1. Natural of Physical World and Measurement

1. What is meant by Scientific method?

The scientific method is a step-by-step approach in studying natural phenomena and establishing laws which govern these phenomena.

2. What are the general features of scientific method?

- Systematic Observation
- Controlled experimentation
- Qualitative and quantitative reasoning
- Mathematical modeling
- Prediction and verification or falsification of theories.

3. What type of approaches are followed in studying physics?

- Unification
- Reductionism

4. What is Unification? Give the example.

An attempt to explain various physical phenomena with a few concepts and laws is Unification.

Ex: Newton's universal law of gravitation explains various events like motion of freely falling body, motion of the planets around the sun, motion of the moon around the earth.

5. What is reductionism? Give the example.

An attempt to explain a macroscopic sysytem in terms of its microscopic constituents is reductionism.

Ex: Macroscopic properties like temperature, entropy, etc., of bulk systems can be easily interpreted in terms of the molecular motion(microscopic constituents).

6. What is technology?

Technology is the application of principles of physics for practical purposes.

7. Describe the relation of Physics with Chemistry.

- Studies of structure of atom, radioactivity, X-ray diffraction, etc., in physics have been used in chemistry to arrange elements in periodic table on the basis of atomic numbers.
- It is further helped to know the nature of valence and chemical bonding and to understand the complex chemical structures.
- Inter-disciplinary branches like Physical chemistry and Quantum chemistry plays vital role here.

8. Describe the relation of Physics with Biology.

- It is impossible to study biology without microscope designed using physical principles.
- Invention of electron microscope has made possible to see even the structure of a cell.
- X-ray diffraction and neutron diffraction techniques are helped to understand the structure of nucleic acids, which helps to control vital life processes.
- X-rays are used for diagnostic purposes.
- Radio-isotopes are used in radiotherapy for the treatment of cancer and other diseases.
- Now-a-days biological processes are being studied from the physical point of view.

9. Describe the relation of Physics with mathematics.

- Physics is a quantitative science.
- Physics is closely related to mathematics as a tool for its developement.

10. Describe the relation of Physics with Astronomy.

- Astronomical telescopes are used to study the motion of the planets and other celestial bodies in the sky.
- Radio telescopes are used to observe distant points of the universe.
- Studies of the universe are done using physical principles.

11. Describe the relation of Physics with Geology.

- Diffraction techniques helps to study the crystal structure of various rocks.
- Radioactivity is used to estimate the age of rocks, fossils and the age of the Earth.

12. Describe the relation of Physics with Oceanography.

- Oceanographers seek to understand the physical and chemical processes of the oceans.
- For that, they measure parameters such as temperature, salinity, current speed, gas fluxes and chemical components of the ocean.

13. Describe the relation of Physics with Psychology.

- All the psychological interactions can be derived from a physical process.
- The movements of neurotransmitters are governed by the physical properties of diffusion and molecular motion.
- The function of our brain is related to our underlying dualism (wave -particle nature).

14. What is measurement?

The comparison of any physical quantity with its standard unit is known as measurement.

15. What is physical quantity? Give the examples.

Quantities that can be measured and in terms of which laws of physics are described are called physical quantities. **Ex :** length, mass, time, force, energy, etc.,

16.What is fundamental or base quantities? Give the examples.

The quantities, which cannot be expressed in terms of any other physical quantities, are called fundamental or base quantities.

Ex: length, mass, time, electric current, temperature, luminous intensity and amount of substance.

17.What is derived quantities? Give the examples.

Quantities that can be expressed in term of fundamental quantities are called derived quantities.

Ex: area, volume, velocity, acceleration, force.

18.What is an unit?

An arbitrarily chosen standard of measurement of a quantity, which is accepted internationally is called unit of the quantity.

19.What is System of Units?

A complete set of units which is used to measure all kinds of fundamental and derived quantities is called a system of units.

20.What is the f.p.s system?

The f.p.s system is the British Engineering system in which length, mass and time are measured in foot, pound and second respectively.

21.What is the c.g.s system?

The c.g.s system is the Gaussian system in which length, mass and time are measured in centimeter, gram and second respectively.

22.What is the m.k.s system?

In the m.k.s system, length, mass and time are measured in meter, kilogram and second respectively.

23.What are the advantages of SI unit system?

- It is a rational system, in which only one unit is used for one physical quantity.
- It is a coherent system, which means all the derived units can be easily obtained form basic and supplementary units.
- It is a metric system, which means multiples and submultiples can be expressed as powers of 10.

24.What is the SI standard of length? (or) What is one meter in SI system of units?

One meter is the length of the path travelled by light in vacuum in $\frac{1}{299,792,458}$ of a second.

25.What is the SI standard of mass? (or) What is one kilogram in SI system of units?

One kilogram is the mass of the prototype cylinder of platinum iridium alloy (whose height is equal to its diameter), preserved at the International Bureau of Weights and Measures at Serves, near Paris, France.

26. What is the SI standard of time? (or) What is one second in SI system of units?

One second is the duration of 9,192,631,770 periods of radiation corresponding to the transition between the two hyperfine levels of the ground state of Cesium-133 atom.

27.What is the SI standard of electric current? (or) What is one ampere in SI system of units?

One ampere is the constant current, which flows through the two parallel straight conductors of infinite length with negligible cross-section, held one meter apart in vacuum, shall produce a force per unit length of 2×10^{-7} Nm^{-1} between them.

28.What is the SI standard of temperature? (or) What is one kelvin in SI system of units?

One kelvin is the fraction of $\frac{1}{273.16}$ of the thermodynamic temperature of the triple point of the water.

29.What is the SI standard of amount of substance ? (or) What is one mole in SI system of units?

One mole is the amount of substance which contains as many elementary entities as there are atoms in 0.012 kg of pure carbon-12.

30.What is the SI standard of luminous intensity? (or) What is one candela in SI system of units?

One candela is the luminous intensity of a source in a given direction that emits monochromatic radiation of frequency 5.4×10^{-14} Hz and that has a radiant intensity of $\frac{1}{683}$ watt / steradian in that direction.

31.what is length? Give its SI unit.

Length is defined as the distance between any two points in space. Its SI unit is metre.

32.what is one radian?

One radian is the plane angle subtended by an arc whose arc length is equal to its radius.

33.What is one steradian?

One steradian is the solid angle subtended by the partial surface of a sphere whose suface area is equal to the square of its radius.

34.Explain the use of Screw gauge in measuring smaller distances.

- It is used to measure accurately the dimension of objects upto the maximum of 50 mm.
- The principle of the instrument is the magnification of linear motion using circular motion of a screw.
- The least count of the screw gauge is 0.01 mm.

35. Explain the use of vernier caliper in measuring smaller distances.

- It is a versatile instrument for measuring the dimensions of an object like diameter and depth of a hole.
- The least count of the vernier caliper is 0.1 mm.

36. What are the methods adopted in measuring larger distances?

- Triangulation method
- Parallax method
- Radar method

37. What is Parallax?

The shift in the position of an object (say a pen) when viewed with left and right eye alternatively is known as Parallax.

(or)

The apparent chage in position of an object with respect to its background, when viewed from two different locations is called Parallax.

38. What is the abbreviation for RADAR?

The word RADAR stands for RAdio Detection And Ranging.

39. What is 1 light year ? Give its value.

1 light year is the distance travelled by light in vacuum in one year.

1 light year = 9.467×10^{15} m.

40. What is 1 astronomical unit(AU)? Give its value.

1 astronomical unit is the mean distance between earth and the sun.

1 AU = 1.496×10^{11} m.

41. What is 1 parsec (Parallactic second)? Give its value.

1 parsec is the radial distance of an arc of arc length 1 AU subtends an angle of 1 second.

1 parsec = 3.08×10^{16} m = 3.26 light year.

42. Define mass?

Mass of a body is defined as the quantity of matter contained in a body. The SI unit of mass is kilogram.

43. What is the difference between Accuracy and Precision?

S.No.	Accuracy	Precision
1	Measurements close to true value.	Measurements close to each other.
2	All the accuracy values are precised.	All the precised values are not accurate.

44. What is meant by an error? Name its types.

The uncertainity in a measurement is called an error.

Types: Systematic errors, Random errors & Gross errors

45. What is meant by Systematic error?

- Systematic errors are reproducible inaccuracies that are consistently in the same direction.
- These occur offen due to a problem that persists throughout the experiment.

46. What are the Classifications of Systematic errors?

- Instrumental errors
- Imperfections in experimental techniques or procedure.
- Personal errors
- Errors due to external causes.
- Least count error

47. Describe Instrumental errors. How is it minimised?

- It is happened when an instrument is not calibrated properly at the time of manufacture.
- For example, If a measurement is made with a meter scale whose end is worn out, result obtains error.
- These errors can be rectified by using the good quality instruments.

48. Describe Imperfections in experimental technique or procedure. How can it be overcomed?

- These errors arise due to the limitations in the experimental arrangements.
- For example, Calorimeter experiment is done without insulation makes radiation loss. This results errors.
- It can be overcomed by applying necessary correction.

49. Describe the Personal errors.

These errors occur due to individual performing experiment without initial setting up or careless observation without precautions.

50. Describe the errors due to external causes.

These errors are due to external conditions like change in temperature, humidity or pressure during an experiment.

51. Describe the least count error. How can it be minimised?

- Least count is the smallest value that can be measured by an instrument.
- The error due to the measurement in least count is called least count error.
- It can be minimised by using high precision instrument.

52. Describe Random errors. How can it be minimised?

- Random errors may arise due to random and unpredictable variation in experimental conditions like pressure,temperature, voltage supply,etc.,
- It is also due to personal errors.
- These errors are happened by chance, so it is called "Chance error".

- It can be minimised by calculating arithmatic mean of measurements taken. i.e. If 'n' number of readings a_1, a_2, a_3, ...,a_n are done, the arithmatic mean is given by,

$$a_m = \frac{a_1 + a_2 + a_3 + \cdots + a_n}{n}$$

$$a_m = \frac{1}{n}\sum_{i=1}^{n} a_i$$

53. Describe Gross error. How can it be minimised?

The error caused due to the complete carelessness of an observer is called gross error.

Example :

- Reading an instrument without setting properly.
- Taking observations in a wrong manner without considering source of errors and the precautions.
- Recording wrong observations.
- Using wrong values of the observations in calculations.

These errors can be minimised only when an observer is careful and mentally alert.

54. What is meant by Absolute error? Explain.

- The magnitude of difference between true value and measured value of a quantity is called absolute error.
- If a_1, a_2, a_3, ...,a_n are the measured values of any quantity, then the arithmatic mean is the true value of the measurements.

$$a_m = \frac{a_1 + a_2 + a_3 + \cdots + a_n}{n}$$

$$a_m = \frac{1}{n}\sum_{i=1}^{n} a_i$$

- The absolute error is given by,

$$\Delta a_1 = |a_m - a_1|$$
$$\Delta a_2 = |a_m - a_2|$$
....
....
$$\Delta a_n = |a_m - a_n|$$

55. What is meant by mean Absolute error? Explain.

The arithmetic mean of the magnitude of absolute errors in all the measurements is called the mean absolute error.

$$\Delta a_m = \frac{|\Delta a_1| + |\Delta a_2| + |\Delta a_3| + \cdots + |\Delta a_n|}{n}$$

$$\Delta a_m = \frac{1}{n}\sum_{i=1}^{n} |\Delta a_i|$$

56. What is meant by Relative error? Explain.

The ratio between mean absolute error to the mean value is called relative error. This is also called fractional error.

$$Relative\ error = \frac{Mean\ absolute\ error}{Mean\ value} = \frac{\Delta a_m}{a_m}$$

57. What is meant by Percentage error? Explain.

The relative error expressed in percentage is called percentage error.

Percentage error = $\frac{\Delta a_m}{a_m}$ x 100 %

58. What are the factors affecting error in final result?

- The errors in the individual measurements.
- Nature of mathematical operations.

59. What are significant figures?

The number of digits which are counted reasonably sure in making a measurement are called significant figures.

60. Explain the significant figures in addition and subtraction with the examples.

In addtion and subtraction, the final result should retain as many decimal places as there are in the original number with the smallest number of decimal places.

Example:

(i) Addition:

3.1 + 1.780 + 2.046 = 6.926 is rounded off to **6.9** as the number 3.1 has least one decimal place.

(ii) Subtraction:

12.637 – 2.42 = 10.217 is rounded off to **10.22** as the number 2.42 has least two decimal places.

61. Explain the significant figures in multipliication and division with the examples.

In multiplication and division, the final result should retain as many significant figures as there are in the original number with the smallest number of significant figures.

Examples:

(i) Multiplication:

1.21 x 36.72 = 44.4312 is rounded off to **44.4** as the number 1.21 has least 3 significant figures.

(ii) Division:

36.72 ÷ 1.2 = 30.6 is rounded off to **31** as the number 1.2 has least 2 significant figures.

62. What is dimension?

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

63. What is dimensional formula? Give an example.

Dimensional formula is an expression which shows how and which of the fundamental units are required to represent the unit of a physical quantity.

Ex: $[M^0LT^{-2}]$ is the dimensional formula of acceleration.

64. What is dimensional equation? Give an example.

When the dimensional formula of a physical quantity is expressed in the form of an equation, such equation is known as the dimensional equation.

Ex: acceleration = $[M^0LT^{-2}]$

65. What is dimensional variables?

Physical quantities, which have dimension and have variable values are called dimensional variables.

Examples: length, velocity, acceleration, etc.,

66. What is dimensionless variables?

Physical quantities,which have no dimension and have variable values are called dimensional variables.

Examples: specific gravity, strain, refractive index,etc.,

67. What is dimensional constants?

Physical quantities, which have dimension and have constant values are called dimensional constants.

Examples: gravitational constant, planck's constant, etc.,

68. What is dimensionless constants?

Physical quantities,which have no dimension and have constant values are called dimensionless constants.
Examples: π, e, numbers, etc.,

69. What is principle of homogeneity of dimensions?

The principle of homogeneity of dimension states that the dimensions of all the terms in a physical expression should be the same.

70. What are the applications of dimensional analysis method?

- Convert a physical quantity from one system of units to another.
- Check the dimensional correctness of a given physical equation.
- Establish relations among various physical quantities.

71. What are the limitations of dimensional analysis method?

- It gives no information about the dimensionless constants like numbers, π, e, etc., in the formula.
- It cannot decide whether the given quantity is a scalar or vector.
- It is not suitable to derive relations involving trignometry, exponential and logarithmic functions.
- It cannot be applied to an equation involving more than three physical quantities.
- It can only check dimensional correctness of an equation but not the correctness of the equation.

