is called one-dimensional motion.

or

When a body moves along a line, then the motion is called one-dimensional motion.

Two-Dimensional Motion When the position of the object changes in two direction, then the motion of an object is called two-dimensional motion.

or

When a body moves on a plane, then the motion is called two-dimensional motion.

Three-Dimensional Motion When the position of the object changes in three direction, then the motion of an object is called three-dimensional motion.

or

When a body moves in a space, then the motion is called three-dimensional motion.

Everyday **Science**

- The motion of a car on the road or an object falling freely under gravity is the example of one-dimensional motion.
- The motion of a planet around the sun and projectile motion are the example of two-dimensional motion.
- The motion of a bird in the sky and motion of a flying kite in the sky, etc are the examples of three-dimensional motion.

Some Basic Terms Related with Motion

The various terms required to describe motion are

Reference Point

A fixed point or a fixed object with respect to which the given body changes its position is known as reference point or origin.

- *An object is said to be in motion, if its position changes continuously with respect to a fixed reference.*

Position

It is the point in space where an object is present with respect to the reference point.

Distance

The distance travelled by a body is the actual length of the path covered by a moving body irrespective of the direction in which the body travels. It is a scalar quantity. Its SI unit is metre.

- *Distance can never be negative.*
- *Odometer is a device used to measure the distance travelled by the vehicle.*

Path Length

It is the length of the curve joining the initial and final positions along which the particle has actually moved. Its SI unit is metre.

Speed

The time rate of change of position of the object in any direction is called speed of the object.

$$\text{Speed } (v) = \frac{\text{Distance travelled } (s)}{\text{Time taken } (t)}$$

It is a scalar quantity. Its SI unit is m/s and its dimensional formula is $[M^0LT^{-1}]$.

For a moving body, speed is always positive and can never be negative and zero.

Types of Speed

There are four types of speed

(i) Uniform Speed or Constant Speed If an object covers equal distances in equal intervals of time, then its speed is called uniform speed or constant speed.

(ii) Non-uniform Speed or Variable Speed If an object covers unequal distances in equal intervals of time, then its speed is called non-uniform speed or variable speed.

(iii) Average Speed The ratio of the total distance travelled by the object to the total time taken is called average speed of the object.

i.e., $$\text{Average speed} = \frac{\text{Total distance travelled}}{\text{Total time taken}}$$

If a particle travels distances s_1, s_2, s_3 .... with times t_1, t_2, t_3 ...., then

$$\text{Average speed} = \frac{s_1 + s_2 + s_3 + ...}{t_1 + t_2 + t_3 + ...}$$

Everyday Science

- A motorcycle moving along a straight line path such that it covers equal distance in equal time intervals, then it is said to be uniform speed.
- A motorcycle moving through a crowded market has non-uniform speed because

Example 1 A car travels first half distance between two places with a speed of 40 km/h and the rest half distance with a speed of 60 km/h. What is the average speed of the car?

Sol Let the total distance travelled be x km. Then, the time taken to travel the first half distance is

$$\frac{\frac{x}{2}}{40} = \frac{x}{80}\,\text{h}$$

Time taken to travel the rest half distance is

$$\frac{\frac{x}{2}}{60} = \frac{x}{120}\,\text{h}$$

$$\therefore \quad \text{Average speed} = \frac{\text{Total distance}}{\text{Total time}}$$

$$= \frac{x}{\frac{x}{80} + \frac{x}{120}} = 48\ \text{km/h}$$

(iv) Instantaneous Speed The speed of a particle at any instant of time is known as its instantaneous speed.

$$\text{Instantaneous speed} = \lim_{\Delta t \to 0} \frac{\Delta s}{\Delta t} = \frac{ds}{dt}$$

Displacement

When a body moves from one position to another, the shortest distance ***i.e.***, straight line between the initial position and final position of the body along with direction is known as displacement. It is a vector quantity directed from initial position to final position. Its SI unit is metre.

- *The* ***magnitude of the displacement*** *for a course of motion may be zero when the corresponding distance covered is not zero.*
- *Displacement of the object can be* ***positive, negative*** *or* ***zero.***

- *Displacement of a moving object can never be greater than the distance travelled by it.*

$$\text{Displacement} \le \text{Distance}$$

$$\therefore \quad \frac{\text{Displacement}}{\text{Distance}} \le 1$$

i.e., the ratio of displacement and distance is always less than or equal to 1.

Velocity

The time rate of change of displacement of a body is called its velocity. It is a vector quantity.

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}}$$

The SI unit of velocity is m/s and its dimensional formula is $[M^0LT^{-1}]$.

- *Velocity of an object can be changed by changing the object's speed or direction of motion or both.*
- *Velocity of an object can be positive, negative and zero.*
- *The velocity of an object is taken to be positive if the object is moving towards the right of the origin and is taken to be negative if the object is moving towards the left of the origin.*
- *For an object in a time interval (t)*

$$|\text{velocity}| \le \text{speed}$$

i.e., the magnitude of velocity of an object is always equal to or less than its speed.

Types of Velocity

There are four types of velocity

(i) Uniform Velocity or Constant Velocity If an object covers equal displacement in equal intervals of time, then it is said to be moving with a uniform velocity or constant velocity.

(ii) Non-uniform or Variable Velocity If an object covers unequal displacement in equal intervals of time, then it is said to be moving with a non-uniform or variable velocity.

(iii) Average Velocity The ratio of the total displacement to the total time taken is called average velocity.

$$\text{Average velocity} = \frac{\text{Total displacement}}{\text{Total time}}$$

If velocity of the object changes at a uniform rate, then

$$\text{Average velocity} = \frac{\text{Initial velocity } + \text{Final velocity}}{2} = \frac{u + v}{2}$$

(iv) Instantaneous Velocity The velocity of a particle at any instant of time is known as its instantaneous velocity. Its unit is m/s.

- *Speed and velocity have the same units i.e., m/s.*
- *If a body is moving in a single straight line, then the magnitude of its speed and velocity will be equal.*

Relative Velocity

The relative velocity of one object with respect to another is the velocity with which one object moves with respect to another object. Hence, relative velocity is defined as the time rate of change of relative position of one object with respect to another.

If two objects ***a*** and ***b*** are moving with velocities v_a and v_b respectively, then

Relative velocity, $v_{ab} = v_a - v_b$ (if objects are moving in same direction)

$v_{ab} = v_a + v_b$ (if objects are moving in opposite directions)

Acceleration

The time rate of change of velocity of a body is called acceleration. It is a vector quantity, denoted by ***a*** and its SI unit is m/s^2.

$$\therefore \quad \text{Acceleration} = \frac{\text{Change in velocity } (\Delta v)}{\text{Time interval } (\Delta t)}$$

If in a given time interval t the velocity of a body changes from u to v, then acceleration a is expressed as

$$a = \frac{\text{Final velocity} - \text{Initial velocity}}{t} = \frac{v - u}{t}$$

When the velocity of a body increases with time, acceleration is positive (i.e., the body is said to be accelerated) and when the velocity of a body decreases with time (i.e., $u > v$), then acceleration becomes negative (i.e., the body is said to be retarded). Negative acceleration is also called deceleration or retardation.

