1.1. Which of the following are equivalent?
(a) 6400 km and $6.4 \times 10^8$ cm
(b) $2 \times 10^4$ cm and $2 \times 10^6$ mm
(c) 800 m and $80 \times 10^2$ m
(d) $100 \, \mu m$ and 1 mm

1.2 Red light has a wavelength of 7000 Å. In μm it is
(a) 0.7 μm
(b) 7 μm
(c) 70 μm
(d) 0.07 μm

1.3 A speck of dust weighs $1.6 \times 10^{-10}$ kg. How many such particles would weigh 1.6 kg?
(a) $10^{10}$
(b) $10^{10}$
(c) 10
(d) $10^{-1}$

1.4 The force acting on a particle is found to be proportional to velocity. The constant of proportionality is measured in terms of
(a) kg s$^{-1}$
(b) kg s
(c) kg m s$^{-1}$
(d) kg m s$^{-2}$

1.5 The number of significant digits in 0.0006032 is
(a) 8
(b) 7
(c) 4
(d) 2

1.6 The length of a body is measured as 3.51 m. If the accuracy is 0.01 m, then the percentage error in the measurement is
(a) 351 %
(b) 1 %
(c) 0.28 %
(d) 0.035 %

1.7 The dimensional formula for gravitational constant is
(a) M$^1$L$^3$T$^{-2}$
(b) M$^{-1}$L$^1$T$^2$
(c) M$^{-1}$L$^3$T$^{-2}$
(d) M$^1$L$^{-3}$T$^2$

1.8 The velocity of a body is expressed as $v = (x/t) + yt$. The dimensional formula for x is
(a) ML$^0$T$^0$
(b) M$^0$L$^0$T$^0$
(c) M$^0$L$^T$
(d) M$^0$L$T^0$

1.9 The dimensional formula for Planck’s constant is
(a) MLT
(b) M$^3$T$^2$
(c) ML$^T^i$
(d) ML$^2$T$^{-1}$
1.10___________have the same dimensional formula
(a) Force and momentum    (b) Stress and strain
(c) Density and linear density   (d) Work and potential energy

**Two mark questions**

1. Distinguish between fundamental units and derived units.
2. Why SI system is considered superior to other systems?
3. What is the need for measurement of physical quantities?
4. You are given a wire and a metre scale. How will you estimate the diameter of the wire?
5. Name four units to measure extremely small distances.
6. What are random errors? How can we minimise these errors?
7. Show that _______ has the same dimensions of distance.
8. What are the limitations of dimensional analysis?
9. What are the uses of dimensional analysis? Explain with one example.
10. What is physics?
11. What is called Mechanics?
13. What are the different types of forces in nature?
14. What is the importance of physical quality? What are its types?
15. Define unit of a physical quantity.
16. What is coherent system of units?
17. What is the SI unit of current? Define it.
18. Define one Kelvin.
19. Define one Candela.
20. Define one Mole.
22. What is Astronomical unit? Give its value.
23. What are the methods adopted for measuring large distances?
25. Distinguish quartz clock from atomic clock.
26. What are instrumental errors? How are they measured?
27. What is constant error?
28. How are the Gross errors and random errors are minimized.
29. What are dimensions of a physical quantity ?
30. What are Dimensional and Dimensionless Quantities ? Give examples.
31. State the principle of homogeneity of Dimensions.
32. Prove that \( a \) has the dimension of velocity.
33. What is torque ? What is its dimension ?
34. Name the quantities which have the following dimension.
35. Prove the dimension of the equation \( \lambda = \) where \( h \) is a Planck’s constant
{dimension of \( h \) is \( ML^2T^{-1} \)}

Three mark questions
1. What is the role of Physics in technology?
2. Write a note on the basic forces in nature.
3. Give the SI standard for (i) length (ii) mass and (iii) time.
4. Define Errors . Explain the all types of errors.

Five mark questions
1. Give the rules and conventions followed while writing SI units.
2. What are the uses of dimensional analysis? Explain with example.