5 Marks Q & A:

1. Explain the propagation of error in the sum of two quantities?

- Let ΔA and ΔB be the absolute errors in the two quantities A and B respectively.
- Then,
  Measured value of A = A ± ΔA
  Measured value of B = B ± ΔB
  Consider the sum, Z = A + B
- The error ΔZ in Z is given by,
  Z ± ΔZ = (A ± ΔA) + (B ± ΔB)
  Z ± ΔZ = (A + B) ± (ΔA + ΔB)
  Z ± ΔZ = Z ± (ΔA + ΔB) $[\because Z = A + B]$
  ΔZ = ΔA + ΔB
- The maximum possible error in the sum of two quantities is equal to the sum of the absolute errors in the individual quantities.

2. Explain the propagation of error in the difference of two quantities?

- Let ΔA and ΔB be the absolute errors in the two quantities A and B respectively.
- Then,
  Measured value of A = A ± ΔA
  Measured value of B = B ± ΔB
  Consider the difference, Z = A - B
- The error ΔZ in Z is given by,
  Z ± ΔZ = (A ± ΔA) - (B ± ΔB)
  Z ± ΔZ = (A - B) ± (ΔA + ΔB)
  Z ± ΔZ = Z ± (ΔA + ΔB) $[\because Z = A - B]$
  ΔZ = ΔA + ΔB
- The maximum possible error in the difference of two quantities is equal to the sum of the absolute errors in the individual quantities.

3. Explain the propagation of error in the product of two quantities?

- Let ΔA and ΔB be the absolute errors in the two quantities A and B respectively.
- Then,
  Measured value of A = A ± ΔA
  Measured value of B = B ± ΔB
  Consider the product, Z = A . B -----> (1)
- The error ΔZ in Z is given by,
  Z ± ΔZ = (A ± ΔA) . (B ± ΔB)
  Z ± ΔZ = AB ± A.ΔB ± B.ΔA ± ΔA.ΔB -----> (2)
  Dividing equation (2) by (1) we get,
  $$1 \pm \frac{\Delta Z}{Z} = 1 \pm \frac{\Delta B}{B} \pm \frac{\Delta A}{A} \pm \frac{\Delta A}{A}.\frac{\Delta B}{B}$$
  As $\frac{\Delta A}{A}$ and $\frac{\Delta B}{B}$ are both smaller values, their products $\frac{\Delta A}{A}.\frac{\Delta B}{B}$ can now be neglected. The maximum fractional error in Z is,
  $$\frac{\Delta Z}{Z} = \frac{\Delta A}{A} + \frac{\Delta B}{B}$$
- The maximum fractional error in the product of two quantities is equal to the sum of the fractional errors in the individual quantities.

4. Explain the propagation of error in the division or quotient of two quantities?

- Let ΔA and ΔB be the absolute errors in the two quantities A and B respectively.
- Then,
  Measured value of A = A ± ΔA
  Measured value of B = B ± ΔB
  Consider the division, $Z = \frac{A}{B}$
- The error ΔZ in Z is given by,

$$Z \pm \Delta Z = \frac{A \pm \Delta A}{B \pm \Delta B} = \frac{A\left(1 \pm \frac{\Delta A}{A}\right)}{B\left(1 \pm \frac{\Delta B}{B}\right)}$$

$$Z \pm \Delta Z = \frac{A}{B}\left(1 \pm \frac{\Delta A}{A}\right)\left(1 \pm \frac{\Delta B}{B}\right)^{-1}$$

- By using binomial theorem, $(1+x)^n = 1 + nx$, when x<<1, we get,

$$1 \pm \frac{\Delta Z}{Z} = \left(1 \pm \frac{\Delta A}{A}\right)\left(1 \mp \frac{\Delta B}{B}\right)$$

$$1 \pm \frac{\Delta Z}{Z} = 1 \pm \frac{\Delta A}{A} \mp \frac{\Delta B}{B} \pm \frac{\Delta A}{A} . \frac{\Delta B}{B}$$

As $\frac{\Delta A}{A}$ and $\frac{\Delta B}{B}$ are both smaller values, their products $\frac{\Delta A}{A} . \frac{\Delta B}{B}$ can now be neglected. The maximum fractional error in Z is,

$$\frac{\Delta Z}{Z} = \frac{\Delta A}{A} + \frac{\Delta B}{B}$$

- The maximum fractional error in the product of two quantities is equal to the sum of the fractional errors in the individual quantities.

5. Explain the propagation of error in the power or a quantity?

- Let ΔA and ΔB be the absolute errors in the two quantities A and B respectively.
- Then,
  Measured value of A = A ± ΔA
  Measured value of B = B ± ΔB
  Consider the n^{th} power of A, $Z = A^n$
- The error ΔZ in Z is given by,

$$Z \pm \Delta Z = (A \pm \Delta A)^n = A^n\left(1 \pm \frac{\Delta A}{A}\right)^n$$

$$Z \pm \Delta Z = A^n\left(1 \pm \frac{\Delta A}{A}\right)^n$$

By using binomial theorem, we solve and get,

$$1 \pm \frac{\Delta Z}{Z} = 1 \pm n\frac{\Delta A}{A}$$

$$\frac{\Delta Z}{Z} = n\frac{\Delta A}{A}$$

The fractional error in the n^{th} power of a quantity is n times the fractional error in that quantity.

6. Explain the rules framed to count significant figures with the examples.

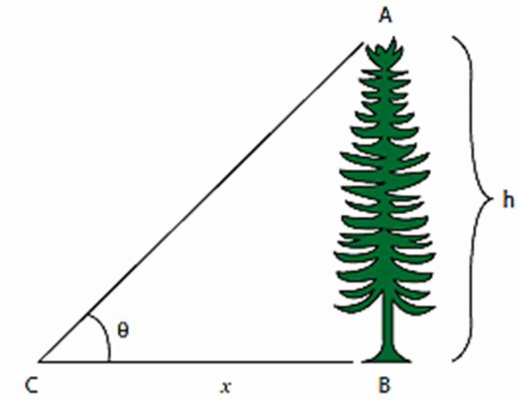
S. No.	Rule	Example
1.	All non-zero digits are significant	1342 has **four** significant figures
2.	All zeros between two non-zero digits are significant	2008 has **four** significant figures
3.	All zeros right to non-zero digit but left to decimal point are significant.	30700. has **five** significant figures
4.	The terminal or trailing zeros in the number without decimal point are not significant.	30700 has **three** significant figures.
5.	All zeros are significant if the number given with measurement unit.	30700 m has **five** significant figures.
6.	If a number is less than1, the zeros between decimal point and first non-zero digit are not significant but the zeros right to last non-zero digit are significant.	(i) 0.00345 has **three** significant figures. (ii) 0.030400 has **five** significant figures. (iii) 40.00 has **four** significant figures.
7.	The number of significant figures doesn't depend on the system of units used	1.53 cm, 0.0153 m, 0.0000153 km all have **three** significant figures.

7. Explain the rules framed for rounding off the numbers with the examples.

S. No.	Rule	Example
1.	If the dropping digit is less than 5, then preceding digit kept unchanged.	7.32 is rounded off to 7.3
2.	If the dropping digit is greater than 5, then preceding digit must be raised by 1.	17.26 is rounded off to 17.3
3.	If the dropping digit is 5 followed by non-zero digits then preceding digit must be raised by1	7.352 is rounded off to 7.4
4.	If the dropping digit is 5 or 5 followed by zero, then preceding digit must be raised by 1 if it is odd.	3.35 & 3.350 are rounded off to 3.4
5.	If the dropping digit is 5 or 5 followed by zero, then preceding digit is not changed if it is even.	3.45 & 3.450 are rounded off to 3.4

8. Explain the Triangulation method to find the height of the tree or the tower.

- Let AB = h be the height of the tree or tower.
- Let C be the the point of observation at distance x from B.
- Place a range finder at C and measure the angle of elevation, ∠ACB = θ as shown in figure.

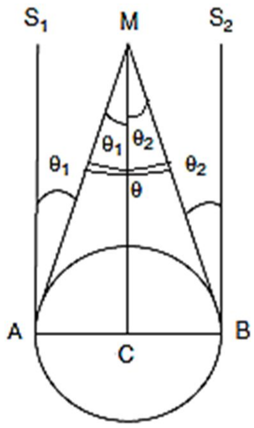


- From ΔABC, $\tan\theta = \frac{AB}{BC} = \frac{h}{x}$

  or $\boxed{h = x\tan\theta}$
- Knowing the distance x, the height h can be determined.

9. Explain the Parallax method to find the distance of the Moon from Earth.

- Let C be the centre of the Earth.
- A & B are two diametrically opposite places on the surface of the Earth.
- AB is the diameter of the Earth and MC is the distance of the Moon from Earth.
- θ_1 & θ_2 are the parallactic angles of the Moon with respect to some distant stars S_1 & S_2 respectively.
- θ_1 and θ_2 are determined by using an astronomical telescope.



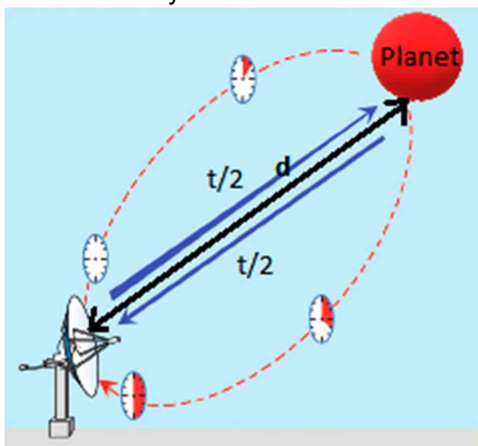
- Thus, the total parallactic angle(parallax) of the Moon subtended on Earth, $\angle AMB = \theta_1 + \theta_2 = \theta$.
- From the figure, $\theta = \frac{AB}{AM} = \frac{AB}{MC}$ $[\because AM = MC]$

$$\boxed{MC = \frac{AB}{\theta}}$$

- Knowing the values of AB and θ, We can calculate distance of the Moon from Earth (MC).

10. Explain the RADAR method to find the distance of a nearby Planet.

- The word RADAR stands for <u>RA</u>dio <u>D</u>etection <u>A</u>nd <u>R</u>anging.
- In this method, radio waves are sent from transmitters which after reflected from the planet are detected by the receiver.



- By measuring the time interval between the instants the radio waves are sent and received, the distance of the planet(d) can be detemined as,

  Distance = Speed of radio waves X time taken,

$$\boxed{d = \frac{v \times t}{2}}$$

- Where v is the speed of radio waves and t is the time taken by radio waves to travel forward and backward hence t/2 is the time taken to cover the distance d.

11. Explain the conversion of physical quantity from one system of units to another with the examples.

- The product of the numerical value (n) and its corresponding unit [u] is constant.

  n [u] = constant
- Consider Physical quantity which has dimension 'a' in mass, 'b' in length and 'c' in time.
- If the fundamental unit in one system are M_1 , L_1 & T_1 and in other system are M_2 , L_2 & T_2, then we can write,

$$n_1[M_1^a\, L_1^b\, T_1^c] = n_2[M_2^a\, L_2^b\, T_2^c]$$

<u>**Example: 1**</u>

Convert 76 cm of mercury into Nm^{-2} using the method of dimension.

Data => h = 76 cm ; ρ = 13.6 g cm^{-3} ; g = 980 cm s^{-2}.

<u>**Solution:**</u>

P_1 = hρg =76 x 13.6 x 980 = 1.01 x 10^6 dyne cm^{-2}.

- The dimension formula of pressure P is $[M L^{-1} T^{-2}]$

  So, **a = 1 , b = -1 , c = -2**

$$P_1[M_1^a\, L_1^b\, T_1^c] = P_2[M_2^a\, L_2^b\, T_2^c]$$

$$P_2 = P_1\left[\frac{M_1}{M_2}\right]^a \left[\frac{L_1}{L_2}\right]^b \left[\frac{T_1}{T_2}\right]^c$$

M_1 = 1 g	L_1 = 1 cm	T_1 = 1 s
M_2 = 1 kg	L_2 = 1 m	T_2 = 1 s

$$P_2 = 1.01 \times 10^6 \left[\frac{1\ g}{1\ kg}\right]^1 \left[\frac{1\ cm}{1\ m}\right]^{-1} \left[\frac{1\ s}{1\ s}\right]^{-2}$$

$$P_2 = 1.01 \times 10^6 \left[\frac{10^{-3}\ kg}{1\ kg}\right]^1 \left[\frac{10^{-2}\ m}{1\ m}\right]^{-1} \left[\frac{1\ s}{1\ s}\right]^{-2}$$

$= 1.01 \times 10^6 \times 10^{-3} \times 10^2 \times 1$

$P_2 = 1.01 \times 10^5\ Nm^{-2}$.

Example 2:

If the value of universal gravitational constant in SI is $6.6 \times 10^{-11}\ Nm^2\ kg^{-2}$, then find its value in CGS System?

Solution:

Let G_{SI} be the gravitational constant in SI system and G_{cgs} be in cgs system.

$G_{SI} = 6.6 \times 10^{-11}\ Nm^2\ kg^{-2}$

- The dimensional formula for G is $M^{-1} L^3 T^{-2}$.

a = -1, b = 3, c = -2

$$G_{cgs} = G_{SI} \left[\frac{M_1}{M_2}\right]^a \left[\frac{L_1}{L_2}\right]^b \left[\frac{T_1}{T_2}\right]^c$$

$M_1 = 1$ kg	$L_1 = 1$ m	$T_1 = 1$ s
$M_2 = 1$ g	$L_2 = 1$ cm	$T_2 = 1$ s

$$G_{cgs} = 6.6 \times 10^{-11} \left[\frac{1\ kg}{1\ g}\right]^{-1} \left[\frac{1\ m}{1\ cm}\right]^3 \left[\frac{1\ s}{1s}\right]^{-2}$$

$$G_{cgs} = 6.6 \times 10^{-11} \left[\frac{1\ kg}{10^{-3}\ kg}\right]^{-1} \left[\frac{1\ m}{10^{-2}\ m}\right]^3 \left[\frac{1\ s}{1s}\right]^{-2}$$

$= 6.6 \times 10^{-11} \times 10^{-3} \times 10^6 \times 1$

$G_{cgs} = 6.6 \times 10^{-8}$ dyne $cm^2\ g^{-2}$

12. Check the dimensional correctness of a given equation with the examples.

Example 1:

Consider an equation, **v = u + at**

Apply dimensions on both sides, we get,

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

$[LT^{-1}] = [LT^{-1}] + [LT^{-1}]$

Since dimensions on both sides are same, the given equation is dimensionally correct.

Example 2:

Consider an equation, $\frac{1}{2}mv^2 = mgh$

Apply dimensions on both sides, we get,

$[M] [LT^{-1}]^2 = [M] [LT^{-2}] [L]$

$[ML^2T^{-2}] = [ML^2T^{-2}]$

Since dimensions on both sides are same, the given equation is dimensionally correct.