Types of Acceleration

There are four types of acceleration

(i) Uniform Acceleration or Constant Acceleration If the velocity changes uniformly at equal intervals of time, then acceleration is said to be uniform acceleration.

(ii) Non-uniform Acceleration or Variable Acceleration If the velocity of the particle does not change equally in equal intervals of time, then the acceleration is said to be non-uniform acceleration.

(ii) Average Acceleration When an object is moving with a variable acceleration, then the average acceleration of the object for the given motion is defined as the ratio of the total change in velocity of the object during motion to the total time.

Average acceleration

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

- *The average acceleration can be positive or negative depending upon the sign of change of velocity. It is zero if the change in velocity of the object in the given interval of time is zero.*

(iv) Instantaneous Acceleration The acceleration of the object at a given instant of time or at a given point during the motion, is called its instantaneous acceleration.

Everyday **Science**

- A body falling down from a height or a body rolling down on a smooth inclined plane, has uniform acceleration.
- The acceleration is created by accelerator of the vehicles and the applications of breaks give the uniform deceleration to the vehicles.
- The acceleration produced in spring-block system is non-uniform acceleration.
- If a car travelling along a straight road increases its speed by unequal amounts in equal intervals of time, then the car is said to be moving with non-uniform acceleration.

Uniform and Non-Uniform Motion

An object covers equal distances in equal intervals of time, it is said to be in uniform motion. ***e.g.,*** a car moving along a straight line path such that it covers equal distances in equal intervals of time, then it is said to be in uniform motion.

On the other hand, if an object covers unequal distances in equal intervals of time, it is said to be in non-uniform motion. ***e.g.,*** when a car is moving on a crowded street or a person is jogging in a park, these are said to be in non-uniform motion.

- *The direction of motion changes at every point of motion in uniform circular motion. This direction is given by that of a tangent drawn at that point.*
- *For uniform motion along a straight line in given direction, the magnitude of the displacement is equal to the actual distance covered by the object.*
- *No force is required for an object to be in uniform motion.*
- *The velocity in uniform motion does not depend upon the time interval.*

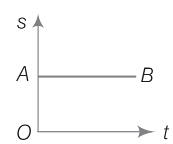
Graphical Representation of Motion

Motion of a point or body or a particle in all aspects can be shown with the help of the graph, such as displacement-time graph, velocity-time graph, displacement-velocity graph, acceleration-time graph, etc.

Displacement-Time Graph

Case I When an object is at rest

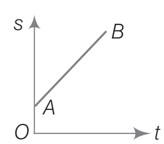
Then the (***s-t***) graph is a straight line parallel to time axis.



From the graph, it is clear that with the passage of time, there is no change in the position of the body, it remains at point A, i.e., the body is stationary.

Case II When an object is moving with zero acceleration

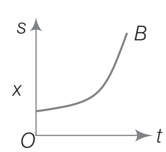
Then the (s-t) graph is a straight line with positive slope and the object is initially at some distance from the origin.



From the graph, it is clear that in equal intervals of time, the body covers equal distances, so the motion is uniform and graph is a straight line.

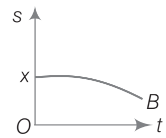
Case III When an object is moving with uniform positive acceleration

Then the (***s***-t) graph is a curve with positive slope and the object is initially at some distance from the origin.



From the graph, it is clear that in equal intervals of time of one second, the body is covering unequal distances and this distance goes on increasing. That means, with the passage of time, the body is covering more and more distance in equal time i.e., the speed of the body is increasing. Hence, the slope of graph is positive.

Case IV When an object is moving with negative acceleration
Then the (s-t) graph is a curve with negative slope and the object is initially at some distance from the origin.

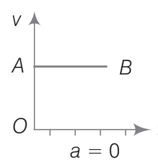


From the graph, it is clear that in equal intervals of time of one second, the body is covering unequal distances and this distance is goes on decreasing. That means, with the passage of time, the body is covering lesser and lesser distance in equal time i.e., the speed of the body is decreasing. Hence, the slope of the graph is negative.

- *Slope of displacement-time graph gives average velocity.*

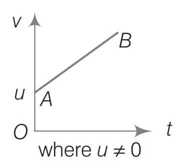
Velocity-Time Graph

Case I When an object is moving with constant velocity (zero acceleration)
Then the (v-t) graph is a straight line parallel to time axis.



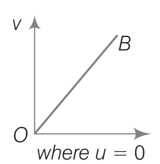
From the graph, it is clear that with the change of time, there is no change in the velocity. Hence, the slope of the graph is zero.

Case II When an object is moving with positive constant acceleration having some initial velocity
Then the (v-t) graph is a straight line.



From the graph, it is clear that for equal change in time, velocity changes by equal amount.

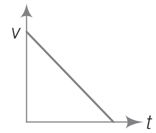
Case III When an object is moving with constant positive acceleration having zero initial velocity
Then the (v-t) graph is a straight line passing through the origin.



From the graph, it is clear that for equal change in time, velocity changes by equal amount.

Case IV When an object is moving with canstant negative acceleration having some positive initial velocity

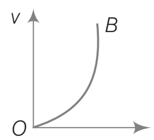
Then the (v-t) graph is a straight line and slope is negative.



From the graph, it is clear that velocity is decreasing uniformly with time.

Case V When an object is moving with increasing acceleration having zero initial velocity

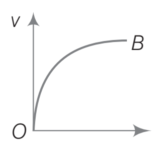
Then the (v-t) graph is a curve.



From the graph, it is clear that for equal change in time, the change in velocity are unequal. That is the reason, the graph is curve shaped.

Case VI When an object is moving with decreasing acceleration

Then the (v-t) graph is a curve.



From the graph it is clear that velocity is decreasing non-uniformly with time.

- *Slope of velocity-time graphs gives average acceleration.*
- *Area of speed-time graph gives distance.*

Equations of Motion

When a body is moving along a straight line with uniform acceleration, we can establish the relation between velocity of the body, acceleration of the body and the distance travelled by the body in a particular time interval by a set of equations. These equations are known as equations of motion.

The three equations of motion on a straight line are

1. $v = u + at$ 2. $s = ut + 1/2\, at^2$ 3. $v^2 - u^2 = 2as$

where ***u*** is the initial velocity of the body, ***a*** is the uniform acceleration of the body, ***v*** is the final velocity of the body after ***t*** second and ***s*** is the distance travelled in this time.

Distance travelled in ***n***th second

$$s_n = u + \frac{1}{2} a\,(2n - 1)$$

where, s_n = distance covered by a body in ***n***th second.