Solved Problems
1.1 A laser signal is beamed towards a distant planet from the Earth and its reflection is received after seven minutes. If the distance between the planet and the Earth is \( 6.3 \times 10^{10} \) m, calculate the velocity of the signal.
1.2 A goldsmith put a ruby in a box weighing 1.2 kg. Find the total mass of the box and ruby applying principle of significant figures. The mass of the ruby is 5.42 g.
1.3 Check whether the equation \( \lambda = \) is dimensionally correct
(\( \lambda \) - wavelength, \( h \) - Planck’s constant, \( m \) - mass, \( v \) - velocity).
1.4 Multiply 2.2 and 0.225. Give the answer correct to significant figures.
1.5 Convert 76 cm of mercury pressure into N m\(^{-2}\) using the method of dimensions.
Book back Problems

1.24 How many astronomical units are there in 1 metre?
1.25 If mass of an electron is $9.11 \times 10^{-31}$ kg how many electrons would weigh 1 kg?
1.26 In a submarine fitted with a SONAR, the time delay between generation of a signal and reception of its echo after reflection from an enemy ship is observed to be 73.0 seconds. If the speed of sound in water is 1450 m s$^{-1}$, then calculate the distance of the enemy ship.
1.27 State the number of significant figures in the following:
(i) 600900 (ii) 5212.0 (iii) 6.320 (iv) 0.0631 (v) $2.64 \times 10^{24}$
1.28 Find the value of $\pi^2$ correct to significant figures, if $\pi = 3.14$.
1.29 5.74 g of a substance occupies a volume of 1.2 cm$^3$. Calculate its density applying the principle of significant figures.
1.30 The length, breadth and thickness of a rectangular plate are 4.234 m, 1.005 m and 2.01 cm respectively. Find the total area and volume of the plate to correct significant figures.
1.31 The length of a rod is measured as 25.0 cm using a scale having an accuracy of 0.1 cm. Determine the percentage error in length.
1.32 Obtain by dimensional analysis an expression for the surface tension of a liquid rising in a capillary tube. Assume that the surface tension $T$ depends on mass $m$ of the liquid, pressure $P$ of the liquid and radius $r$ of the capillary tube (Take the constant $k =$).
1.33 The force $F$ acting on a body moving in a circular path depends on mass $m$ of the body, velocity $v$ and radius $r$ of the circular path. Obtain an expression for the force by dimensional analysis (Take the value of $k = 1$).
1.34 Check the correctness of the following equation by dimensional analysis
(i) $F = \text{kg}$ where $F$ is force, $m$ is mass, $v$ is velocity and $r$ is radius
(ii) $n = \text{m}$ where $n$ is frequency, $g$ is acceleration due to gravity and $l$ is length.
(iii) $= \text{m}$ where $m$ is mass, $v$ is velocity, $g$ is acceleration due to gravity and $h$ is height.
1.35 Convert using dimensional analysis
(i) kmph into m s$^{-1}$
(ii) m s$^{-1}$ into kmph
(iii) 13.6 g cm$^{-3}$ into kg m$^{-3}$
Self evaluation

2.1. A particle at rest starts moving in a horizontal straight line with uniform acceleration. The ratio of the distance covered during the fourth and the third second is

(a) (b) (c) (d) 2

2.2. The distance travelled by a body, falling freely from rest in one, two and three seconds are in the ratio

(a) 1 : 2 : 3 (b) 1 : 3 : 5 (c) 1 : 4 : 9 (d) 9 : 4 : 1

2.3. The displacement of the particle along a straight line at time t is given by, \( x = a_0 + a_1 t + a_2 t^2 \) where \( a_0, a_1 \) and \( a_2 \) are constants. The acceleration of the particle is

(a) \( a_0 \) (b) \( a_1 \) (c) \( a_2 \) (d) \( 2a_2 \)

2.4. The acceleration of a moving body can be found from:

(a) area under velocity-time graph (b) area under distance-time graph (c) slope of the velocity-time graph (d) slope of the distance-time graph

2.5. Which of the following is a vector quantity?

(a) Distance (b) Temperature (c) Mass (d) Momentum

2.6. An object is thrown along a direction inclined at an angle 45° with the horizontal. The horizontal range of the object is

(a) vertical height (b) twice the vertical height (c) thrice the vertical height (d) four times the vertical height

2.7. Two bullets are fired at angle \( \theta \) and \( (90 - \theta) \) to the horizontal with some speed. The ratio of their times of flight is

(a) 1:1 (b) \( \tan \theta : 1 \) (c) \( 1 : \tan \theta \) (d) \( \tan 2 \theta : 1 \)

2.8. A stone is dropped from the window of a train moving along a horizontal straight track, the path of the stone as observed by an observer on ground is