13. Explain how to establish the relation among various physical quantities with the examples.

- If physical quantity Q depends on Q_1, Q_2 and Q_3, then we write, $Q \propto Q_1^a\ Q_2^b\ Q_3^c$

$$Q = k\ Q_1^a\ Q_2^b\ Q_3^c$$

- Where k is dimensionless constant. Applying the dimensions of Q_1, Q_2 and Q_3 and using principle of homogeneity, the powers of M, L and T are made equal on both sides. Then we get values of a, b and c to form relation.

Example 1:

Obtain an expression for the time period of T of a simple pendulam. The time period T depends upon (i) mass 'm' of the bob (ii) length 'l' of the pendulam and (iii) acceleration due to gravity 'g' at the place where the pendulam is suspended. (Constant k = 2π)

Solution:

$T \ \alpha\ m^a\, l^b\, g^c$

$T = k\, m^a\, l^b\, g^c$ -----> (1)

- Here k is dimensional constant. Applying dimensions on both sides, we get,

$[T] = [M^a] [L^b] [LT^{-2}]^c$

$[M^0 L^0 T^1] = [M^a L^{b+c} T^{-2c}]$

- Comparing the powers of M, L, T on both sides, a = 0, b + c = 0, -2c = 1 .
- Solving it, we get, a = 0, b =1/2, c= -1/2
- From equation (1),

$T = 2\pi\, m^0\, l^{1/2}\, g^{-1/2}$

$$T = 2\pi\sqrt{\frac{l}{g}}$$

Example 2:

The force F acting on a body moving in a circular path depends on mass of the body (m), velocity and radius (r) of the circular path. Obtain the expression for the force by dimensional analysis method. (Take the value of k = 1)

Solution:

$F \ \alpha\ m^a\, v^b\, r^c$

$F = k\, m^a\, v^b\, r^c$ -----> (1)

- Here k is dimensional constant. Applying dimensions on both sides, we get,

$[M L T^{-2}] = [M^a] [LT^{-1}]^b [L]^c$

$[M L T^{-2}] = [M^a L^{b+c} T^{-b}]$

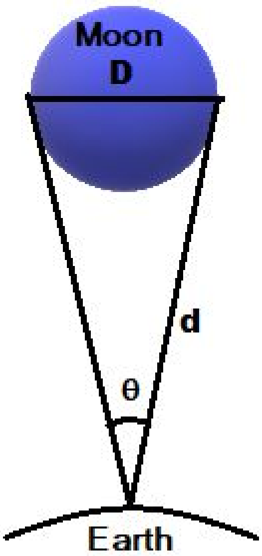
- Comparing the powers of M, L, T on both sides, a = 1, b + c = 1, -b = -2 .
- Solving it, we get, a = 1, b = 2, c= -1
- From equation (1),

$F = m^1\, v^2\, r^{-1}$

$$F = \frac{mv^2}{r}$$

Book back Q & A:

1. **How will you measure the diameter of the Moon using parallax method?**
   - Let θ be the angle subtended by the Moon at the surface of the Earth.
   - d is the distance of the Moon from Earth.
   - D is the diameter of the Moon.



   - From figure,

     Arc angle, $\theta = \frac{D}{d}$
   - From this, diameter of the Moon, D = d . θ
   - Knowing the values of **d** and θ, we can calculate the diameter of the Moon.

Mark distribution

Exam	Total marks	Pass mark
Theory	70	15
Practical	20	20 (or) Exam attended
Internal Assessment	10	
Total	100	35

Internal Assessment:

1. **Attendance:** 2
   Above 80% - 2 Marks
   75-80 % - 1 Mark
2. **Internal class test:** 4
   (Calculated to 4 marks from best three test)
3. **Assignment :** 2
4. **Co-curricular activities** 2
   (Any 3 activities out of 33 given)

Total : 10

External Exam:

1. Record Note 3
2. Expt. Skill 2
3. Practical Exam 15

Total : 20

Question Pattern :

Part/ Question type	Marks	No. of questions asked	No. of questions to be answered	Total marks
I 1 marks	1	15	15	15
II Short Q	2	8+1(9)	5+1(6)	12
III Brief Q	3	8+1(9)	5+1(6)	18
IV Long Q	5	5 (with internal choice)	5	25
			மொத்தம்	70

Note : Part II and Part III have one compulsory question respectively.

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2. Kinematics

1. What is kinematics?

Kinematics is the branch of mechanics which deals with the motion of objects without taking force into account.

2. What is meant by Frame of reference?

Frame of reference is a coordinate system with respect to which position of an object is described.

3. What is meant by Cartesian coordinate system?

Cartesian coordinate system is the frame of reference with respect to which the position of the object is described in terms of position coordinates(x,y,z).

4. What is the point mass? Give the examples.

The mass of an object, which is concentrated at a point is called "point mass". It has no internal structures like shape and size.

Example: (i) In the event of motion of Earth around the Sun, Earth can be treated as point mass.
(ii) When stone is thrown in space, stone is considered as point mass.

5. What are the types of motion?

- Linear motion
- Circular motion
- Rotational motion
- Vibratory (or) Oscillatory motion.

6. What is linear motion? Give the examples.

When an object is moving in a straight line, it is called linear motion.

Example: (i) An athlete running on a straight track.
(ii) A particle falling vertically downwards.

7. What is circular motion? Give the examples.

When an object is moving in a circular path, it is called circular motion.

Example: (i) The whirling motion of a stone attached to a string.
(ii) The motion of a satellite around the Earth.

8. What is Rotational motion? Give the examples.

If any object is revolving about an axis, the motion is called Rotational motion.

Example: (i) Rotation of a disc about its central axis.
(ii) Spinning of the Earth about its own axis.

9. What is vibratory motion? Give the examples.

If an object executes to and fro motion about a fixed point, it is called vibratory or oscillatory motion.

Example: (i) Vibration of a string on a guitar.
(ii) movement of a swing.

10. What is one dimensional motion? Give the examples.

Motion of a particle along a straight line is called one dimensional motion.

Example: (i) Motion of a train along a straight track.
(ii) An object falling freely down under gravity.

11. What is two dimensional motion? Give the examples

Curved motion of a particle in a plane is called two dimensional motion.

Example: (i) Motion of a coin on a carrom board.
(ii) An insect crawling over the floor.

12. What is three dimensional motion?Give the examples

If a particle moving in a three dimensional space, then it is called three dimensional motion.

Example: (i) A bird flying in the sky.
(ii) Random motion of molecules.
(iii) Flying kite on a windy day.

13. What is Scalar? Give examples

A physical quantity which can be described only by magnitude is called Scalar.

Ex: Distance, mass, temperature, speed, energy, etc.,

14. What is Vector? Give examples

A physical quantity which can be described by both magnitude and direction is called Vector.

Ex: Force, velocity, displacement, acceleration, etc.,

15. How to denote a vector quantity?

A vector quantity can be geometrically represented by line arrow, in which lengh of the line denotes magnitude and arrow denotes its direction.

16. What are the types of vectors?

- Equal vectors
- Collinear vectors
- Parallel vectors
- Anti-parallel vectors
- Unit vectors
- Orthogonal unit vectors

17. What is equal vectors?

Two vectors of same physical quantity having same magnitude and direction are called equal vectors.

18. What is collinear vectors?

Two vectors acting along the same line act either both in same direction or opposite to each other are called collinear vectors.

19. What is parallel vectors?

Two vectors act in the parallel lines along the same direction are called parallel vectors.

20. What is anti-parallel vectors?

Two vectors act in the parallel lines along the opposite directions are called anti-parallel vectors.

21. What is unit vector?

A vector with unit magnitude is called unit vector. It is equal to the ratio of a vector and its magnitude.

$$\hat{A} = \frac{\vec{A}}{|\vec{A}|}$$

22. What is orthogonal unit vector?

If unit vectors are mutually perpendicular to each other, then they are called orthogonal unit vectors.

23. State triangle law of addition of two inclined vectors.

It is stated that if two vectors are represented by the two adjacent sides of a triangle in same order, then the resultant is given by the third side of the triangle in opposite order.

24. Define Scalar or Dot product of two vectors.

The scalar or dot product of two vectors is defined as the product of the magnitude of the both vectors and the cosine of the angle between them.

$$\vec{A} \cdot \vec{B} = ABCos\theta = C$$

25. Define Vector or Cross product of two vectors.

The Vector or Cross product of two vectors is defined as the product of the magnitude of the both vectors and the sine of the angle between them.

$$\vec{A} \times \vec{B} = ABSin\theta\ \hat{n} = \vec{C}$$

26. State right hand thumb rule in vector product.

According to this law, if the curvature of the right hand fingers represents rotating direction of a vector $\vec{A}$ towards another vector $\vec{B}$, then the stretched thumb points out the direction of resultant vector $\vec{C}$.

27. What is distance? Give its unit.

Distance is the actual path length travelled by an object in the given interval of time during the motion. Its unit is metre.

28. What is displacement? Give its unit.

Displacement is the shortest distance between initial and final position of the object in the given interval of time during the motion. Its unit is metre.

.

29. What are the differences between distance and displacement?

S. No.	Distance	Displacement
1	It is total length of path travelled.	It is shortest distance between initial and final position of an object.
2	It is a scalar quantity.	It is a vector quantity.
3	It can be zero or positive but not negative	It can be zero, positive and negative.
4	It may be equal to or greater than the displacement.	It may be equal to or less than the distance.
5	It has many values between two positions of an object.	It has only one value between two positions of an object.

30. Define average velocity.

The average velocity is defined as the ratio of change in displacement vector to the corresponding time interval. $\vec{v}_{avg} = \frac{\Delta\vec{r}}{\Delta t}$

31. Define average speed.

The average speed is defined as the ratio of total path length travelled by the particle to a given interval of time.

32. Define instantaneous velocity. Give its unit.

The velocity at an instant is defined as the change in position vector with respect to time. Its unit is ms^{-1}.

$$\vec{v} = \lim_{\Delta t\to 0}\frac{\Delta\vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$$

33. What are the differences between velocity and average velocity?

S.No	Velocity (or) Instantaneous velocity	Average velocity
1.	Velocity at an instant of time (or) Rate of change of displacement vector	Ratio of change in displacement vector to the time interval.
2.	It is measured at particular instant of time in motion.	It is measured for a given interval of time in motion.
3.	$\vec{v} = \lim_{\Delta t\to 0}\frac{\Delta\vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$	$\vec{v}_{avg} = \frac{\Delta\vec{r}}{\Delta t}$

34. What is momentum (or) linear momentum? Give its unit.

The momentum or linear momentum is the product of mass of a particle and its velocity. Its unit is kg ms^{-1} . i.e. $\vec{p} = m\vec{v}$

35. What is relative velocity?

The velocity of one object with respect to another object is called relative velocity.

36. What is uniform motion?

If an object is moving with constant velocity, then the motion is called uniform motion.

37. What is non-uniform or accelerated motion?

If an object is moving with various velocity with time, then the motion is called non-uniform or accelerated motion.

38. What is uniform accelerated motion?

If change in velocity of an object in given interval of time is constant, then the motion is called uniform accelerated motion.

39. What is non-uniform accelerated motion?

If change in velocity of an object in given interval of time is not constant, then the motion is called non-uniform accelerated motion.

40. Define average acceleration.

Average acceleration is defined as the ratio of change in velocity over the given time interval.

$$\vec{a}_{avg} = \frac{\Delta\vec{v}}{\Delta t}$$

41. Define instantaneous acceleration. Give its unit.

The acceleration at an instant is defined as the change in velocity with respect to time. Its unit is ms^{-2}.

$$\vec{a} = \lim_{\Delta t \to 0} \frac{\Delta\vec{v}}{\Delta t} = \frac{d\vec{v}}{dt}$$

42. What is free fall of a body?

The motion of a body falling towards the Earth from a small altitude, purely under gravitational force is called free fall of a body.

43. What is meant by a projectile? Give the examples.

An object is thrown in the air with some initial velocity and allowed to move under gravity is called a projectile.

<u>Ex:</u>

- An object dropped from window of a moving train
- A bullet fired from a rifle.
- A ball thrown in any direction.

44. What are the types of projectile motion?

- Projectile given initial velocity in the horizontal direction.
- Projectile given initial velocity at an angle to the horizontal.

45. What are the assumptions made in projectile motion?

- Air resistance is neglected.
- The effect due to rotation of Earth and curvature of earth is negligible.
- The acceleration due to gravity is constant throughout the motion of the projectile.

46. What is trajectory?

The path followed by the projectile is called trajectory.

47. What is time of flight?

The time interval between the instant of projection and the instant when the projectile hits the ground.

48. What is horizontal range?

The maximum horizontal distance between the point of projection and the point where the projectile hits the ground.

49. What is maximum height?

The maximum vertical distance travelled by the projectile during its journey is called maximum height.

50. What is angular displacement? Give its unit.

The angle described by the particle about the axis of rotation in a given time is called angular displacement. Its unit is radian.

$$\theta = \frac{S}{r}$$

51. What is angular velocity? Give its unit.

The rate of change of angular displacement is called angular velocity. Its unit is rad s^{-1} .

$$\omega = \lim_{\Delta t \to 0} \frac{\Delta\theta}{\Delta t}$$

52. What is angular acceleration? Give its unit.

The rate of change of angular velocity is called angular acceleration. Its unit is rad s^{-2} .

$$\vec{\alpha} = \lim_{\Delta t \to 0} \frac{\Delta\vec{\omega}}{\Delta t}$$

53. What is tangential acceleration?

The acceleration which is acting along the direction of linear velocity and tangent to the circular motion is called tangential acceleration.

54. What is uniform circular motion?

When an object is moving on a circular path with constant speed, it is called uniform circular motion.

55. What is non-uniform circular motion?

When an object is moving on a circular path with change in speed and direction, it is called non-uniform circular motion.

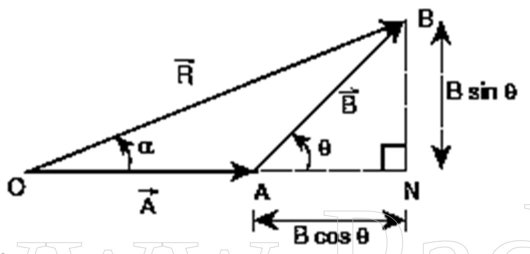
56. What is centripetal acceleration or radial acceleration or normal acceleration?

The acceleration which is acting towards the center along the radial direction and perpendicular to linear velocity of circular motion is called centripetal acceleration.