Example 2 A car starts from rest and accelerates uniformly at 4 m/s² for 6 s. Find the velocity acquired by car and the distance it covers during this time.

Sol Given, initial velocity (***u***) = 0, acceleration (***a***) = 4 m/s^2 and time (***t***) = 6 s

Now, using first equation of motion, $v = u + at$

$$= 0 + 4 \times 6 = 24 \text{ m/s}$$

Again, using second equation of motion,

$$s = ut + \frac{1}{2}at^2 = 0 \times t + \frac{1}{2} \times 4 \times (6)^2 = 0 + 2 \times 36$$

$$s = 72 \text{ m}$$

Example 3 A train is travelling at speed of 90 km/h. Brakes are applied so as to produce a uniform acceleration of – 0.5 m/s². Find how far the train will go before it is brought to rest.

Sol Given, initial speed $= 90 \text{ km/h} = 90 \times \frac{5}{18} \text{ m/s} = 25 \text{ m/s}$

Acceleration, $a = -0.5 \text{ m/s}^2$

Train brought to rest, so final speed, $v = 0$

From third equation of motion,

$$v^2 = u^2 + 2as$$

$$(0)^2 = (25)^2 + 2 \times (-0.5) \times s$$

$$0 = 625 - 1 \times s$$

$$s = 625 \text{ m}$$

Freely Falling Objects

The objects falling towards the earth under the gravitational force alone, are called freely falling objects and such fall is called free fall.

Whenever an object falls towards the earth, an acceleration is involved, this acceleration is due to the earth's gravitational pull and is called acceleration due to gravity. The value of acceleration due to gravity near the earth surface is 9.8 m/s^2.

Though the value of g is independent of freely falling mass, a feather falls much slowly than a coin when released from a height. This is due to the resistance offered by air to the falling mass. If both the bodies were released at the same time in vacuum, they would reach the earth surface within the same duration of time.

The three equations of free fall of an object near the surface of the earth are

1. $v = u + gt$ 2. $h = ut + 1/2gt^2$ 3. $v^2 = u^2 + 2gh$

where h is the height from which the object falls, t is the time of fall, u is the initial velocity and v is the final velocity when the body accelerates at g.

- *The only difference between the equations of motion for object moving in straight line is that in place of acceleration a, we take acceleration due to gravity g.*

Cases of Free Fall

- If an object falls vertically downward then acceleration due to gravity is taken as positive (since its velocity increases while falling).
- If an object is thrown vertically upward then acceleration due to gravity is taken as negative (since its velocity decreases as it moves upward).
- If an object is dropped freely from a height, its initial velocity u is zero.
- If an object is thrown vertically upwards, its final velocity v becomes zero.
- Time taken by an object to fall from a height is same as that taken by it to rise the same height.

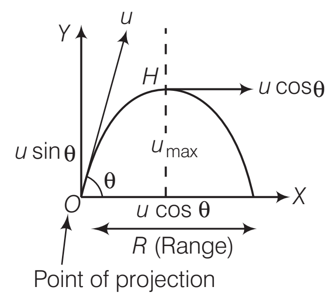
Motion in a Plane

If an object is in the motion such that its position at any time can be given with reference axes (two mutually perpendicular lines passing through the origin) then the motion of object is said to be motion in a plane. Projectile motion, circular motion, etc are the examples of this motion.

Projectile Motion

When an object is thrown obliquely near the earth's surface, its motion on a parabolic path is known as projectile motion and path followed by the object is called trajectory.

Projectile motion can be considered as combination of two independent one-dimensional motion ***i.e.***, motion along a straight line; one along horizontal direction with constant velocity and the other along vertical direction under gravity effects.



e.g.,

- The motion of bullet fired through the firing tank shows the projectile motion.
- The motion of a rocket after burn out.
- The motion of a bomb dropped from an aeroplane.
- The motion of a ball thrown in a horizontal direction.
- The motion of a ball after hitting the bat, etc.

Formulae for Projectile Motion

(i) Component of Velocity The horizontal component of initial velocity, $u_x = u\cos\theta$, where θ is the angle by which object is projected near the earth's surface called angle of projection and ***u*** is velocity of projection also called muzzle velocity.

The vertical component of initial velocity $u_y = u\sin\theta$

The equation of trajectory of the projectile is given by

$$y = (\tan\theta)x - \frac{1}{2}\frac{g}{u^2\cos^2\theta}x^2$$

(ii) Time of Ascent The time for which the projectile is ascending up is termed as time of ascent. It is denoted by t_a.

$$\text{Time of ascent, } t_a = \frac{u\sin\theta}{g}$$

(iii) Time of Descent The time for which the projectle is descending down is termed as time of descent. It is denoted by t_d.

$$\text{Time of descent, } t_d = \frac{u\sin\theta}{g}$$

It is clear that time of ascent is equal to time of descent and it can also easily be interpreted by symmetrical motion of projectile under the earth's gravity effect.

(iv) Time of Flight The total time for which the projectile is in motion is termed as time of flight. It is denoted by ***T***.

$$\text{Time of flight, } T = t_a + t_d = \frac{u\sin\theta}{g} + \frac{u\sin\theta}{g} = \frac{2u\sin\theta}{g}$$

(v) Maximum Height The maximum value of vertical displacement of projectile during its course of motion is termed as the maximum height. It is denoted by ***H***.

$$\text{Maximum height, } H = \frac{u^2 \sin^2\theta}{2g}$$

(vi) Range The horizontal displacement of projectile during its motion is termed as range of the projectile. It is denoted by ***R***.

$$\text{Range, } R = \frac{u^2 \sin 2\theta}{g}$$

Maximum range of projectile, $R_{max} = \frac{u^2}{g}$ (when $\sin 2\theta$ is maximum i.e., $\theta = 45°$)

When range of projectile is maximum, then maximum height of projectile,

$$H_{max} = \frac{u^2}{4g} = \frac{R_{max}}{4}$$

- *Horizontal distance or range for a projectile would be maximum at an angle of projection 45° for a particular speed of projectile.*
- *For the angles of projection θ and $(90° - \theta)$, the horizontal ranges are same.*
- *In projectile motion, horizontal component of the velocity of projectile always remains constant.*
- *Speed of the projectile is minimum at the topmost point on the trajectory and it is equal to $u_x = u\cos\theta$.*
- *Acceleration of projectile during its motion always remains constant.*

Everyday **Science**

- In base ball game, a player adjusts the speed and angle of projection so that ball covers the desired distance in minimum time.
- An athelete, taking part in javellian throw (or long jump) runs along a track fastly for some distance to acquire high velocity before reaching the marking point and then throws the javellian (or takes long jump), making an angle of 45° with the horizontal. The horizontal range of javellian throw (or long jump) is maximum.