(a) Straight line (b) Parabola
2.9 A gun fires two bullets with same velocity at 60° and 30° with horizontal. The bullets strike at the same horizontal distance. The ratio of maximum height for the two bullets is in the ratio
(a) 2 : 1  (b) 3 : 1  
(c) 4 : 1  (d) 1 : 1

2.10 Newton’s first law of motion gives the concept of
(a) energy  (b) work  
(c) momentum  (d) Inertia

2.11 Inertia of a body has direct dependence on
(a) Velocity  (b) Mass  
(c) Area  (d) Volume

2.12 The working of a rocket is based on
(a) Newton’s first law of motion  (b) Newton’s second law of motion  
(c) Newton’s third law of motion  (d) Newton’s first and second law

2.13 When three forces acting at a point are in equilibrium
(a) each force is equal to the vector sum of the other two forces.  
(b) each force is greater than the sum of the other two forces.  
(c) each force is greater than the difference of the other two force.  
(d) each force is to product of the other two forces.

2.14 For a particle revolving in a circular path, the acceleration of the particle is
(a) along the tangent  (b) along the radius  
(c) along the circumference of the circle  (d) Zero

2.15 If a particle travels in a circle, covering equal angles in equal times, its velocity vector
(a) changes in magnitude only  
(b) remains constant  
(c) changes in direction only  
(d) changes both in magnitude and direction

2.16 A particle moves along a circular path under the action of a force. The work done by the force is
(a) positive and nonzero  (b) Zero  
(c) Negative and nonzero  (d) None of the above
2.17 A cyclist of mass m is taking a circular turn of radius R on a frictional level road with a velocity v. In order that the cyclist does not skid,
(a) \( \frac{mv^2}{2} > \mu mg \)
(b) \( \frac{mv^2}{r} > \mu mg \)
(c) \( \frac{mv^2}{r} < \mu mg \)
(d) \( \frac{v}{r} = \mu g \)

2.18 If a force \( F \) is applied on a body and the body moves with velocity \( v \), the power will be
(a) \( Fv \)
(b) \( \frac{F}{v} \)
(c) \( Fv^2 \)
(d) \( \frac{F}{v^2} \)

2.19 For an elastic collision
(a) the kinetic energy first increases and then decreases
(b) final kinetic energy never remains constant
(c) final kinetic energy is less than the initial kinetic energy
(d) initial kinetic energy is equal to the final kinetic energy

2.20 A bullet hits and gets embedded in a solid block resting on a horizontal frictionless table. Which of the following is conserved?
(a) momentum and kinetic energy
(b) Kinetic energy alone
(c) Momentum alone
(d) Potential energy alone

Two mark questions

1. Compute the (i) distance travelled and (ii) displacement made by the student when he travels a distance of 4 km eastwards and then a further distance of 3 km northwards.
2. What is the (i) distance travelled and (ii) displacement produced by a cyclist when he completes one revolution?
3. Differentiate between speed and velocity of a body.
4. What is meant by retardation?
5. What are scalar and vector quantities?
6. What is the magnitude and direction of the resultant of two vectors acting along the same line in the same direction?
7. State: Parallelogram law of vectors and triangle law of vectors.
9. Define impulse of a force
10. What is centrifugal reaction?
11. What is meant by banking of tracks?
12. What is Mechanics? What are its branches?
13. What is Dynamics? What are its types?
14. Distinguish between distance and displacement.
15. Define uniform velocity. Express it through graph.
17. Draw the following:
   (i) Displacement – time graph (ii) Velocity – time graph (iii) Acceleration – time graph
18. Differentiate Scalars and Vectors
19. What is a unit vector?
20. What is a Null vector or zero vector?
21. What is meant by resolution of vectors?
22. Define Scalar product of vectors.
23. Define vector product of vectors.
24. What is inertia? What are its types?
25. Define inertia
26. Define force
27. What is impulsive force? Give examples.
28. A rocket explodes in mid air. How does this effect its total momentum and kinetic energy?
29. Explain the propulsion of a rocket.
30. State Lamis theorem.
31. What is centripetal acceleration?
32. Define Co – efficient of friction.
33. What are the conditions that should be satisfied for work to be done.
34. Define Joule.
35. What is power? Define its unit.
36. What is Mechanical energy? What are its types?
37. State Work – Energy theorem
38. What are conservative and non conservative forces?
40. Define Collision.
41. What is elastic collision?
42. What is inelastic collision? Give example.