5 Marks Q & A:

1. Find the magnitude and direction of resultant of the two vectors by using triangle law of vector addition.

- Let $\vec{A}$ and $\vec{B}$ are two vectors they are inclined at angle θ between them.
- According to triangle law of vector addition, head of the vector $\vec{A}$ is connected to tail of the vector $\vec{B}$ and both are represented in adjescent side of a triangle in some order.
- Let $\vec{R}$ be the resultant vector, which is represented in third closing side of the triangle in opposite order.
- Let α be the angle made by the resultant vector $\vec{R}$ with vector $\vec{A}$.
- Thus we can write, $\vec{R} = \vec{A} + \vec{B}$



(a) Magnitude of resultant vector :

- From ⊿ABN,

$$\cos\theta = \frac{AN}{B} \;;\; AN = B\cos\theta$$
$$\sin\theta = \frac{BN}{B} \;;\; BN = B\sin\theta$$

- From ⊿OBN,

$OB^2 = ON^2 + BN^2$

$$R^2 = (A + B\cos\theta)^2 + (B\sin\theta)^2$$
$$R^2 = A^2 + B^2\cos^2\theta + 2AB\cos\theta + B^2\sin^2\theta$$
$$R = |\vec{A} + \vec{B}| = \sqrt{A^2 + B^2 + 2AB\cos\theta}$$

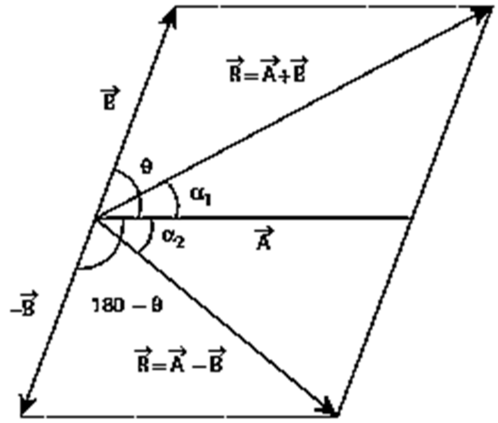
(b) Direction of resultant vector :

- From ⊿OBN,

$$\tan\alpha = \frac{BN}{ON} = \frac{BN}{OA + AN}$$
$$\tan\alpha = \frac{B\sin\theta}{A + B\cos\theta}$$

2. Discuss Subtraction of two vectors geometrically and write the equations for magnitude and direction of resultant vector.

- Let $\vec{A}$ and $\vec{B}$ are two vectors they are inclined at angle θ between them.
- Obtain $-\vec{B}$ as in figure and now angle between $\vec{A}$ and $\vec{B}$ is $180^0 - \theta$.



- Thus, Resultant $\vec{R} = \vec{A} + (-\vec{B}) = \vec{A} - \vec{B}$
- According to triangle law of vectors,

(a) Magnitude of difference :

$$R = |\vec{A} - \vec{B}| = \sqrt{A^2 + B^2 + 2AB\cos(180^0 - \theta)}$$

Since, $\cos(180^0 - \theta) = -\cos\theta$

$$|\vec{A} - \vec{B}| = \sqrt{A^2 + B^2 - 2AB\cos\theta}$$

(b) Direction of difference :

$$\tan\alpha = \frac{B\sin(180^0 - \theta)}{A + B\cos(180^0 - \theta)}$$

But $\sin(180^0 - \theta) = \sin\theta$

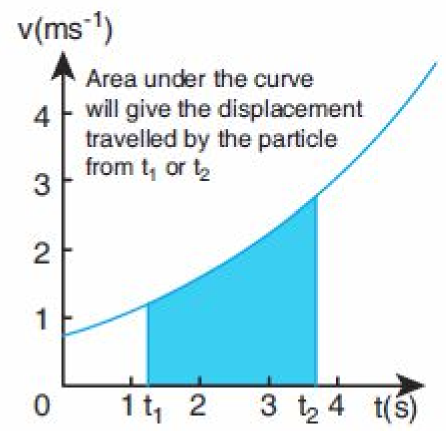
$$\tan\alpha = \frac{B\sin\theta}{A - B\cos\theta}$$

3. **Give the Comparison of the properties of Scalar and Vector product.**

S. No	Scalar / Dot product	Vector / Cross product
1	Product quantity C=$\vec{A}\cdot\vec{B}$ is always a scalar. $\vec{A}\cdot\vec{B} = +ve$ if θ is acute (θ<90⁰) $\vec{A}\cdot\vec{B} = -ve$ if θ is obtuse (90⁰ > θ < 180⁰)	Product quantity $\vec{C} = \vec{A}\times\vec{B}$ is always a Vector. $\vec{C}$ is always orthogonal to $\vec{A}$ & $\vec{B}$ but $\vec{A}$ and $\vec{B}$ may or may not be mutually orthogonal.
2	It obeys Commutative law. $\vec{A}\cdot\vec{B} = \vec{B}\cdot\vec{A}$	It doesn't obey Commutative law. $\vec{A}\times\vec{B} \neq \vec{B}\times\vec{A}$. But, $\vec{A}\times\vec{B} = -\vec{B}\times\vec{A}$ and $\lvert\vec{A}\times\vec{B}\rvert = \lvert\vec{B}\times\vec{A}\rvert$.
3	It obeys Distributive law. $\vec{A}\cdot(\vec{B}+\vec{C})$ $= \vec{A}\cdot\vec{B} + \vec{B}\cdot\vec{A}$	It obeys Distributive law. $\vec{A}\times(\vec{B}+\vec{C})$ $= \vec{A}\times\vec{B} + \vec{B}\times\vec{A}$
4	When $\vec{A}$ & $\vec{B}$ are parallel, θ = 0⁰ , $(\vec{A}\cdot\vec{B})_{max} = AB$	When $\vec{A}$ & $\vec{B}$ are parallel, θ = 0⁰ , $(\vec{A}\times\vec{B})_{min} = 0$
5	When $\vec{A}$ & $\vec{B}$ are anti-parallel, θ = 180⁰ , $(\vec{A}\cdot\vec{B})_{min} = -AB$	When $\vec{A}$ & $\vec{B}$ are anti-parallel, θ = 180⁰ , $(\vec{A}\times\vec{B})_{min} = 0$
6	When $\vec{A}$ & $\vec{B}$ are perpendicular, θ = 90⁰, $\vec{A}\cdot\vec{B} = 0$	When $\vec{A}$ & $\vec{B}$ are perpendicular, θ = 90⁰ , $(\vec{A}\times\vec{B})_{max} = AB\,\hat{n}$
7	Self-dot product of a vector, $\vec{A}\cdot\vec{A} = AAcos0^0 = A^2$	Self-cross product of a vector, $\vec{A}\times\vec{A} = AAsin0^0\hat{n} = \vec{0}$
8	Self-dot product of a unit vector, $\hat{n}\cdot\hat{n} = 1\times1\,cos0^0 = 1$ $\hat{\imath}\cdot\hat{\imath} = \hat{\jmath}\cdot\hat{\jmath} = \hat{k}\cdot\hat{k} = 1$	Self-cross product of a unit vector, $\vec{A}\times\vec{A} = AAsin0^0\hat{n} = \vec{0}$ $\hat{\imath}\times\hat{\imath} = \hat{\jmath}\times\hat{\jmath} = \hat{k}\times\hat{k} = \vec{0}$
9	Dot product of orthogonal unit vectors, $\hat{\imath}\cdot\hat{\jmath} = \hat{\jmath}\cdot\hat{k} = \hat{k}\cdot\hat{\imath} = 0$	Cross product of orthogonal unit vectors, $\hat{\imath}\times\hat{\jmath} = \hat{k}$; $\hat{\jmath}\times\hat{\imath} = -\hat{k}$ $\hat{\jmath}\times\hat{k} = \hat{\imath}$; $k\times\hat{\jmath} = -\hat{\imath}$ $\hat{k}\times\hat{\imath} = \hat{\jmath}$; $\hat{\imath}\times\hat{k} = -\hat{\jmath}$
10	Scalar product of vector components, $\vec{A}\cdot\vec{B} = (A_x\hat{\imath} + A_y\hat{\jmath} + A_z\hat{k})\cdot(B_x\hat{\imath} + B_y\hat{\jmath} + B_z\hat{k})$ $\vec{A}\cdot\vec{B} = A_xB_x + A_yB_y + A_zB_z$	Vector product of vector components, $\vec{A}\cdot\vec{B} = \begin{vmatrix}\hat{\imath} & \hat{\jmath} & \hat{k}\\ A_x & A_y & A_z\\ B_x & B_y & B_z\end{vmatrix}$ $= \hat{\imath}(A_yB_z - A_zB_y) + \hat{\jmath}(A_zB_x - A_xB_z) + \hat{k}(A_xB_y - A_yB_x)$

4. **Elucidate the significance of velocity – time graph.**

❖ By using velocity – time graph we can find out the distance and displacement by calculating the area under the curve.



❖ We know, velocity $v = \frac{dx}{dt}$

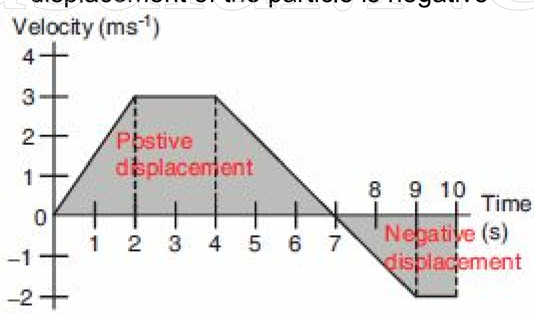
or dx = v dt

By integrating both sides, we get,

$$\int_{x_1}^{x_2} dx = \int_{t_1}^{t_2} v\,dt$$

Displacement, $x_2 - x_1$ = Area under the curve

❖ If area under the curve is negative, the displacement of the particle is negative



5. **Discuss about relative velocity.**

❖ When two objects A and B moving with different velocities, then the velocity of one object with respect to another is called relative velocity.

(a) <u>Case 1 :</u> **A and B moving in same direction.**

❖ Let V_A and V_B are the uniform velocities of A and B respectively.

❖ If A and B are moving in same direction,

The relative velocity of A with respect to B is,

$$\overrightarrow{V_{AB}} = \overrightarrow{V_A} - \overrightarrow{V_B}$$

The relative velocity of B with respect to A is,

$$\overrightarrow{V_{BA}} = \overrightarrow{V_B} - \overrightarrow{V_A}$$

❖ Thus, magnitude of relative velocity of one object with respect to other is equal to difference in magnitude of two velocities.

(b) Case 2 : A and B moving in opposite direction.

- Let V_A and V_B are the uniform velocities of A and B respectively.
- If A and B are moving in opposite direction,

  The relative velocity of A with respect to B is,
  $$\overrightarrow{V_{AB}} = \overrightarrow{V_A} - (-\overrightarrow{V_B}) = \overrightarrow{V_A} + \overrightarrow{V_B}$$

  The relative velocity of B with respect to A is,
  $$\overrightarrow{V_{BA}} = -\overrightarrow{V_B} - \overrightarrow{V_A} = -(\overrightarrow{V_A} + \overrightarrow{V_B})$$
- Thus, magnitude of relative velocity of one object with respect to other is equal to sum of magnitude of two velocities.

(c) Case 3 : A and B moving with an angle θ.

- Let V_A and V_B are the uniform velocities of A and B respectively inclined at an angle θ between them.
- The relative velocity of A with respect to B is
  $$\overrightarrow{V_{AB}} = \overrightarrow{V_A} - \overrightarrow{V_B}$$

  Then, the magnitude of $\overrightarrow{V_{AB}}$ is given by,
  $$V_{AB} = \sqrt{V_A^2 + V_B^2 - 2V_AV_B\cos\theta}$$

  The direction of $\overrightarrow{V_{AB}}$ is given by,
  $$\tan\beta = \frac{V_B\sin\theta}{V_A - V_B\cos\theta}$$
- **(1) When θ = 0⁰** (V_A & V_B in same direction)

  $V_{AB} = V_A - V_B$ along the direction of $\overrightarrow{V_A}$.

  $V_{BA} = V_B - V_A$ along the direction of $\overrightarrow{V_B}$.
- **(2) When θ = 180⁰** (V_A & V_B in opposite direction)

  $V_{AB} = V_A + V_B$ along the direction of $\overrightarrow{V_A}$.

  $V_{BA} = V_B + V_A$ along the direction of $\overrightarrow{V_B}$.
- **(3) When θ = 90⁰**

  (V_A & V_B in perpendicualr direction)

  $V_{AB} = \sqrt{V_A^2 + V_B^2}$ along the direction of $\overrightarrow{V_A}$.

  $V_{BA} = \sqrt{V_B^2 + V_A^2}$ along the direction of $\overrightarrow{V_B}$.

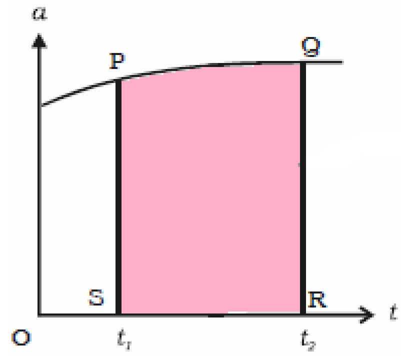
6. Write the expression for magnitude and direction of relative velocity of rain with respect to man.

- If velocity of man $\overrightarrow{V_M}$ is right angle to velocity of rain $\overrightarrow{V_R}$ falling veritically downwards, Then the relative velocity of the rain with respect to the man is,
  $$\overrightarrow{V_{RM}} = \overrightarrow{V_R} - \overrightarrow{V_M}$$
- Magnitude $V_{RM} = \sqrt{V_R^2 + V_M^2}$

  Direction $\theta = \tan^{-1}\frac{V_M}{V_R}$
- In order to save himself from rain he should hold the umbrella at an angle θ with the verticle.

7. Elucidate the significance of acceleration–time graph.

- By using acceleration– time graph we can find out the speed and velocity by calculating the area under the curve.



- We know, acceleration $a = \frac{dv}{dt}$

  or dv = a dt

  By integrating both sides, we get,
  $$\int_{v_1}^{v_2} dv = \int_{t_1}^{t_2} a\,dt$$
  Velocity, $V_2 - V_1$ = Area under the curve

8. Obtain kinematic equations for uniformally accelerated motion.

- Consider an object moving along a straight line with uniform or constant acceleration 'a'.
- Let 'u' be the initial velocity at time t=0 and 'v' be the final velocity at time t.
- Let 'S' be the displacement.