Circular Motion

The motion in which a particle moves along a circular path, is called circular motion.

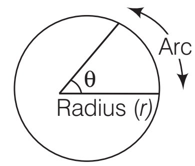
When a particle moves on a circular path with a constant speed, then its motion is said to be a uniform circular motion in a plane. In this motion, velocity of particle change continuously (due to direction of particle changes). That is, these is an acceleration in circular motion whose magnitude remains constant, but direction change continuously.

Some terms related to circular motion are given below

(i) Time Period In circular motion, the time period is defined as the time taken by the particle to complete one revolution on circular path. It is denoted by T and its unit is second.

(ii) Frequency The frequency is defined as the number of revolutions completed by the object on its circular path in a unit time. It is denoted by ***n*** and its unit is s^{-1} or Hertz.

(iii) Angular Displacement The angular displacement of the object in a given time, moving around a circular path is defined as the angle swept by the radius of the circular path in the given time. It is denoted by θ and its unit is radian.



$$\text{Angular displacement} = \frac{\text{Arc}}{\text{Radius}}$$

(iv) Angular Velocity The angular velocity of an object moving around a circular path is defined as the time rate of change of its angular displacement. It is denoted by ω and its unit is radian/second. Its direction is normal to the plane of circle.

$$\text{Angular velocity} = \frac{\text{Angular displacement}}{\text{Time}} \quad \text{or } \omega = \frac{\theta}{t}$$

If $\theta = 2\pi$, then $t = T$

$\therefore \quad \omega = 2\pi / T$ or $\omega = 2\pi n \quad (\because n = 1/T)$

When a particle performs uniform circular motion, then along with angular velocity it also has linear velocity ($\boldsymbol{v}$) along the tangent of the circular path.

(v) Angular Acceleration The angular acceleration of an object moving around a circular path is defined as the time rate of change of its angular velocity. It is denoted by α and its unit is radian/second^2.

It occurs due to change in direction of angular velocity. So, its direction is also normal to the plane of circle in accordance with the direction change of angular velocity.

(vi) Centripetal Acceleration

Acceleration acting on the particle undergoing a uniform circular motion towards the centre of the circle is called centripetal acceleration. It always acts on the particle along the radius and given by

$$\text{Centripetal acceleration, } a = \frac{v^2}{r} = r\omega^2$$

where, r is the radius of the circular path and v is linear velocity of particle.

Thus, a particle describing circular motion with constant (uniform) linear speed experiences two types of acceleration; angular or tangential acceleration and centripetal acceleration.

Everyday **Science**

- While going in a bus from plane to hill station on a road with slopes and curves, one feels vomiting because on a sloppy and curved road of the hills, the tangential and centripetal accelerations of the bus are not constant. It causes uneven vibrations in the stomach of the passengers sitting in the bus, resulting in vomiting.

- *Relation between time period and frequency,*

$$\textit{time period} = \frac{1}{\textit{frequency}} \quad \text{or} \quad T = \frac{1}{n}$$

- *Relation between angular velocity and linear velocity,*

$$v = r\omega$$

- *Relation between angular acceleration and linear acceleration,*

$$a = r\alpha$$

Assessment

1. For an object, the state of rest is considered to be the state of .... speed. **[SSC CGL 2017]**

(a) increasing (b) decreasing
(c) inverse (d) zero

2. Match the following lists.

List I	List II
A. Motion of billiards ball	1. One-dimensional motion
B. Motion of flying insect	2. Two-dimensional motion
C. Motion of freely falling body	3. Three-dimensional motion

Codes

	A	B	C		A	B	C
(a)	1	2	3	(b)	1	2	2
(c)	2	3	1	(d)	3	2	2

3. An object travels 20 m in 6s and then another 30 m in 4s. What is the average speed of the object? **[RRB Group D 2018]**

(a) 8 m/s (b) 6 m/s
(c) 5 m/s (d) 7 m/s

4. After meeting with an accident, a train starts moving at $\frac{2}{3}$ its speed. Due to this, it is 45 min late. Find the original time of the journey beyond the point of the accident. **[RRB Group D 2018]**

(a) 90 min (b) 120 min
(c) 45 min (d) 135 min

5. If the distance s covered by a moving car in rectilinear motion with a speed v in time t is given by $s = vt$, then the car undergoes **[NDA/NA 2014]**

(a) a uniform acceleration
(b) a non-uniform acceleration
(c) a uniform velocity
(d) a non-uniform velocity

6. Which of the following statements is false?

(a) A body can have zero velocity and still be accelerated.
(b) A body can have a constant velocity and still have a varying speed.
(c) A body can have a constant speed and still have varying velocity.
(d) The direction of the velocity of a body can change when its acceleration is constant.

7. A car starts from Bengaluru, goes 50 km in a straight line towards South, immediately turns around and returns to Bengaluru. The time taken for this round trip is 2h. The magnitude of the average velocity of the car for this round trip **[NDA 2019]**

(a) is zero (b) is 50 km/h
(c) is 25 km/h
(d) cannot be calculated without knowing acceleration

8. As the object covers unequal distances in equal intervals of time, it is said to be in .... motion. **[SSC (10 + 2) 2018]**

(a) uniform (b) linear
(c) non-uniform (d) equilibrium

9. The rate of change of displacement with time is called as .... **[SSC 2017]**

(a) force (b) acceleration
(c) retardation (d) velocity

10. During .... motion of an object along a straight line, the change in velocity of the object for any time interval is zero. **[SSC (10 + 2) 2018]**

(a) linear (b) translational
(c) equilibrium (d) uniform

11. Which one of the following does not match the group? **[RRB NTPC 2016]**

(a) Speed (b) Time
(c) Mass (d) Acceleration

12. In negative acceleration, the velocity of a body .... **[RRB Group D 2018]**

(a) is zero (b) increases
(c) decreases (d) remains constant

13. .... is the change in velocity per unit time. **[RRB Group D 2018]**

(a) Acceleration (b) Momentum
(c) Force (d) Inertia

14. For a body moving with uniform acceleration its final velocity equals .... **[SSC (10 + 2) 2018]**

(a) average velocity – initial velocity
(b) 2 × average velocity – initial velocity
(c) 2 × average velocity + initial velocity
(d) average velocity + initial velocity

15. Find the acceleration (in m/s^2) of a body which accelerates from 10 m/s to 20 m/s in 4 seconds. **[SSC (10 + 2) 2018]**
(a) 7.5 (b) 5 (c) 15 (d) 2.5

16. If an object moves with constant velocity, then which one of the following statement is not correct? **[NDA 2018]**
(a) Its motion is along a straight line.
(b) Its speed changes with time.
(c) Its acceleration is zero.
(d) Its displacement increases linearly with time.