Three mark questions

1. What is the significance of velocity-time graph?
2. Derive the equations of motion for an uniformly accelerated body.
3. How will you represent a vector quantity?
4. Obtain the expression for magnitude and direction of the resultant of two vectors when they are inclined at an angle ‘θ’ with each other.
5. Explain the different types of inertia with examples.
6. Obtain an expression for centripetal acceleration.
7. What are the two types of collision? Explain them.
8. Discuss the motion of projectile projected at an angle with the horizontal. Prove that the path of the projectile is a parabola.
9. How can the law of conservation of momentum be applied during the recoil of a gun.
10. How will you determine the resultant of concurrent forces?
11. Give an experiment to verify (i) Parallelogram law of forces (ii) Triangle law of forces (iii) Lamis theorem
12. Derive the relation between linear velocity and angular velocity.
13. Explain centripetal force with the help of the diagram.
14. Explain the condition for skidding when a car is moving on a level circular road.
15. Deduce the condition for skidding of a vehicle while negotiating a curve.
17. Define kinetic energy. Derive expression for it.

Five mark questions

1. Obtain an expression for the critical velocity of a body revolving in a vertical circle.
2. State and prove law of conservation of linear momentum.
3. Obtain an expression for the angle of lean when a cyclist takes a curved path.
4. Obtain the expressions for the velocities of the two bodies after collision in the case of one dimensional motion.
5. Prove that in the case of one dimensional elastic collision between two bodies of equal masses, they interchange their velocities after collision.
6. State and explain triangle law of vectors.
7. State and prove parallelogram law of vectors. Discuss the special cases.
8. Prove that the path of a projectile is a parabola when a body is projected from the top of a building.
9. State and prove work energy theorem.
10. What is meant by inelastic collision? Prove that in a perfectly inelastic collision kinetic energy after impact is less than the kinetic energy before impact.

Solved Problems

2.1 The driver of a car travelling at 72 kmph observes the light 300 m ahead of him turning red. The traffic light is timed to remain red for 20 s before it turns green. If the motorist wishes to pass the light without stopping to wait for it to turn green, determine (i) the required uniform acceleration of the car (ii) the speed with which the motorist crosses the traffic light.

2.2 A stone is dropped from the top of the tower 50 m high. At the same time another stone is thrown up from the foot of the tower with a velocity of 25 m s\(^{-1}\). At what distance from the top and after how much time the stones cross each other?

2.3 A boy throws a ball so that it may just clear a wall 3.6m high. The boy is at a distance of 4.8 m from the wall. The ball was found to hit the ground at a distance of 3.6m on the other side of the wall. Find the least velocity with which the ball can be thrown.

2.4 Prove that for a given velocity of projection, the horizontal range is same for two angles of projection \(\alpha\) and \((90^\circ - \alpha)\).

2.5 The pilot of an aeroplane flying horizontally at a height of 2000 m with a constant speed of 540 kmph wishes to hit a target on the ground. At what distance from the target should release the bomb to hit the target?

2.6 Two equal forces are acting at a point with an angle of 60\(^\circ\) between them. If the resultant force is equal to 20\(\sqrt{3}\) N, find the magnitude of each force.
2.7 If two forces $F_1 = 20$ kN and $F_2 = 15$ kN act on a particle as shown in figure, find their resultant by triangle law.

2.8 Two forces act at a point in directions inclined to each other at $120^\circ$. If the bigger force is 5 kg wt and their resultant is at right angles to the smaller force, find the resultant and the smaller force.

2.9 Determine analytically the magnitude and direction of the resultant of the following four forces acting at a point.

(i) 10 kN pull N $30^\circ$ E;
(ii) 20 kN push S $45^\circ$ W;
(iii) 5 kN push N $60^\circ$ W;
(iv) 15 kN push S $60^\circ$ E.

2.10 A machine weighing 1500 N is supported by two chains attached to some point on the machine. One of these ropes goes to a nail in the wall and is inclined at $30^\circ$ to the horizontal and other goes to the hook in ceiling and is inclined at $45^\circ$ to the horizontal. Find the tensions in the two chains.

2.11 The radius of curvature of a railway line at a place when a train is moving with a speed of 72 kmph is 1500 m. If the distance between the rails is 1.54 m, find the elevation of the outer rail above the inner rail so that there is no side pressure on the rails.

2.12 A truck of weight 2 tonnes is slipped from a train travelling at 9 kmph and comes to rest in 2 minutes. Find the retarding force on the truck.