(a) Velocity – time relation :

- Acceleration, $a = \frac{dv}{dt}$

  or $dv = a\,dt$
- By integrating both sides, we get,
  $$\int_u^v dv = \int_0^t a\,dt = a\int_0^t dt = a[t]_0^t$$
  $$v - u = at$$
  $$\boxed{v = u + at}$$

(b) Displacement – time relation :

- Velocity, $v = \frac{dS}{dt}$

  or $dS = v\,dt = (u + at)dt$

  $[\because v = u + at]$
- By integrating both sides, we get,
  $$\int_0^S dS = \int_0^t (u + at)\,dt$$
  $$\int_0^S dS = u\int_0^t dt + a\int_0^t t\,dt$$
  $$\boxed{S = ut + \frac{1}{2}at^2}$$

(c) Velocity - displacement relation :

- Acceleration, $a = \frac{dv}{dt} = \frac{dv}{dS}\frac{dS}{dt} = \frac{dv}{dS}v$

$$dS = \frac{1}{a}v\,dv$$

- By integrating both sides, we get,

$$\int_0^S dS = \frac{1}{a}\int_u^v v\,dv = \frac{1}{a}\left[\frac{v^2}{2}\right]_u^v$$

$$S = \frac{1}{2a}(v^2 - u^2)$$

$$v^2 - u^2 = 2aS$$

$$\boxed{v^2 = u^2 + 2aS}$$

(d) Displacement – average velocity relation :

- Final Velocity, $v = u + at$

$$at = v - u \quad \text{-----> (1)}$$

- We know displacement,

$$S = ut + \frac{1}{2}at^2$$

- Substituting equation(1) , we get,

$$S = ut + \frac{1}{2}(v - u)t$$

$$S = ut + \frac{1}{2}vt - \frac{1}{2}ut$$

$$\boxed{S = \frac{(u + v)\,t}{2}}$$

9. Derive the equations of motion for a particle falling vertically.

- Consider an object of mass 'm' falling from a height h.
- Assume that there is no air resistance and acceleration due to gravity is constant near the surface of the Earth.
- If the object is thrown with an initial velocity u along the Y-axis, then its final velocity and displacement at any time 't' is v and y respectively. Further acceleration a is equal to g.
- Therefore equations of motion are,

$$v = u + gt$$

$$y = ut + \frac{1}{2}gt^2$$

$$v^2 = u^2 + 2gy$$

- Suppose initial velocity u = 0, then

$$v = gt$$

$$y = \frac{1}{2}gt^2$$

$$v^2 = 2gy$$

- Time taken by the object to reach the ground(T), If t= T and y = h, then

$$h = \frac{1}{2}gT^2$$

$$T = \sqrt{\frac{2h}{g}}$$

- The Speed of the object when it reaches the ground,

$$v_{ground}^2 = 2gh$$

$$v_{ground} = \sqrt{2gh}$$

10. Derive the equations of motion for a particle projected vertically upward.

- Consider an object of mass 'm' thrown vertically upward with an initial velocity u.
- Assume that there is no air resistance and acceleration due to gravity is constant near surface of the Earth.
- The final velocity and displacement at any time 't' is v and y respectively. Further acceleration a is equal to -g.
- Therefore equations of motion are,

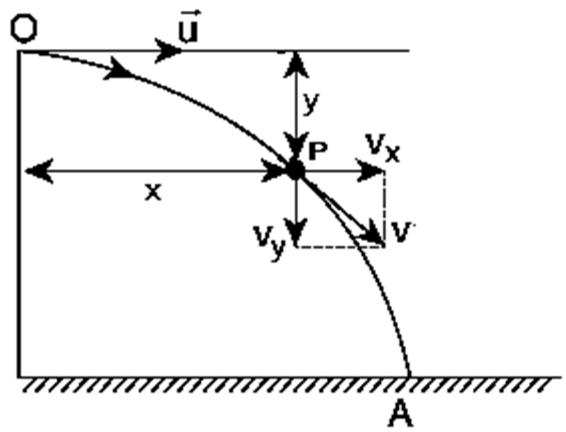
$$v = u - gt$$

$$y = ut - \frac{1}{2}gt^2$$

$$v^2 = u^2 - 2gy$$

11. Obtain the following expressions in the event of horizontal projection of a projectile from the top of a tower of height 'h' (a) the path of the projectile (b) time of flight (c) horizontal range (d) resultant velocity and (e) speed of the projectile when hits the ground.

- Consider an object is thrown horizontally with initial velocity u along x-direction.
- Since acceleration due to gravity acts vertically downwards, velocity along the horizontal x-direction u_x doesn't change throught the motion. Whereas velocity along the y-direction u_y is changed.



(a) The path of the projectile :

(i) Motion along horizontal direction:

- The horizontal distance travelled by the projectile at a point P after a time t can be written as,

$$S_x = u_x t + \frac{1}{2}a_x t^2$$

- Here, $S_x = x$, $u_x = u$ and $a_x = 0$, Therefore,

$$x = ut$$

$$t = \frac{x}{u} \text{ ---------> (1)}$$

(ii) Motion along downward direction:

- The downward distance travelled by the projectile at a point P after a time t can be written as,

$$S_y = u_y t + \frac{1}{2} a_y t^2$$

- Here, $S_y = y$, $u_y = 0$ and $a_y = g$, Therefore,

$$y = \frac{1}{2} g t^2$$

- Substituting equation (1), we get,

$$y = \frac{1}{2} g \left(\frac{x}{u}\right)^2 = \left(\frac{g}{2u^2}\right) x^2$$

$$y = Kx^2 \text{--------> (2)}$$

Where $K = \frac{g}{2u^2}$ is a constant.

- The equation(2) represents the equation of a parabola. Thus, the path travelled by the projectile is a parabola.

(b) Time of flight : (T_f)

- The time of flight(T_f) is the time taken by the projectile to hit the ground after thrown.

- The downward distance travelled by the projectile at a time t can be written as,

$$S_y = u_y t + \frac{1}{2} a_y t^2$$

- Here substituting the values $S_y = h$, $t = T_f$, $u_y = 0$, and $a_y = g$ we get,

$$h = \frac{1}{2} g T_f^2$$

- Therefore, $$\boxed{T_f = \sqrt{\frac{2h}{g}}}$$

(c) Horizontal range : (R)

- The horizontal range(R) is the maximum horizontal distance covered by the projectile from the foot of the tower to the point where the projectile hits the ground.

- The horizontal distance travelled by the projectile at a time t can be written as,

$$S_x = u_x t + \frac{1}{2} a_x t^2$$

- Here, $S_x = R$, $u_x = u$, $a_x = 0$ and $t = T_f$

$$R = uT_f$$

- Therefore, $$\boxed{R = u\sqrt{\frac{2h}{g}}} \qquad \left[\because T_f = \sqrt{\frac{2h}{g}}\right]$$

(d) Resultant Velocity at any time : (v)

- The velocity of the projectile at point p after the time t has two components V_x and V_y.

- The velocity component along x-direction is,

$$v_x = u_x + a_x t$$

Since, $u_x = u$, $a_x = 0$, we get, $v_x = u$

- The velocity component along y-direction is,

$$v_y = u_y + a_y t$$

Since, $u_y = 0$, $a_y = g$, we get, $v_y = gt$

- Hence the resultant velocity at any time t is,

$$\vec{v} = v_x \hat{\imath} + v_y \hat{\jmath}$$

$$\vec{v} = u\,\hat{\imath} + gt\,\hat{\jmath}$$

- The magnitude of resultant velocity or speed is given by,

$$v = \sqrt{v_x^2 + v_y^2}$$

$$\boxed{v = \sqrt{u^2 + g^2 t^2}}$$

(e) Speed of the projectile when hits the ground :

- As the horizontal component of the velocity is same as initial velocity, $v_x = u$

- The vertical component of the velocity at a time t is,

$$v_y = u_y + a_y t$$

- Here $u_y = 0$, $a_y = g$ and $t = T_f$. Substituting this we get,

$$v_y = gT_f$$

or $$v_y = g\sqrt{\frac{2h}{g}}$$

$$v_y = \sqrt{2gh}$$

- The speed of the projectile when hits the ground,

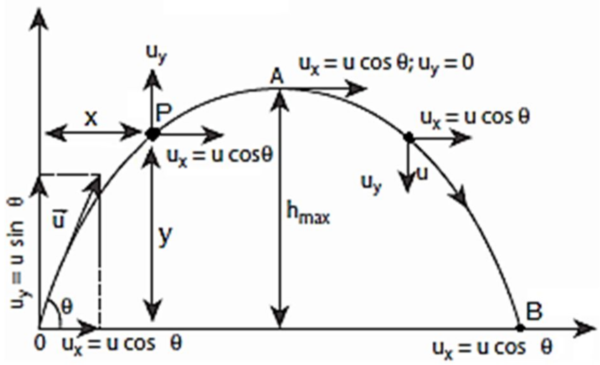
$$v = \sqrt{v_x^2 + v_y^2}$$

$$\boxed{v = \sqrt{u^2 + 2gh}}$$

12. Obtain the following expressions in the event of angular projection of a projectile with the horizontal (a) the path of the projectile (b) maximum height (c) time of flight (d) horizontal range.

- Consider an object is thrown with initial velocity u at an angle θ with the horizontal.

- Since acceleration due to gravity acts vertically downwards, velocity along the horizontal x-direction u_x doesn't change throught the motion. Whereas velocity along the y-direction u_y is changed.



❖ **The path of the projectile :**

(i) Motion along x-direction:

❖ The horizontal distance travelled by the projectile at a point P after a time t can be written as,

$$S_x = u_x t + \frac{1}{2}a_x t^2$$

❖ Here, S_x = x , u_x = u cosθ and a_x = 0, Therefore,

$$x = ucos\theta \cdot t$$

$$t = \frac{x}{ucos\theta} \text{ ---------> (1)}$$

(ii) Motion along y-direction:

❖ The downward distance travelled by the projectile at a point P after a time t can be written as,

$$S_y = u_y t + \frac{1}{2}a_y t^2$$

❖ Here, S_y = y , u_y = u sinθ and a_y = -g , Therefore,

$$y = u\,sin\theta \cdot t - \frac{1}{2}gt^2$$

❖ Substituting equation (1), we get,

$$y = u\,sin\theta \cdot \frac{x}{ucos\theta} - \frac{1}{2}g\left(\frac{x}{ucos\theta}\right)^2$$

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

❖ Thus, the path travelled by the projectile is an inverted parabola.

❖ **Maximum Height : (h_{max})**

❖ The maximum vertical distance travelled by the projectile during its journey is called maximum height.

❖ For the vertical part of the motion,

$$v_y^2 = u_y^2 + 2a_yS_y$$

❖ Here, V_y =0, S_y = h_{max} , u_y = u sinθ and a_y = -g , Therefore,

$$0 = u^2sin^2\theta - 2gh_{max}$$

$$\boxed{h_{max} = \frac{u^2sin^2\theta}{2g}}$$

❖ **Time of flight : (T_f)**

❖ The time of flight(T_f) is the time taken by the projectile to hit the ground after thrown.

❖ The downward distance travelled by the projectile at a time t can be written as,

$$S_y = u_y t + \frac{1}{2}a_y t^2$$

❖ Here substituting the values S_y = 0, t = T_f , u_y = u sinθ , and a_y = -g we get,

$$0 = usin\theta - \frac{1}{2}gT_f^2$$

Therefore, $\boxed{T_f = \frac{2usin\theta}{g}}$

❖ **Horizontal range : (R)**

❖ The horizontal range(R) is the maximum horizontal distance distance between the point of projection and the point where the projectile hits the ground.

❖ The horizontal distance travelled by the projectile at a time t can be written as,

$$S_x = u_x t + \frac{1}{2}a_x t^2$$

❖ Here, S_x = R , u_x = u cosθ , a_x = 0 and t = T_f

$$R = ucos\theta \cdot T_f$$

$$R = ucos\theta \cdot \frac{2usin\theta}{g} = \frac{2u^2sin\theta\,cos\theta}{g}$$

$$\left[\because T_f = \frac{2usin\theta}{g}\right]$$

❖ Therefore, $\boxed{R = \frac{u^2sin2\theta}{g}}$

$$[\because \sin 2\theta = 2sin\,\theta \cdot cos\theta]$$

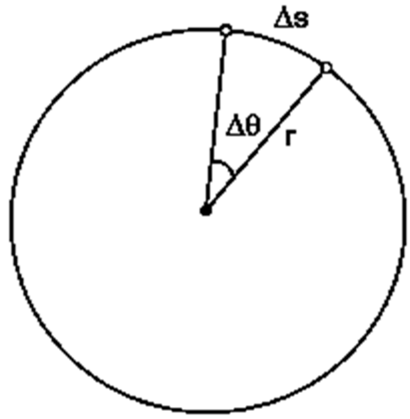
❖ For maximum range, $sin2\theta = 1$

$$2\theta = \frac{\pi}{2}$$

$$\theta = \frac{\pi}{4}$$

The maximum range is, $\boxed{R = \frac{u^2}{g}}$

13. Obtain the relation between linear velocity and angular velocity.



- Consider an object moving along a circle of radius r. In a time Δt, the object travels an arc distance ΔS as shown in figure. The corresponding angle subtended is $\Delta\theta$.
- From figure, the ΔS can be written as,

$$\Delta S = r\Delta\theta$$

- Dividing both sides by Δt, we get,

$$\frac{\Delta S}{\Delta t} = r\frac{\Delta\theta}{\Delta t}$$

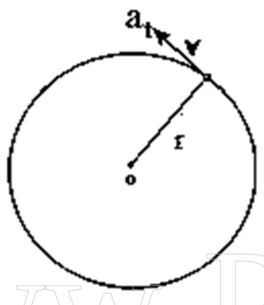
- In the limit $\Delta t \to 0$, the above equation becomes,

$$\frac{dS}{dt} = r\frac{d\theta}{dt}$$

- Here, $v = \frac{dS}{dt}$ and $\omega = \frac{d\theta}{dt}$, therefore,

$$\boxed{v = r\omega}$$

14. Derive an expression for tangential acceleration in the circular motion.



- Consider the circular motion of radius r with linear velocity v and angular velocity ω. In this,

$$v = r\omega$$

- Differentiating the above equation with respect to time, we get,

$$\frac{dv}{dt} = r\frac{d\omega}{dt}$$

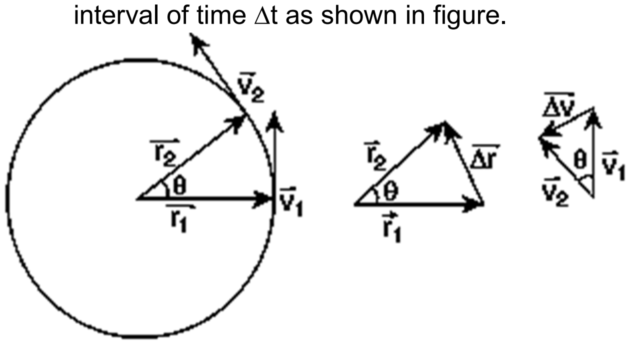
- Here, $a_t = \frac{dv}{dt}$ and $\alpha = \frac{d\omega}{dt}$, therefore,

$$\boxed{a_t = r\alpha}$$

where a_t is the tangential acceleration and α is the angular acceleration

15. Derive an expression for centripetal acceleration in the uniform circular motion.

- Consider the position vectors and velocity vectors shift through the some angle θ in a small interval of time Δt as shown in figure.