17. A passenger in a moving train tosses a five rupees coin. If the coin falls behind him, then the train must be moving with a uniform **[NDA/NA 2014]**
(a) acceleration (b) deceleration
(c) speed (d) velocity

18. The speed of a car travelling on a straight road is listed below at successive intervals of 1 s.

Time (s)	0	1	2	3	4
Speed (m/s)	0	2	4	6	8

Which of the following is/are correct? The car travels **[NDA 2017]**
I. with a uniform acceleration of 2 m/s^2.
II. 16 m in 4 s.
III. with an average speed of 4 m/s.
(a) Only I (b) I and II
(c) II and III (d) All of these

19. In the equation of motion $v = u + at$, u represents .... **[SSC (10 + 2) 2018]**
(a) initial velocity (b) final velocity
(c) kinetic energy (d) potential energy

20. The first equation of motion gives the relation between **[RRB ALP 2018]**
(a) position and time
(b) velocity and time
(c) position and velocity
(d) velocity and acceleration

21. The second equation of motion gives the relation between **[RRB 2018]**
(a) velocity and time
(b) position and time
(c) position and velocity
(d) velocity and acceleration

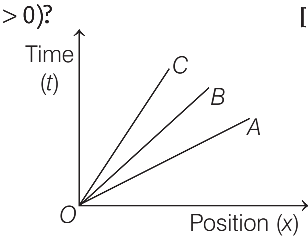
22. The motion of a freely falling body is an example of .... accelerated motion. **[SSC (10 + 2) 2018]**
(a) non-uniformly (b) uniformly
(c) uniquely (d) specially

23. In a vacuum, a five-rupee coin a, feather of sparrow bird and a mango are dropped simultaneously from the same height. The time taken by them to reach the bottom is t_1, t_2 and t_3, respectively. In this situation, we will observe that **[NDA 2017]**
(a) $t_1 > t_2 > t_3$
(b) $t_1 > t_3 > t_2$
(c) $t_3 > t_1 > t_2$
(d) $t_1 = t_2 = t_3$

24. The distance - time graph for the motion of an object moving with a constant speed is a **[SSC CGL 2018]**
(a) dot (b) circle
(c) straight line (d) curve

25. If an object is at rest, then the time (X-axis) *versus* distance (Y - axis) graph **[CDS 2019]**
(a) is vertical
(b) is horizontal
(c) has 45° positive slope
(d) has 45° negative slope

26. The figure shown below gives the time (t) *versus* position (x) graph of three objects A, B and C. Which one of the following is the correct relation between their speeds v_A, v_B and v_C, respectively at any instant ($t > 0$)? **[NDA 2019]**

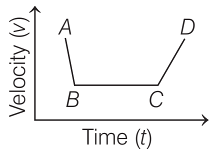


(a) $v_A < v_B < v_C$
(b) $v_A > v_B > v_C$
(c) $v_A = v_B = v_C \neq 0$
(d) $v_A = v_B = v_C = 0$

27. The slope of a velocity-time graph represents **[SSC CHSL 2018]**
(a) acceleration (b) displacement
(c) distance (d) speed

28. An object is moving with uniform acceleration a. Its initial velocity is u and after time t, its velocity is v. The equation of its motion is $v = u + at$. The velocity (along Y-axis)-time (along X-axis) graph will be a straight line **[NDA 2018]**
(a) passing through origin
(b) with X-intercept u
(c) with Y-intercept u
(d) with slope u

29. In the given velocity (v) *versus* time (t) graph, accelerated and decelerated motions are respectively represented by line segments **[NDA 2019]**



(a) CD and BC (b) BC and AB
(c) CD and AB (d) AB and CD

30. If an object moves at a non-zero constant acceleration for a certain interval of time, then the distance it covers in that time **[NDA 2019]**
(a) depends on its initial velocity
(b) is independent of its initial velocity
(c) increases linearly with time
(d) depends on its initial displacement

31. Which of the following equations represents the velocity - time relation? **[RRB Group-D 2018]**
(a) $s = ut + \frac{1}{2}at^2$ (b) $2as = v^2 - u^2$
(c) $v = u + at$ (d) $v = u - at$

32. An iron ball and a wooden ball of the same radius are released from the same height in a vacuum. The time taken by both of the these to reach the ground is
(a) roughly equal (b) zero
(c) exactly equal (d) unequal

33. During the motion of a projectile fired from the earth surface, **[SSC CGL 2016]**
(a) its kinetic energy remains constant
(b) its momentum remains constant
(c) vertical component of its velocity remains constant
(d) horizontal component of its velocity remains constant

34. A body moving in a circular path with a constant speed has a **[SSC CGL 2016]**
(a) constant velocity
(b) constant acceleration
(c) constant kinetic energy
(d) constant displacement

35. If an object moves in a circular path with uniform .... its motion is called uniform circular motion. **[SSC CGL 2017]**
(a) speed (b) time
(c) velocity (d) acceleration

36. A car undergoes a uniform circular motion. The acceleration of the car is **[CDS 2019 (II)]**
(a) zero
(b) a non-zero constant
(c) non-zero but not a constant
(d) None of the above

37. If an object undergoes a uniform circular motion, then its **[NDA/NA 2013]**
(a) acceleration remains uniform
(b) velocity changes
(c) speed changes
(d) velocity remains uniform

38. A motor vehicle is moving on a circle with a uniform speed. The net acceleration of the vehicle is **[NDA/NA 2013]**
(a) zero
(b) towards the centre of the circle
(c) away from the centre along the radius of the circle
(d) perpendicular to the radius and along the velocity

39. A person standing at the middle point of a wooden ladder which starts slipping between a vertical wall and the floor of a room, while continuing to remain in a vertical plane. The path traced by a person standing at the middle point of the slipping ladder is
(a) a straight line (b) an elliptical line
(c) a circular path (d) a parabolic path

40. An object moves in a circular path with a constant speed. Which one of the following statement is correct? **[NDA 2017]**
(a) The centripetal acceleration of the object is smaller for a gentle curve (i.e. curve of larger radius) than that for a sharp curve (i.e. curve of smaller radius).
(b) The centripetal acceleration is greater for a gentle curve than that for a sharp curve.
(c) The centripetal acceleration is the same for both the gentle and sharp curves.
(d) The centripetal acceleration causes the object to slow down.

1. (d)	**2.** (c)	**3.** (c)	**4.** (a)	**5.** (c)	**6.** (b)	**7.** (a)	**8.** (c)	**9.** (d)	**10.** (d)
11. (c)	**12.** (c)	**13.** (a)	**14.** (b)	**15.** (d)	**16.** (d)	**17.** (a)	**18.** (a)	**19.** (a)	**20.** (b)
21. (b)	**22.** (b)	**23.** (d)	**24.** (c)	**25.** (b)	**26.** (b)	**27.** (a)	**28.** (c)	**29.** (a)	**30.** (a)
31. (c)	**32.** (c)	**33.** (d)	**34.** (b)	**35.** (a)	**36.** (b)	**37.** (b)	**38.** (b)	**39.** (c)	**40.** (a)

3

Force *and* Laws *of* Motion

Force

Any action which causes pull or push on a body is called force. Forces are used in our everyday actions like pushing, pulling, lifting, stretching, twisting and pressing.