2.13 A body of mass 2 kg initially at rest is moved by a horizontal force of 0.5N on a smooth frictionless table. Obtain the work done by the force in 8 s and show that this is equal to change in kinetic energy of the body.

2.14 A body is thrown vertically up from the ground with a velocity of 39.2 m s$^{-1}$. At what height will its kinetic energy be reduced to one – fourth of its original kinetic energy.

2.15 A 10 g bullet is fired from a rifle horizontally into a 5 kg block of wood suspended by a string and the bullet gets embedded in the block. The impact causes the block to swing to a height of 5 cm above its initial level. Calculate the initial velocity of the bullet.
Problems

2.44 Determine the initial velocity and acceleration of particle travelling with uniform acceleration in a straight line if it travels 55 m in the 8th second and 85 m in the 13th second of its motion.

2.45 An aeroplane takes off at an angle of 45° to the horizontal. If the vertical component of its velocity is 300 kmph, calculate its actual velocity. What is the horizontal component of velocity?

2.46 A force is inclined at 60° to the horizontal. If the horizontal component of force is 40 kg wt, calculate the vertical component.

2.47 A body is projected upwards with a velocity of 30 m s⁻¹ at an angle of 30° with the horizontal. Determine (a) the time of flight (b) the range of the body and (c) the maximum height attained by the body.

2.48 The horizontal range of a projectile is $4\sqrt{3}$ times its maximum height. Find the angle of projection.

2.49 A body is projected at such an angle that the horizontal range is 3 times the greatest height. Find the angle of projection.

2.50 An elevator is required to lift a body of mass 65 kg. Find the acceleration of the elevator, which could cause a reaction of 800 N on the floor.

2.51 A body whose mass is 6 kg is acted on by a force which changes its velocity from 3 m s⁻¹ to 5 m s⁻¹. Find the impulse of the force. If the force is acted for 2 seconds, find the force in newton.

2.52 A cricket ball of mass 150 g moving at 36 m s⁻¹ strikes a bat and returns back along the same line at 21 m s⁻¹. What is the change in momentum produced? If the bat remains in contact with the ball for 1/20 s, what is the average force exerted in newton.

2.53 Two forces of magnitude 12 N and 8 N are acting at a point. If the angle between the two forces is 60°, determine the magnitude of the resultant force?

2.54 The sum of two forces inclined to each other at an angle is 18 kg wt and their resultant which is perpendicular to the smaller force is 12 kg wt. Find the forces and the angle between them.
2.55 A weight of 20 kN supported by two cords, one 3 m long and the other 4 m long with points of support 5 m apart. Find the tensions $T_1$ and $T_2$ in the cords.

2.56 The following forces act at a point
(i) 20 N inclined at 30° towards North of East
(ii) 25 N towards North
(iii) 30 N inclined at 45° towards North of West
(iv) 35 N inclined at 40° towards South of West.
Find the magnitude and direction of the resultant force.

2.57 Find the magnitude of the two forces such that if they are at right angles, their resultant is N. But if they act at 60°, their resultant is N.

2.58 At what angle must a railway track with a bend of radius 880 m be banked for the safe running of a train at a velocity of 44 m s$^{-1}$?

2.59 A railway engine of mass 60 tonnes, is moving in an arc of radius 200 m with a velocity of 36 kmph. Find the force exerted on the rails towards the centre of the circle.

2.60 A horse pulling a cart exerts a steady horizontal pull of 300 N and walks at the rate of 4.5 kmph. How much work is done by the horse in 5 minutes?

2.61 A ball is thrown downward from a height of 30 m with a velocity of 10 m s$^{-1}$. Determine the velocity with which the ball strikes the ground by using law of conservation of energy.

2.62 What is the work done by a man in carrying a suitcase weighing 30 kg over his head, when he travels a distance of 10 m in (i) vertical and (ii) horizontal directions?

2.63 Two masses of 2 kg and 5 kg are moving with equal kinetic energies. Find the ratio of magnitudes of respective linear momenta.

2.64 A man weighing 60 kg runs up a flight of stairs 3 m high in 4 s. Calculate the power developed by him.

2.65 A motor boat moves at a steady speed of 8 m s$^{-1}$, If the water resistance to the motion of the boat is 2000 N, calculate the power of the engine.