- In uniform circular motion,

$$r = |\vec{r_1}| = |\vec{r_2}| \text{ and } v = |\vec{v_1}| = |\vec{v_2}|$$

- From figure, the geometrical relationship between the magnitude of position and velocity vectors is given by,

$$\frac{\Delta r}{r} = -\frac{\Delta v}{v} = \theta$$

- Here the negative sign implies that Δv points radially inward, towards the center of the circle.

$$\Delta v = -v\left(\frac{\Delta r}{r}\right)$$

- Dividing both sides by Δt, we get,

$$\frac{\Delta v}{\Delta t} = -\frac{v}{r}\left(\frac{\Delta r}{\Delta t}\right)$$

- Applying the limit $\Delta t \to 0$, We get,

$$\frac{dv}{dt} = -\frac{v}{r}\left(\frac{dr}{dt}\right)$$

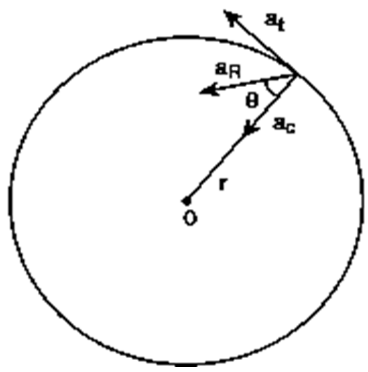
- Since $a_c = \frac{dv}{dt}$ and $v = \frac{dr}{dt}$, We can write,

$$\boxed{a_c = -\frac{v^2}{r}}$$

Where a_c is the centripetal acceleration.

16. Derive an expression for total acceleration in the non-uniform circular motion.

- Consider the non-uniform circular motion of an object. (**Ex:** vertical circular motion)
- In non-uniform circular motion both centripetal and tangential acceleration act on the object as shown in figure.



- The resultant acceleration is obtained by vector sum of centripetal and tangential acceleration.
- Hence, $\vec{a_R} = \vec{a_t} + \vec{a_c}$
- Therefore, the magnitude of resultant acceleration is given by,

$$a_R = \sqrt{a_t^2 + a_c^2}$$

$$\boxed{a_R = \sqrt{a_t^2 + \left(\frac{v^2}{r}\right)^2}} \qquad \left[\because a_c = \frac{v^2}{r}\right]$$

3. Laws of motion

1. State the Newton's first law of motion.

Every body continues its state of rest or in uniform motion until external force acting on it.

2. What is inertia? What are its types?

The inability of an object to change its state of rest or motion.

Types :

- Inertia of rest
- Inertia of motion
- Inertia of direction

3. What is inertia of rest? Give an example.

The inability of an object to change its state of rest is called inertia of rest.

Example:

When a bus start to move from rest position, all the passengers inside the bus suddenly will be pushed back. Here passengers cannot change their state of rest on its own that's why they pushed back.

4. What is inertia of motion? Give an example.

The inability of an object to change its state of motion on its own is called inertia of rest.

Example:

When a bus in motion suddenly braked, all the passengers inside the bus will move forward. Here passengers cannot change their state of motion on its own that's why they moved forward.

5. What is inertia of direction? Give an example.

The inability of an object to change its state of direction on its own is called inertia of rest.

Example:

When a stone attached to a string is in whirling motion suddenly cut out, the stone will move in the tangential direction of the circle. Here the whirling stone cannot change its state of direction on its own that's why it couldn't continue its circular motion.

6. State Newton's second law of motion.

The force acting on an object is equal to the rate of change of its momentum.

7. Define one Newton.

One Newton is defined as the force which acts on 1 kg of mass to give an acceleration 1 ms^{-2} in the direction of the force.

8. State Newton's third law.

For every action there is an equal and opposite reaction.

9. What is free body diagram?

Free body diagram is a simple tool to analyse the motion of the object using Newton's laws.

10. What are the steps followed in developing the free body diagram?

- Identify the forces acting on the object
- Represent the object as a point.
- Draw the vectors representing the forces acting on the object.

11. What is concurrent forces?

The lines of forces acting at a common point are called concurrent forces.

12. What is coplanar forces?

The lines of forces they are in the same plane are called coplanar forces.

.

13. State Lami's theorem.

If a system of three concurrent and coplanar forces is in equilibrium, each force is directly proportional to sine of the angle between the other two forces.

14. State law of conservation of total linear momentum.

If there is no external force acting on the system, the total linear momentum of the system is always a constant vector.

15. What is impulsive force or impulse? Give its unit.

If a very large force acts on an object in a very short time, the force is called impulsive force.Its unit is Ns.

$$J = F \times \Delta t$$

16. Illustrate the average force with the examples.

- When a cricket player catches the ball, he pulls his hands gradually in the direction of the ball's motion because to reduce average large force which hurts his hands.
- When a car meets with an accident, the air bag system inside a car prevents the passengers by reducing average forces acting on them.
- When a two wheeler bumps on the road, the shock absorbers make comfort to rider by reducing average force.
- Jumping on a concrete cemented road is more dangerous than jumping on the sand since the sand reduces the average force on jumping.

17. What is meant by static friction?

Static friction is the force which opposes the initiation of motion of an object on the surface.

18. What is meant by kinetic friction?

Kinetic friction is the force which opposes the motion of an object during movement.

19. Define angle of friction.

The angle of friction is defined as the angle between the normal force(N) and resultant force(R) of normal force and maximum friction force(f_s^{max}).

20. Define angle of repose.

The angle of repose is defined as the angle of the inclined plane at which the object starts to slide.

21. Describe the applications of angle of repose.

- Antilons make sand traps in such way that its angle of inclination is made equal to angle of repose. So that insects enter the edge of the trap start to slide towards the bottom where the antilons hide itself.
- Children sliding boards are always inclined just above the angle of repose. So that children playing on that slide smoothly. At the same time, much greater inclined angle may hurt the sliding children.

22. Compare the static and kinetic friction.

S.No.	Static friction	Kinetic friction
1.	It opposes initiation of motion.	It opposes relative motion of the object with respect to the surface.
2.	Independent of surface contact	Independent of surface contact
3.	μ_s depends on the nature of material in mutual contact.	μ_k depends on the nature of material and temperature of the surface.
4.	Depends on the magnitude of applied force.	Independent of magnitude of applied force.
5.	It takes values from 0 to μ_sN.	It is always equal to μ_kN.
6.	$f_s^{max} > f_k$	$f_k < f_s^{max}$
7.	$\mu_s > \mu_k$	$\mu_k < \mu_s$

23. State the empirical laws of static and kinetic friction.

- The empirical law of static friction states that the static frictional force is directly proportional to the normal force. i.e. $f_s = \mu_s N$ where, $0 \le f_s \le \mu_s N$.
- The empirical law of kinetic friction states that the kinetic frictional force is directly proportional to the normal force. i.e. $f_k = \mu_k N$.

24. What is rolling friction?

The rolling friction is the minimal force, which opposes the rotational motion of the wheel on the surface.

25. What is centripetal force?

If a particle is in uniform circular motion with respect to an inertial frame, there is a force acting towards the center of the circle is called centripetal force.

26. Suggest a few methods to reduce friction.

- By using lubricants in machinary parts.
- By using ball bearings.

27. What is meant by pseudo force?

The pseudo force is a fictitious force. It is just an apparent but it makes real effect. It is represented only in non-inertial frames.

Example : centrifugal force.

28. What are inertial frames?

The frame of reference, which is not accelerated, is known as inertial frame. Newton's laws are applicable in these frames.

29. What are non-inertial frames?

The frame of reference, which is accelerated, is known as non-inertial frame. Newton's laws are not applicable in these frames.

30. Illustrate the centripetal force with the examples.

- In the whirling motion of a stone tied with a string, the centripetal force is given by tensional force through the string.
- In the motion of satellites around the Earth, the gravitational force gives the centripetal force.
- When a car is moving on a circular track, the frictional force between road and tyre gives the centripetal force.
- When the planets orbit around the Sun experience the centripetal force towards the sun is given by the gravitational force of the Sun.

31. What is meant by banking of tracks?

When the coefficient of static friction is not enough on the leveled circular road, the outer edge of the road is slightly raised compared to the inner egde to avoid skidding. It is called banking of tracks.

32. What is centrifugal force?

If a particle is in circular motion with respect to a non-inertial frame, there is a pseudo force acting away from the center of the circle is called centrifugal force.

33. Compare the centripetal and centrifugal forces.

S.No.	Centripetal force	Centrifugal force
1.	It is a real force given by external agencies like gravitational force, tensional force, normal force,etc.	It is a pseudo force or fictitious force cannot be derived from any external agencies.
2.	Acts in both inertial and non-inertial frames	Acts only in non-inertial frames(rotating frames)
3.	It acts towards the axis of rotation or center of the circular motion.	It acts away from the axis of rotation or center of the circular motion
4.	Real force and has real effects.	Pseudo force but has real effects.
5.	It orginates from interaction of two objects	It orginates from inertia of the object.
6.	It is included in free body diagram for both inertial and non-inertial frames.	It is included in free body diagram for only non-inertial frames.
7.	Magnitudely it is equal to centrifugal force.	Magnitudely it is equal to centripetal force.

Conceptual Questions:

34. Why it is not possible to push a car from inside?

It is not possible to push a car from inside because the pushing force is equalised by the reactional force of the car seat.

35. There is a limit beyond which polishing of a surface increases frictional resistance rathar than decreasing it why?

Polishing the surface beyond the certain limit induces the electrostatic addisive force on the surface, which will inturn developes the frictional resistance.

36. Can a single isolated force exist in nature? Explain your answer.

No. It cannot. According to Newton's third law "For every action there is an equal and opposite reaction". So the forces always exist in pairs.

37. Why does a parachute descend slowly?

The large area covered by the parachute experiences more air resistive force acting opposite to downward gravitational force. So that the parachute descends slowly.

38. When we walk on ice one should take short steps. Why?

As the surface of the ice is very smooth, in order to avoid skidding, short steps help us to make necessary static friction to walk.

39. When a person walks on a surface, the frictional force exerted by the surface on the person is opposite to the direction of motion. True or false?

False. When the person walks on the surface, he pushes the surface backward, whereas surface gives frictional force forward which is in the direction of motion.

40. Can the coefficient of friction be more than one?

Yes. The coefficient of friction can be more than one. It means friction is greater than normal force. For example, rubber has coefficient of friction 1.16.

41. Can we predict the direction of motion of a body from the direction of force on it?

No. It cannot. The direction of motion can be along the direction of force or opposite to force or perpendicular force or without the force.

42. The momentum of a system of particle is always conserved. True or false?

False. The momentum of a system of particle is conserved only when external force acting on it is zero.

43. When you walk on the tiled floor where water is spilled, you are likely to slip. Why?

Water on tiled floor reduces the coefficient of friction of the surface. So when we walk on wet tile, it drags our leg to slide. Now the friction becomes kinetic friction, which is much weaker than static friction. That's why we likely to slip.

44. When a bicycle moves in the forward direction, what is the direction of frictional force in the rear and front wheels?

- When a bicycle moves in the forward direction, static friction in the rear wheel acts forward.
- So that front wheel gets backward static friction. When wheels slip friction becomes kinetic friction.
- In addition to static friction, rolling friction also acts both wheels in the backward direction.

45. Under What condition will a car skid on a leveled circular road?

When a car moves on a leveled circular road with greater speed, static friction given by road not able provide enough centripetal force to turn. So that car will start to skid.

46. It is dangerous to stand near the open door (or) steps while travelling in the bus. Why?

When the bus takes sudden turn, the person standing near the open door or steps is pushed away from the bus due to centrifugal force.

5 Marks Q & A:

1. Discuss the significance of Newton's laws.

(a) Newton's laws are vector laws.

- From Newton's 2nd law, $\vec{F} = m\vec{a}$
- It can be written in the components as,

$$F_x\hat{\imath} + F_y\hat{\jmath} + F_z\hat{k} = ma_x\hat{\imath} + ma_y\hat{\jmath} + ma_z\hat{k}$$

- By comparing components on both sides,
- $F_x = ma_x$. The acceleration along x-direction depends on component of force along x direction.
- $F_y = ma_y$. The acceleration along y-direction depends on component of force along y direction.
- $F_z = ma_z$. The acceleration along z-direction depends on component of force along z direction.
- So that Force acting along one direction doesn't affect force acting along the other direction.

(b) The acceleration experienced by the body at time depends only on the force at that instant.

- Time dependent force can be written as,

$$\vec{F}(t) = m\vec{a}(t)$$

- So that acceleration of the object doesn't depend on the previous history of the force.
- For example, when a ball is bowled, the acceleration of the ball leaves the hand doesn't depend on the force in which it is bowled.

(c) Direction of motion doesn't depend on the direction of force.

Case(i): Force and motion in the same direction.

When an apple falls from a tree, direction of motion of the apple is along the gravitational force.

Case(ii): Force and motion not in the same direction.

The Moon experiences a force in different direction when it revolves elliptically around the Earth.

Case(iii): Force and motion in the opposite direction.

If an object is thrown vertically upwards, the direction of motion and gravitational force are opposite.

Case(iv): Zero net force, but there is motion.

When a raindrop gets detached from the cloud, downward gravitational force is equalised by the air drag (viscous) force in upward direction in certain time. Now raindrops moves with constant velocity without the net force till the surface of the Earth.

(d) Net force of multiple forces provides acceleration.

If multiple forces $\vec{F_1}, \vec{F_2}, \vec{F_3}, \ldots \vec{F_n}$ act on the same body, then the total force ($\vec{F}_{net}$) is equal to the vector sum of the individual forces. Their net force provides the acceleration.

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \cdots + \vec{F}_n$$

(e) Newton's 2nd law is second order differential equation

- Since the acceleration is the second order derivative of position vector of the body, i.e. $\left[\vec{a} = \frac{d^2\vec{r}}{dt^2}\right]$ the force can be written as,

$$\vec{F} = m\vec{a} = m\frac{d^2\vec{r}}{dt^2}$$

- So that Newton's 2nd law is second order differential equation.

(f) Newton's first and second laws are internally consistent.

- If force acting on the body is zero, according to Newton's 2nd law,

$$m\frac{d\vec{v}}{dt} = 0$$

- It implies $\vec{v}$ = constant. It is essentially Newton's first law. Though Newton's 2nd law is internally consistent with first law, it cannot be derived from each other.