Force is a vector quantity, its SI unit is newton and the CGS unit is dyne.

$$1 \text{ newton} = 1 \text{ kg-ms}^{-2}$$
$$1 \text{ newton} = 10^5 \text{ dyne}$$

e.g., a force is used when we kick a football, we lift a box from the floor, we stretch a rubber band, etc.

Fundamental or Basic Forces in Nature

Mainly there are four types of forces occurring in nature

(i) Gravitational Forces Every object in this universe attracts each other, this force of attraction is called gravitational force. It is the weakest force among all existing forces and is negligible for all lighter and smaller bodies but becomes significant and considerable in all celestial bodies.

(ii) Weak Nuclear Forces These forces were discovered during the study of the phenomenon of β-decay, in radioactivity. These are the forces of interaction between elementary particles of short life times. The weak nuclear forces are 10^{25} times stronger than gravitational forces.

(iii) Electromagnetic Forces The electromagnetic forces are the forces between charged particles. When the charges are at rest, the forces are called electrostatic forces. The forces between unlike charges are attractive and the forces between like charges are repulsive. These forces are governed by Coulomb's law.

Matter consists of elementary particles like electrons and protons. The electrons and protons are charged. Electromagnetic force is much stronger than the gravitational force, it dominates all phenomena on atomic and molecular scales.

(iv) Strong Nuclear Forces The forces that bind the neutrons and protons together in a nucleus are called the strong nuclear forces. These forces act between two protons or two neutrons or a proton and a neutron, but only if the particles are very close together. These are the strongest forces in nature. These are 10^{38} times stronger than gravitational forces, 10^2 times stronger than electrostatic forces and 10^{13} times stronger than the weak forces.

Fundamental Forces in Nature

S. No.	Name	Relative Strength	Range	Operates Among
1.	Gravitational force	1	Infinite	All objects in universe
2.	Weak nuclear force	10^{25}	Very short subnuclear size ($\approx 10^{-16}$ m)	Some elementary particles like electron and neutrino
3.	Electromagnetic force	10^{36}	Not very large	Charged particles
4.	Strong nuclear force	10^{38}	Very short nuclear size ($\approx 10^{-15}$ m)	Nucleons, heavier elementary particles

Types of Force

There are two types of force

(i) Balanced Forces When the net effect produced by a number of forces acting on a body is zero, then the forces are said to be balanced forces. Balanced forces can only bring a change in the shape of the body. ***e.g.,*** If the block is pulled from both the sides with equal forces, the block will not move, such forces are called balanced forces.

(ii) Unbalanced Forces When the net effect produced by a number of forces on a body is non-zero, then the forces are said to be unbalanced forces.

- *An object moves with a uniform velocity when the force acting on the object are balanced and there is no net external force on it.*
- *If an unbalanced force is applied on the object, there will be a change, either in its speed or in the direction of its motion. Thus, to accelerate the motion of an object, an unbalanced force is required.*

Contact Forces and Field Forces

Force by the virtue of bodies in contact is called contact forces while force between the two body which is not in contact is known as field force such as gravitational force, electric force, etc.

Inertia

The property of an object to resist any change in its state of motion along a straight line or rest is called inertia.

There are three types of inertia

(i) Inertia of Rest If an object resists the change in its state of rest, its inertia is called inertia of rest.

(ii) Inertia of Motion If an object resists the change in its state of motion, its inertia is called inertia of motion.

(iii) Inertia of Direction If an object resists the change in direction of its motion, its inertia is called inertia of direction.

Newton's Laws of Motion

Laws of motion was propounded by Sir Isaac Newton in 1687, in his book ***Principia.***
There are three laws of motion

Newton's First Law of Motion

Every body retains its state of rest or state of motion along a straight line until an external force is applied on it. This law is also known as law of inertia.

Some Common Phenomena based on Newton's First Law of Motion

- A person standing in a bus falls backward when bus starts moving suddenly. This happens because the person and bus both are in rest while bus is not moving. As bus starts moving, the legs of the person start moving alongwith bus but rest portion of his body has tendency to remain in rest.
- If a moving bus suddenly stops, then the passenger falls in forward direction, because the passengers who had inertia of motion, oppose a change in their state. However, the lower portion of their body comes to rest with the bus. So, they fall forward.
- When we shake a tree vigorously, its fruits and leaves fall down. This happens because the fruits and leaves were at rest initially and as tree is shaken vigorously, the tree moves to and fro but the force is not acting on leaves and fruits, and they try to maintain their states of rest due to inertia and hence fall.
- The seat belts are used in car and other vehicles to prevent the passengers being thrown, in the condition of sudden stopping of the vehicles. This is because in that condition passengers may be thrown in the direction of the motion of vechicle due to the tendency to remain in the state of motion (***i.e.,*** inertia of motion).
- If we suddenly and rapidly pull the table cloth on which dishes are placed, then dishes remain on the table and the cloth comes out from the table. This is because of the fact that dishes were initially at rest and due to their inertia, they try to maintain their state of rest and force exerted by us on table cloth is not transmitted to the dishes.

Momentum

The momentum of a moving body is equal to the product of its mass and its velocity. It is a vector quantity having SI unit kg-m/s.

If a body of mass (m) moves with a velocity (v), then momentum (p) is given by $p = mv$

Everyday **Science**

- ✔ A much greater force is required to push a truck than a car to bring them to the same speed in the same time, because due to higher mass heavy body requires higher momentum. Similarly, a greater force is required to stop a heavy body than a light body in the same time.
- ✔ A bullet fired from a gun can easily pierce through a target but a stone of same thrown by hand can be easily stopped, because bullet fired from gun has much higher velocity than stone so due to its higher momentum it pierces the target easily.

Law of Conservation of Momentum

If no external force acts upon a system of two (or more) bodies, then the total momentum of the system remains constant. This is called the law of conservation of momentum.

If m_1 and m_2 be the two masses of colliding particles, u_1 and u_2 are the velocities of the respective particles before collision and v_1 and v_2 are the velocities of the particles after collision, then by the law of conservation of linear momentum.

Total linear momentum before collision = $m_1u_1 + m_2u_2$

Total linear momentum after collision = $m_1v_1 + m_2v_2$

Thus, $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

Some Common Phenomena based on Law of Conservation of Momentum

- When a man jumps out of a boat to the shore, the boat is pushed slightly away from the shore. The momentum of the boat is equal and opposite to that of the man in accordance with the law of conservation of momentum.
- **Rocket Propulsion** The conservation law of momentum can be applied to study the motion of the body.

  In a rocket, the fuel burns and produces gas at high temperature. The gas is ejected out of the rocket from a nozzle, at the back side of the rocket.

  The ejecting gas exerts a forward force on the rocket which helps in accelerating. Though the mass of gas escaping per second is very small and its momentum is very large due to its tremendous velocity of escape, an equal and opposite momentum is imparted to the rocket which despite its large mass builds up a high velocity.

Newton's Second Law of Motion

The second law of motion states that the rate of change of momentum of an object is proportional to the applied unbalanced force in the direction of force.

According to Newton's second law,

$$\text{Force, } F \propto \text{Rate of change of momentum}$$

$$F \propto \frac{dp}{dt}$$

where, dp = change in momentum and dt = change in time.

On further calculation, $F = ma$

where, m = mass of the body and a = acceleration of the body.

If acceleration $a = 0$, then $F = 0$ (mass of the body can never be zero)

It means that in the absence of external force the body either moves with constant velocity or comes to rest.

By Newton's second law $F = ma$, here if $m = 1$ kg and $a = 1\ m/s^2$, then $F = 1$ N. Thus, 1 N is the force required to produce an acceleration of 1 m/s in a body of mass 1 kg.

Some Common Phenomena based on Newton's Second Law of Motion

- During the game of table tennis if the ball hits a player, it does not hurt him. On the other hand, when a fast moving cricket ball hits a spectator, it may hurt him because the speed of cricket ball is higher due to which its acceleration is also higher.

- In a high jump athletic event, the athletes are made to fall either on a cushioned bed or on a sand bed. This is to increase the time of the athlete's fall to stop after making the jump. This decreases the rate of change of momentum and hence the force.
- A cricket player moves his hand backwards on catching a fast cricket ball, because the cricket player increases the time during which the high velocity of moving ball decreases to zero. Thus, the acceleration of the ball is decreased and therefore, the impact of catching the fast moving ball is also reduced. If the ball is stopped suddenly then its high velocity decreases to zero in a very short interval of time. Thus, the rate of change of momentum of the ball will be large. Therefore, a large force would have to be applied for holding the catch that may hurt the palm of the player.

Newton's Third Law of Motion

For every action, there is an equal and opposite reaction and both acts on two different bodies. So, this law is also known as law of action and reaction.

Some Common Phenomena based on Newton's Third Law of Motion

- While walking a person presses the ground in the backward direction (action) by his feet, the ground pushes the person in forward direction (reaction), with equal force making the person to walk.
- A swimmer pushes the water backwards (action) with a force. The water pushes the swimmer forward (reaction) with the same force. Hence, the swimmer swims.
- It is difficult to walk on sand, because on pushing, sand gets displaced and reaction from sandy ground is small.

Impulse

If a large force is acting on a body for a very short time, then the product of this large force and time is known as impulse and large force itself is called impulsive force.

$$\boxed{\text{Impulse} = \text{Change in momentum} = \text{Force} \times \text{Time}}$$

It is a vector quantity. Its SI unit is N-s or kg-m/s.

Some Common Phenomena based on Impulse

- Chinawares are wrapped in paper or straw pieces while packing. In the event of fall, impact will take a longer time to reach the glass/chinawares through paper or straw. Due to which the force on the chinawares is small and chances of their breaking reduce.
- Bogies of a train are provided with the buffers, due to which they avoid severe jerks during shunting of the train. The presence of buffer increases the time of impact, so force during jerks decreases, hence the chances of damage decrease.
- An athlete is advised to come to stop slowly after finishing a fast race, so that time to stop increases and hence force experienced by him decreases.

Reference Frame

In study of various physical activities the position of a system or body is made to be fixed and distances of other bodies are measured called reference frame.

Inertial and Non-inertial Frame of Reference

- A frame of reference is know as an inertial frame if all acceleration of any particle in it are caused by real forces. On the other hand, a frame of reference is called a non-inertial frame, if the accelerations are caused by fictitious forces or pseudo forces.

- In inertial frame of reference Newton's law of motion holds good, while Newton's law of motion are not applicable in non-inertial frame of reference.

Apparent Weight of a Person in a Lift

Suppose a person of mass *m* is in a lift, then the actual weight of the person is *mg*, which acts on the lift floor in downward direction, due to which the floor offers the reaction (*R*). This reaction is called apparent weight of the person. Relation between *R* and *mg* in different situation is discussed below in different cases

Case I **When the lift is at rest**
When the left or elevator is at rest then the apparent weight of the person is equal to the actual weight of the person.

Case II **When the lift is moving uniformly in upward/downward direction**
In uniform motion, the apparent weight of the person is equal to the actual weight of the person.

Case III **When the lift is accelerating upwards**
If lift is accelerating upwards, then the apparent weight of the person is more than the actual weight of the person.

Case IV **When the lift is accelerating downwards**
If the lift is accelerating downwards, then the apparent weight of the person is less than the actual weight of the person.

Case V **When the lift is falling freely**
If chord of the lift breaks then it is said to be falling freely. In this case, the apparent weight of the person becomes zero *i.e.,* the person feels the condition of weightlessness.

Friction

When a body slides or rolls over another body or on a surface, then a force opposing the motion acts between those surfaces of the body which are in contact, this force is called force of friction. Actually, whenever the surface of a body slides over the surface of another body, each body exerts a frictional force on the other which is parallel to the surface in contact.

Types of Friction

There are three types of friction which are discussed below

1. Static Friction

The force of friction that comes into play between two surfaces in contact before the actual motion starts, is called static friction. Static friction is a self adjusting force which increases as the applied force is increased.

$$\therefore \qquad \text{Static friction } (f_s) = \mu_s R$$

where, μ_s = coefficient of static friction and R = normal reaction.

If angle of friction is θ, then coefficient of static friction $\mu_s = \tan\theta$.

2. Limiting Friction

The maximum force of static friction which comes into play before a body just begins to slide over the surface of another body, is called limiting friction.

$$\therefore \qquad \text{Limiting friction } (f_l) = \mu_l R$$

where, μ_l = coefficient of limiting friction and R = normal reaction.

Limiting friction does not depend on area of contact surface but depends on their nature, ***i.e.,*** smoothness or roughness.

3. Kinetic Friction

When a body moves over the other body, then the force of friction acting between two surfaces in contact in relative motion is called kinetic friction (f_k).

$$\text{Kinetic friction, } f_k = \mu_k R$$

where, μ_k = coefficient of kinetic friction and R = normal reaction.

The kinetic friction does not depend on the magnitude of relative speed but for very high speed it drops to zero.

Kinetic friction is of two types

(i) Rolling Friction When one body rolls over the other body, then the frictional force acting between the two is called rolling friction. Rolling friction is negligible in comparison to the static or kinetic friction which may be present simultaneously.