(g) Newton's second law is cause and effect relation.

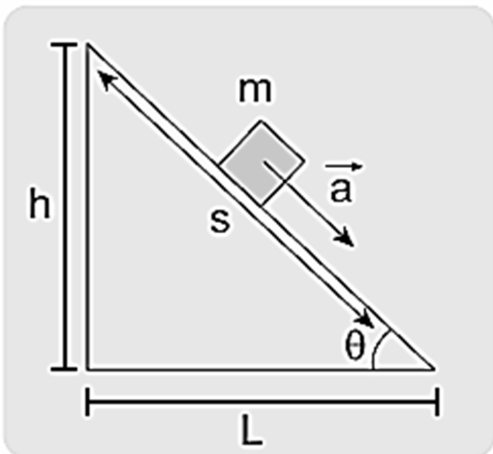
- Since Newton's 2nd law is cause and effect relation, conventionally cause (Force) should be written in right and effect ($m\vec{a}$) in the left of the equation.

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

$$\frac{d\vec{p}}{dt} = \vec{F}$$

2. Obtain the expressions for acceleration and speed of an object moving in an inclined plane.

- When an object of mass m slide on a frictionless inclined surface at an angle θ.
- The forces acting on the object is (i) Downward gravitational force (ii) Normal force perpendicular to the inclined surface.



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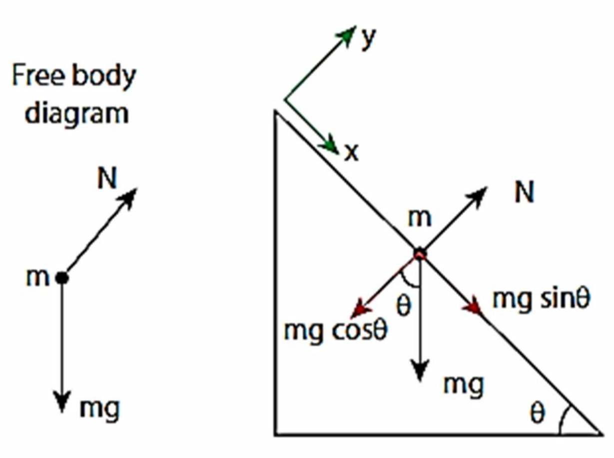
- To draw free body diagram the block is assumed to be point mass. Now the coordinate system is taken parallel to inclined surface.
- The gravitational force mg is resolved into mgsinθ and mgcosθ. They are parallel and perpendicular to inclined surface respectively.
- The angle made by the mg with mg cosθ is θ as shown in figure.



- As the normal force N is compensated by mgcosθ, there is no motion along y-axis.

$$-mgcos\theta\hat{j} + N\hat{j} = 0$$
$$N\hat{j} = mgcos\theta\hat{j}$$

- Comparing components on both sides,

$$N = mgcos\theta$$

- Since the component mgsinθ is not compensated by any force, the object starts to slide along x-direction. By using Newton's 2nd law, We write,

$$mgsin\theta\hat{i} = ma\hat{i}$$

- Comparing components on both sides,

$$mgsin\theta = ma$$

- The acceleration of the object is, $\boxed{a = gsin\theta}$
- If θ =90⁰ , the object moves vertically downward with acceleration *a = g* .
- Applying 3rd equation of motion along x-direction, we get,

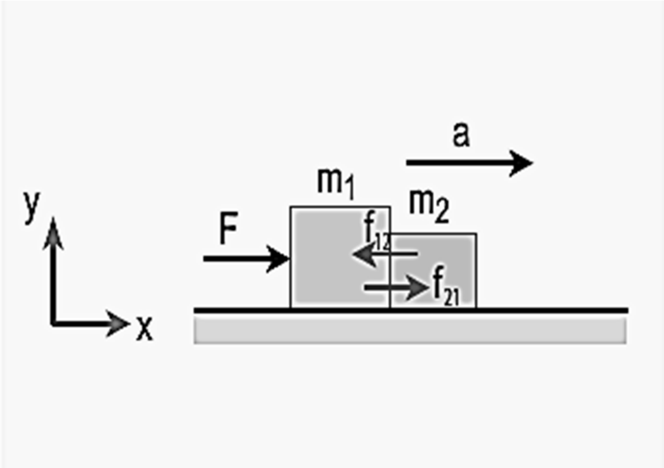
$$v^2 = u^2 + 2aS$$

- Here the initial speed u = 0 and a = gsinθ , the speed of the object sliding can written as,

$$\boxed{v = \sqrt{2Sg\ sin\theta}}$$

3. Obtain the expressions for acceleration of two bodies of different masses and show that forces acting on each other is equal and opposite.

- Consider two blocks of masses m_1 and m_2 ($m_1>m_2$) kept in contact with each other on horizontal frictionless surface as shown in figure.



- By the application of a horizontal force F, both the blocks move with acceleration a simultaneously along F.
- If m = m_1 + m_2 , according to Newton's 2nd law,

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

- If motion is along x-direction,

$$F\hat{i} = ma\hat{i}$$

- Comparing the components on both sides,

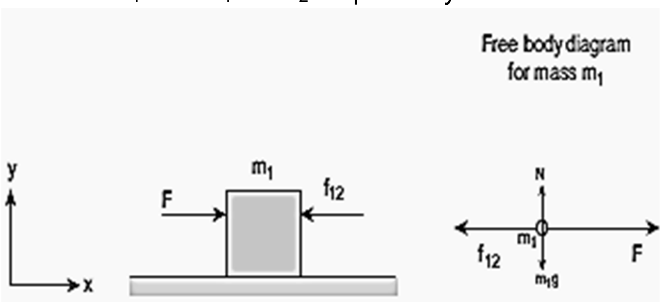
$$F = ma$$
$$F = (m_1 + m_2)a \quad [m = m_1 + m_2]$$

- The acceleration of the system is given by,

$$\boxed{a = \frac{F}{m_1 + m_2}}$$

<u>Proof :</u> **Forces acting on each other is equal and opposite.**

- Let F_{12} and F_{21} are forces of contact exerted by m_2 on m_1 and m_1 on m_2 respectively.



- According to the above free body diagram,

$$F\hat{i} - f_{12}\hat{i} = m_1a\hat{i}$$

- By comparing the components, we get,

$$F - f_{12} = m_1a$$
$$f_{12} = F - m_1a$$

- Substituting the value of 'a', we get,

$$f_{12} = F - m_1\left(\frac{F}{m_1 + m_2}\right)$$

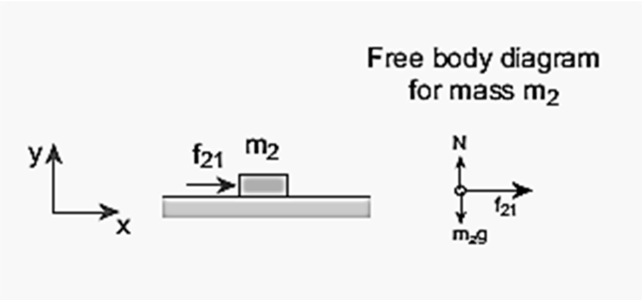
$$f_{12} = F\left[1 - \frac{m_1}{m_1+m_2}\right]$$

$$f_{12} = \frac{Fm_2}{m_1+m_2}$$

- In vector form, the contact force on m_1 by m_2 is given by,

$$\boxed{\vec{f}_{12} = -\frac{Fm_2}{m_1+m_2}\hat{\imath}}$$

The –ve sign indicates that $\vec{f}_{12}$ is along negative x-direction.



- According to the above free body diagram,

$$f_{21}\hat{\imath} = m_2 a\hat{\imath}$$

- By comparing the components, we get,

$$f_{21} = m_2 a$$

- Substituting the value of 'a', we get,

$$f_{21} = \frac{Fm_2}{m_1+m_2}$$

- In vector form, the contact force on m_1 by m_2 is given by,

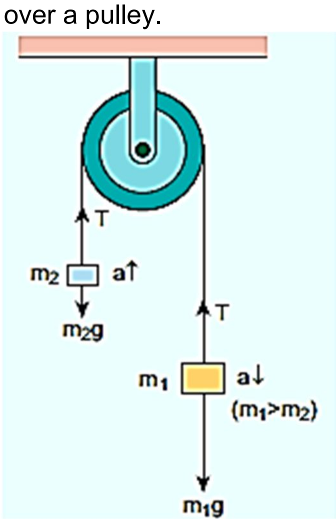
$$\boxed{\vec{f}_{21} = \frac{Fm_2}{m_1+m_2}\hat{\imath}}$$

$\vec{f}_{21}$ is along positive x-direction.

- Therefore, $\vec{f}_{12} = -\vec{f}_{21}$, which confirm Newton's 3rd law.

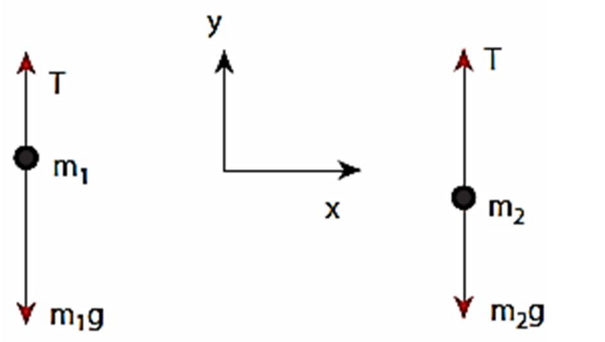
4. Explain the motion of blocks connected by a string in verticle direction.

- Consider two blocks of masses m_1 and m_2 ($m_1>m_2$) are connected by a light inextensible string that passes over a pulley.



- Let T be the tension in the string. When the system is released m_1 moves downward and m_2 moves upward with the same acceleration 'a'.

Free body diagram



(a) To find acceleration:

- Applying Newton's 2nd law for m_2, we get,

$$T\hat{\jmath} - m_2 g\hat{\jmath} = m_2 a\hat{\jmath}$$

- Comparing the components on both sides,

$$T - m_2 g = m_2 a \quad \text{------> (1)}$$

- Applying Newton's 2nd law for m_1, we get,

$$T\hat{\jmath} - m_2\hat{\jmath} = -m_1 a\hat{\jmath}$$

The –ve sign on R.H.S denotes m_1 moves along the negative y-direction.

- Comparing the components on both sides,

$$T - m_2 g = -m_1 a$$

$$m_2 g - T = m_1 a \quad \text{-------> (2)}$$

- Adding equations (1) & (2), we get,

$$m_1 g - m_2 g = m_1 a + m_2 a$$

$$(m_1 - m_2)g = (m_1 + m_2)a$$

$$\boxed{a = \left(\frac{m_1-m_2}{m_1+m_2}\right)g} \longrightarrow (3)$$

- If $m_1 = m_2$, then a = 0. It shows if masses are equal whole system will be at rest.

- In vector form, $\vec{a} = \left(\frac{m_1-m_2}{m_1+m_2}\right)g\,\hat{\jmath}$ for m_1

$$\vec{a} = -\left(\frac{m_1-m_2}{m_1+m_2}\right)g\,\hat{\jmath} \quad \text{for } m_2$$

(b) To find the tension in the string :

- Substituting equation (3) in (1), we get,

$$T - m_2 g = m_2\left(\frac{m_1-m_2}{m_1+m_2}\right)g$$

$$T = m_2 g + m_2\left(\frac{m_1-m_2}{m_1+m_2}\right)g$$

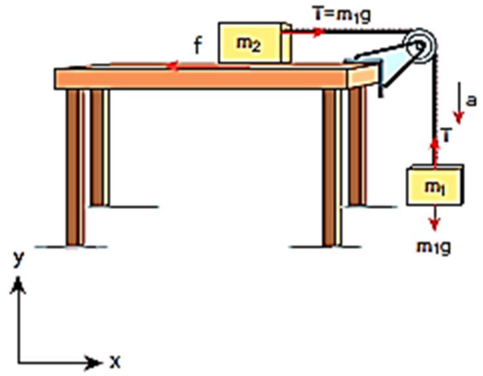
$$T = m_2 g\left(1 + \frac{m_1-m_2}{m_1+m_2}\right)$$

$$T = m_2 g\left(\frac{m_1+m_2+m_1-m_2}{m_1+m_2}\right)$$

$$\boxed{T = \left(\frac{2m_1 m_2}{m_1+m_2}\right)g}$$

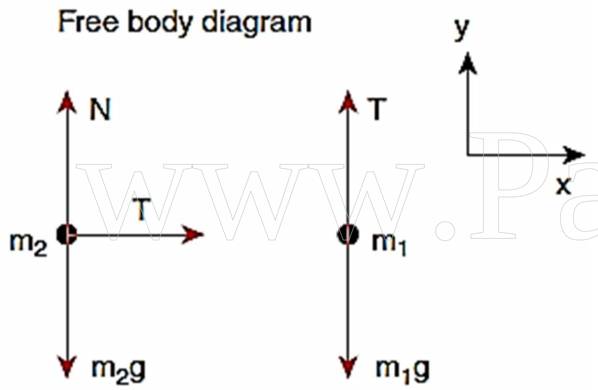
5. **Explain the motion of blocks connected by a string in horizontal direction.**

- Consider the m_2 is kept on a frictionless horizontal table.The mass m_2 is connected with hanging mass m_1 by a string which pass through a small pulley as shown in figure.



- As both the blocks are connected to the unstretchable string, m_1 moves downward and m_2 moves horizontal with same acceleration.

- Forces acting on m_1 and m_2 are as shown in free body diagram.



- Applying Newton's 2nd law for m_1, we get,

$$T\hat{j} - m_1 g\hat{j} = m_1 a\hat{j}$$

- Comparing the components on both sides,

$$T - m_1 g = m_1 a \quad \text{------> (1)}$$

- Applying Newton's 2nd law for m_2, we get,

$$T\hat{i} = m_2 a\hat{i}$$

- Comparing the components on both sides,

$$T = m_2 a \quad \text{------> (2)}$$

- As gravitation force on m_2 and Normal force are balanced, there is no vertical acceleration in m_2.

$$N\hat{j} - m_2 g\hat{j} = 0$$

- Comparing the components on both sides,

$$N - m_2 g = 0$$
$$N = m_2 g$$

- Substituting equation (2) in (1), we get,

$$m_2 a - m_1 g = m_1 a$$
$$m_2 a + m_1 a = m_1 g$$

$$\boxed{a = \left(\frac{m_1}{m_1 + m_2}\right) g} \quad ---\rightarrow (3)$$

- Substituting equation (3) in (2), we get,

$$\boxed{T = \left(\frac{m_1 m_2}{m_1 + m_2}\right) g}$$

- It is shown that tension in the string for horizontal motion is half that in vertical motion for same m_1 and m_2.