(ii) Sliding Friction When a body slides over the other body, the frictional force between the two is called sliding friction. Sliding friction is always more than rolling friction.

Friction is a Necessary Evil

Friction is called necessary evil. It is a necessity, because we cannot do without it and at the same time, it is evil because it involves unnecessary wastage of energy.

Friction is a Necessity

(i) Walking will not be possible without friction. If there is no friction, then our foot pressing the ground for walking will slip.

(ii) No two bodies will stick each other if there is no friction.

(iii) Brakes of the vehicles will not work without friction.

(iv) Nuts and bolts for holding the parts of machinery together will not work without friction.

(v) Writing on black board or on paper will also not be possible without friction.

Friction is an Evil

(i) Friction causes wear and tear of the parts of the machinery in contact, thus their life time reduces.

(ii) Frictional forces result in the production of heat, which causes damage to the machinery.

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✔ When the forces causing the rocks to slide exceed the force of friction, the rock will tend to move with the consequent release of tremendous amounts of energy causing the earthquake.

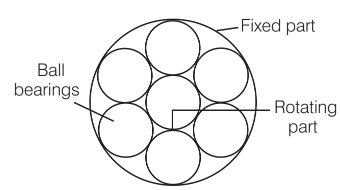
Methods of Reducing Friction

Some of the ways of reducing friction are

(i) By Polishing the surfaces can be made smoother, therefore friction reduces.

(ii) Lubricants like oil, grease etc., fill up the irregularities of the surfaces, making them smoother. Hence, friction decreases.

(iii) Ball Bearing To reduce the wear and tear and energy loss against friction, small steel balls are kept between the rotating part of machines which are known as ball bearings. In a ball bearing system, one part moves with respect to the other, the balls roll on between two parts. No kinetic friction is involved and rolling friction being very small, causes much less energy loss.



Ball Bearing

Centripetal Force

A body performing circular motion is acted upon by a force directed along the radius towards the centre of the circle. This force is called the centripetal force.

$\because$ Centripetal force = Mass × Centripetal acceleration

$$F = \frac{mv^2}{r} \Rightarrow F = mr\omega^2$$

where, v = linear velocity of the body on circular track.

Some Phenomena based on Centripetal Force

(i) **Circular Motion in Nature** The earth moves round the sun under a centripetal force directed towards the sun. This force is provided by gravitational attraction on the earth by the sun. Similarly the moon moves around the earth under the centripetal force provided by the gravitational attraction exerted on the moon by the earth.

(ii) **Circular Motion in Atom** In an atom, electrons continue to revolve around the nucleus in circular orbits. The centripetal force is provided by the electrostatic force of attraction between the negatively-charged electron and positively-charged nucleus.

Centrifugal Force

It is a force that arises when a body is moving actually along a circular path, by virtue of tendency of the body to regain its natural straight line path. It is regarded as reaction of centripetal force. It acts along the radius and away from the centre of the circle.

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- When a vehicle goes round a curved road, it requires some centripetal force. So, to provide the necessary centripetal force, outer edge of the curved road is raised above the inner edge. By doing so, a component of normal reaction of the road provides the centripetal force. This phenomenon of raising other edge of curved road is called banking of roads.
- **Centrifuge** A device by means of which light particles and heavy particles are separated to each other.
- **Cream Separator** It is a device working on the principle of centrifugal force. It is a vessel containing milk. On rotating fast, the lighter particles of cream collect in a cylindrical layer around the axis and the skimmed milk is drained through an outlet fitted on the wall of the vessel. The particles, whose density is less than those of the liquid are driven towards the axis of rotation and those whose density is greater than that of the liquid are driven away from the axis.
- **Washing Machine Drier** In washing machine or in laundries, wet clothes are dried by packing them in a cylindrical vessel with perforated walls which are rotated with a very high speed. Due to centrifugal force, the water particles move through the walls of the vessel and escape through the holes.

Assessment

1. The displacement-time (s-t) graph of a particle acted upon by a constant force is
(a) a straight line **[NDA 2015]**
(b) a circle
(c) a parabola
(d) any curve depending upon initial conditions

2. Which one of the following is not a contact force? **[NDA 2016]**
(a) Push force (b) Gravitational force
(c) Frictional force (d) Strain force

3. The known forces of nature can be divided into four classes, *viz*, gravity, electromagnetism, weak nuclear force and strong nuclear force. With reference to them, which one of the following statements is not correct? **[UPSC 2013]**
(a) Gravity is the strongest of the four
(b) Electromagnetism acts only on particles with an electric charge
(c) Weak nuclear force causes radioactivity
(d) Strong nuclear force holds protons and neutrons inside the nucleus of an atom

4. Which of the following quantity is a measure of inertia?
[SSC 2017, Delhi Police SI 2017]
(a) Velocity (b) Acceleration
(c) Mass (d) Weight

5. The tendency of undisturbed objects to stay at rest or to keep moving with the same velocity is called **[RRB 2018]**
(a) velocity (b) force
(c) momentum (d) inertia

6. Which one of the following has maximum inertia? **[NDA 2018]**
(a) An atom (b) A molecule
(c) A one rupee coin (d) A cricket ball

7. The inertia of an object tends to cause the object
(a) to increase its speed
(b) to decrease its speed
(c) to resist any change in its state of motion
(d) to decelerate due to friction

8. When a running car stops suddenly, the passengers tend to lean forward because of **[SSC (10 + 2) 2012]**
(a) centrifugal force (b) inertia of rest
(c) inertia of motion (d) gravitational force

9. An athlete runs before long jump to get advantage on
(a) inertia of motion
(b) frictional force
(c) moment of a force
(d) principle of moments

10. A passenger falls in the direction when a moving bus applies brakes to stop and falls backwards when it accelerates from rest. This is because of **[RRB Group-D 2018]**
(a) force (b) displacement
(c) inertia (d) momentum

11. Newton's first law is also known as ....
[SSC CHSL 2017, Chhattisgarh PCS 2019]
(a) law of friction (b) law of momentum
(c) law of inertia (d) law of motion

12. Newton's laws of motion do no hold good for objects
(a) at rest
(b) moving slowly
(c) moving with high velocity
(d) moving with velocity comparable to velocity of light

13. A particle is moving with constant speed along a straight line path. A force is not required to
(a) increase its speed
(b) decrease the momentum
(c) change the direction
(d) keep it moving with uniform velocity

14. A batsman hits a cricket ball which than rools on a level ground. After covering a short distance, the ball cames to rest. The ball slews to a stop because
[MPPCS 2017]
(a) the batsman did not hit the ball hard enough
(b) velocity is proportional to the force exerted on the ball
(c) There is a force on the ball opposing the motion
(d) There is no unbalanced force on the ball, so the ball would try to come to rest

15. Linear momentum is equal to **[RRB 2018]**
(a) mass × velocity
(b) speed × weight
(c) force × height
(d) mass × volume