6. **State and Prove the law of conservation of linear momentum.**

- **Statement :** If there is no external force acting on the system, the total linear momentum of the system is always a constant vector.

- When two particles interact with each other, F_{12} and F_{21} are the forces exerted by the particle 2 on 1 and by the particle 1 on 2 respectively.

- According to Newton's 3rd law,

$$\vec{F}_{12} = -\vec{F}_{21} \text{------->(1)}$$

- According to Newton's 2nd law,

$$\vec{F}_{12} = \frac{d\vec{p}_1}{dt} \quad and \quad \vec{F}_{21} = \frac{d\vec{p}_2}{dt} \quad --\rightarrow (2)$$

Here p_1 and p_2 are the linear momentum of particle 1 and 2.

- Substituting equation (2) in (1), we get,

$$\frac{d\vec{p}_1}{dt} = -\frac{d\vec{p}_2}{dt}$$
$$\frac{d\vec{p}_1}{dt} + \frac{d\vec{p}_2}{dt} = 0$$
$$\frac{d}{dt}(\vec{p}_1 + \vec{p}_2) = 0$$

$$\boxed{\vec{p}_1 + \vec{p}_2 = constant}$$

- Hence the the total linear momentum ($\vec{p}_1 + \vec{p}_2$) of the system is a constant vector.

7. **Using conservation of linear momentum, find the recoil velocity of a gun when a bullet is fired from it.**

- Consider $\vec{p}_1$ and $\vec{p}_2$ are the initial momentum of a bullet and a gun before firing.

- Since initially both the gun and bullet are at rest,

$$\vec{p}_1 = 0 \;\; and \;\; \vec{p}_2 = 0$$

- Hence, total linear momentum before firing can be written as,

$$\vec{p}_1 + \vec{p}_2 = 0$$

- When the gun is fired, the momentum of the bullet changes from $\vec{p}_1$ to $\vec{p}_1'$ and the momentum of the gun changes from $\vec{p}_2$ to $\vec{p}_2'$.
- According to conservation of linear momentum, total linear momentum after firing must be equal to total linear momentum before firing. So that,

$$\vec{p}_1' + \vec{p}_2' = 0 \text{ ------> (1)}$$

- Let m_b & m_g are the mass of the bullet and the gun and v_b & v_g are the velocity and recoil velocity of the bullet and the gun respectively.
- Hence $\vec{p}_1'$ and $\vec{p}_2'$ can be written as,

$$\vec{p}_1' = m_b\vec{v}_b \quad \text{and} \quad \vec{p}_2' = m_g\vec{v}_g$$

- Substituting the valus of $\vec{p}_1'$ and $\vec{p}_2'$ in equation (1), we get,

$$m_b\vec{v}_b + m_g\vec{v}_g = 0$$

- Hence, the recoil velocity of the gun is given by,

$$\boxed{\vec{v}_g = -\frac{m_b}{m_g} \times \vec{v}_b}$$

8. Obtain the impulse – momentum equation.

- If a large force F acts on a object in a very short time dt, Newton's 2nd law can be written as,

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

$$dp = F\,dt$$

- Integrating over the time from an initial time t_i to a final time t_f, we get

$$\int_{p_i}^{p_f} dp = \int_{t_i}^{t_f} F\,dt$$

Here p_i and p_f are the initial and final momentum at time t_i and t_f .

- If force F is constant over the time interval, then

$$\int_{p_i}^{p_f} dp = F\int_{t_i}^{t_f} dt$$

$$p_f - p_i = F(t_f - t_i)$$

$$\boxed{\Delta p = F\Delta t} \text{------>(1)}$$

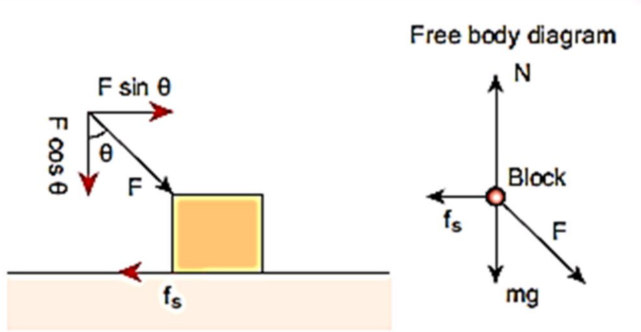
$$\Delta p = J \qquad [\because J = F\,\Delta t]$$

- Here $\Delta p = p_f - p_i$, change in momentum and $\Delta t = t_f - t_i$, time interval.
- The equation (1) is called momentum – impulse equation.

9. Using free body diagram, show that it is easy to pull an object than push it.

(a) Pushing an object :

- When an object is pushed at an arbitrary angle θ, the applied force F can be resolved into two components as shown in figure.



- From the diagram the normal force N is balance by the total downward force mg + Fcosθ. Thus,

$$N_{push} = mg + F\cos\theta$$

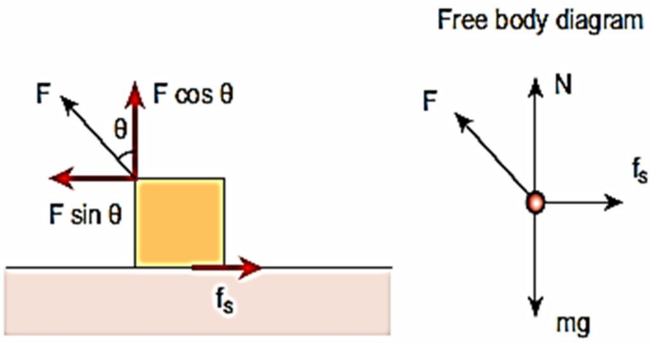
- In this case, maximum static friction f_s^{max} can be written as,

$$f_s^{max} = \mu_s N_{push}$$

$$f_s^{max} = \mu_s (mg + F\cos\theta) \text{ --->(1)}$$

(b) Pulling an object :

- When an object is pulled at an arbitrary angle θ, the applied force F can be resolved into two components as shown in figure.



- From the diagram the normal force N is balance by the total downward force mg - Fcosθ. Thus,

$$N_{pull} = mg - F\cos\theta$$

- In this case, maximum static friction f_s^{max} can be written as,

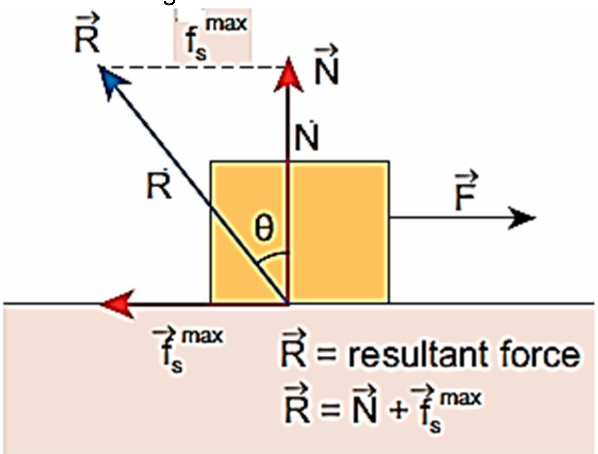
$$f_s^{max} = \mu_s N_{pull}$$

$$f_s^{max} = \mu_s (mg - F\cos\theta) \text{--->(2)}$$

- From equation (1) and (2), to overcome f_s^{max} and to move the object, it is easier to pull an object than to push it.

10. Prove that the coefficient of static friction is equal to tangent of the angle of friction.

- Let N be the normal force, f_s^{max} be the maximum friction force, R be the resultant force of N and f_s^{max} and θ be the angle between R and f_s^{max} as shown in figure.



- From the figure, the resultant force is given by,

$$R = \sqrt{(f_s^{max})^2 + N^2}$$

- And from the figure,

$$tan\theta = \frac{f_s^{max}}{N}$$

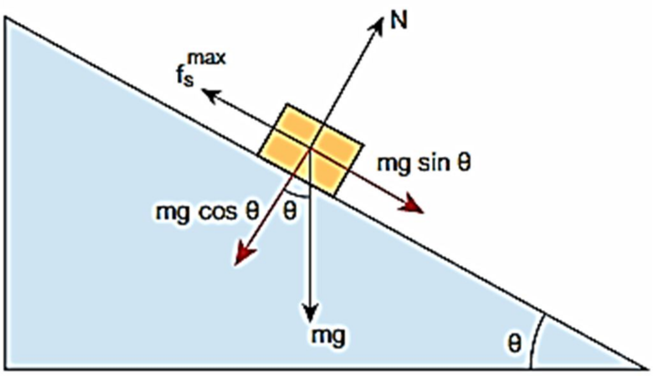
- Since $f_s^{max} = \mu_s N$, $\mu_s = \frac{f_s^{max}}{N}$
- Hence, $tan\theta = \mu_s$

or $$\boxed{\mu_s = tan\theta}$$

- Therefore, the coefficient of static friction is equal to tangent of the angle of friction.

11. Show that in an inclined plane, the angle of friction is equal to angle of repose.

- Consider an inclined plane on which an object is placed as shown in figure.



- Let θ be the angle of inclined plane with the horizontal, which is made equal to the angle of repose. So that the object placed on it start to slide.
- From the figure, the component mg cosθ is balanced by Normal force N can be written as,

$$N = mg\,cos\theta$$

- When the object start to slide, the maximum static friction is given by,

$$f_s^{max} = \mu_s N$$
$$f_s^{max} = \mu_s\, mg\, cos\theta \text{ ----->(1)}$$

- From the figure, f_s^{max} can also be wrtten as,

$$f_s^{max} = mg\, sin\theta \text{ ----->(2)}$$

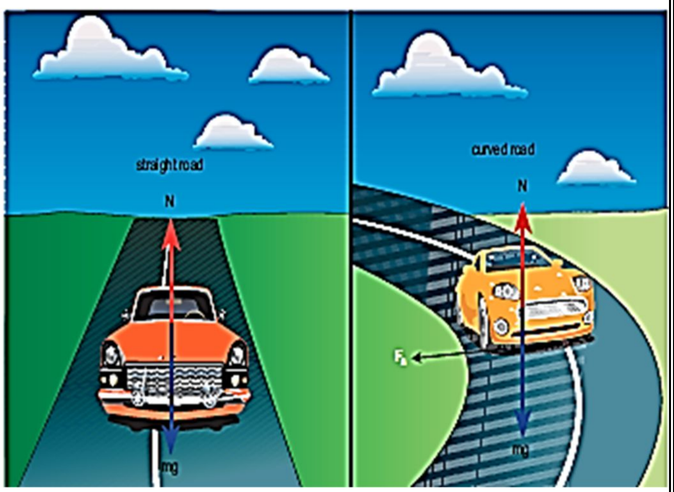
- Equating equation (1) and (2), we get

$$\mu_s\, mg\, cos\theta = mg\, sin\theta$$
$$\mu_s = \frac{sin\theta}{cos\theta}$$
$$\boxed{\mu_s = tan\theta} \text{ ------> (3)}$$

- It shows that equation (3) is like the definition of angle of friction $\mu_s = tan\theta$ where θ is the angle of friction.
- Thus, the angle of repose θ in equation (3) is same as the angle of friction.

12. Obtain the conditions for safe and unsafe(skid) turn of a car on a leveled circular road.

- Consider a car of mass 'm' moving at a speed 'v' in the circular track of radius 'r'.



- When the car is on the road, the normal force N is balanced by gravitational force mg is given by,

$$N = mg$$

- When the car turns on the circular track, the static friction provides the centripetal force can be expressed as,

$$\frac{mv^2}{r} = F_s$$

- As we know, $F_s \le \mu_s mg$, there are two conditions possible.

(a) For safe turn :

$$\frac{mv^2}{r} \le \mu_s mg \quad (or) \quad \mu_s \ge \frac{v^2}{rg} \quad (or) \quad \sqrt{\mu_s rg} \ge v$$

- In this case static friction gives necessary centripetal force to bend the car on the road.
- Here the co-efficient of friction between tyre and the surface of the road determines what maximum speed the car can have for safe turn.

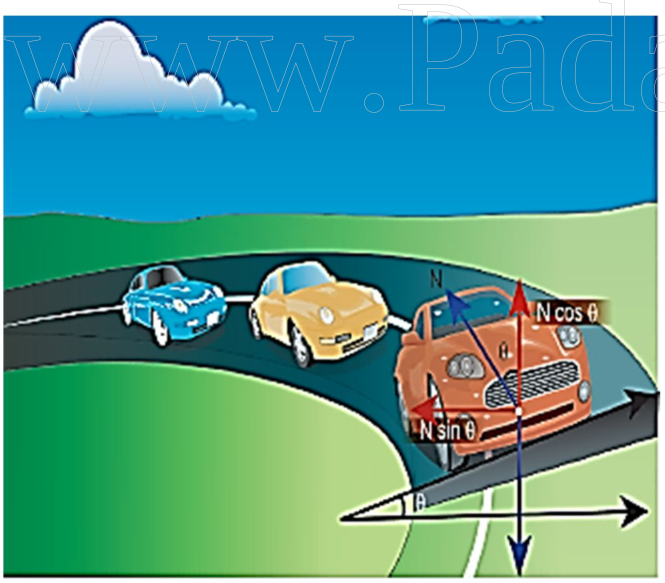
(b) For unsafe(skid) turn :

$$\frac{mv^2}{r} > \mu_s mg \quad (or) \quad \mu_s < \frac{v^2}{rg}$$

- In this case, static friction is not able to provide enough centripetal force to turn, the car will start to skid.

13. Obtain the expression for safe speed of a car when it turns on a banking of tracks and discuss how it prevents from skidding.

- Consider a banking of track, whose outer edge is raised at an angle θ with the horizontal as shown in figure.



- So that the normal force makes same angle θ with the vertical, can be resolved into N cosθ and N sinθ
- From the diagram, the component N cosθ is balanced by mg is written as,

$$N\cos\theta = mg \quad \text{-----> (1)}$$

- From the diagram, the centripetel force is given by N sinθ can be written as,

$$N\sin\theta = \frac{mv^2}{r} \longrightarrow (2)$$

- Dividing equation (2) by (1), we get

$$\tan\theta = \frac{v^2}{rg}$$

$$v = \sqrt{rg\tan\theta}$$

- The banking angle θ and radius of curvature of the road or track(r) determines the safe speed of the car at the turning.
- When the car just exceeds the safe speed, it will start to skid outward but the frictional force will provide additional centripetal force to prevent the outward skidding.
- When the car little slows the safe speed, it will start to skid inward but frictional force will reduce centripetal force to prevent the inward skidding.
- However, frictional force cannot prevent the car from skidding when the car speed is much greater than the safe speed.