2.66 Two blocks of mass 300 kg and 200 kg are moving toward each other along a horizontal frictionless surface with velocities of 50 m s$^{-1}$ and 100 m s$^{-1}$ respectively. Find the final velocity of each block if the collision is completely elastic.
Self evaluation

3.1 The angular speed of minute arm in a watch is:
(a) $\pi/21600$ rad $s^{-1}$
(b) $\pi/12$ rad $s^{-1}$
(c) $\pi/3600$ rad $s^{-1}$
(d) $\pi/1800$ rad $s^{-1}$

3.2 The moment of inertia of a body comes into play
(a) in linear motion
(b) in rotational motion
(c) in projectile motion
(d) in periodic motion

3.3 Rotational analogue of mass in linear motion is
(a) Weight
(b) Moment of inertia
(c) Torque
(d) Angular momentum

3.4 The moment of inertia of a body does not depend on
(a) the angular velocity of the body
(b) the mass of the body
(c) the axis of rotation of the body
(d) the distribution of mass in the body

3.5 A ring of radius $r$ and mass $m$ rotates about an axis passing through its centre and perpendicular to its plane with angular velocity $\omega$. Its kinetic energy is
(a) $mr\omega^2$
(b) $mr\omega^2$
(c) $I\omega^2$
(d) $I\omega^2$

3.6 The moment of inertia of a disc having mass $M$ and radius $R$, about an axis passing through its centre and perpendicular to its plane is
(a) $MR^2$
(b) $MR^2$
(c) $MR^2$
(d) $MR^2$

3.7 Angular momentum is the vector product of
(a) linear momentum and radius vector
(b) moment of inertia and angular velocity
(c) linear momentum and angular velocity
(d) linear velocity and radius vector

3.8 The rate of change of angular momentum is equal to
(a) Force
(b) Angular acceleration
(c) Torque
(d) Moment of Inertia

3.9 Angular momentum of the body is conserved
(a) always
(b) never
(c) in the absence of external torque
(d) in the presence of external torque
3.10 A man is sitting on a rotating stool with his arms outstretched. Suddenly he folds his arm. The angular velocity
(a) decreases (b) increases
(c) becomes zero (d) remains constant

3.11 An athlete diving off a high springboard can perform a variety of exercises in the air before entering the water below. Which one of the following parameters will remain constant during the fall. The athlete’s
(a) linear momentum (b) moment of inertia
(c) kinetic energy (d) angular momentum

Two mark questions
1. Define centre of mass of the body.
2. Define centre of gravity.
3. What is a rigid body ?
4. Explain the rotational motion of a rigid body .
5. What is two important concept in rotational motion.
6. Relate moment of inertia and kinetic energy.
7. Define Radius of gyration of a rotating body.
8. Define the magnitude of the moment of force.
9. Explain the clockwise and anticlockwise moment.
10. What is couple ? Define the moment of couple. ?
11. Give example of couple. ?
12. Define the angular momentum of a particle. ?

Three mark questions
1. Explain the motion of centre of mass of a system with an example.
2. What are the different types of equilibrium?
3. Compare linear motion with rotational motion.
4. Explain the physical significance of moment of inertia.
5. Obtain an expression for the angular momentum of a rotating rigid body.
6. A cat is able to land on its feet after a fall. Which principle of physics is being used? Explain.
7. Define and derive an expression for radius of gyration.
8. Obtain an expression for the moment of a couple and hence the work done by a couple.
9. Obtain relation between torque and angular acceleration.

**Five mark questions**

1. Obtain an expression for position of centre of mass of two particle system.
2. Show that the moment of inertia of a rigid body is twice the kinetic energy of rotation.
4. Obtain the expressions for moment of inertia of a ring (i) about an axis passing through its centre and perpendicular to its plane. (ii) about its diameter and (iii) about a tangent.
5. Obtain the expressions for the moment of inertia of a circular disc (i) about an axis passing through its centre and perpendicular to its plane. (ii) about a diameter (iii) about a tangent in its plane and (iv) about a tangent perpendicular to its plane.
6. State the law of conservation of angular momentum

**Solved Problems**

3.1 A system consisting of two masses connected by a massless rod lies along the X-axis. A 0.4 kg mass is at a distance \( x = 2 \) m while a 0.6 kg mass is at \( x = 7 \) m. Find the \( x \) coordinate of the centre of mass.
3.2 Locate the centre of mass of a system of bodies of masses \( m_1 = 1 \) kg, \( m_2 = 2 \) kg and \( m_3 = 3 \) kg situated at the corners of an equilateral triangle of side 1 m.
3.3 A circular disc of mass \( m \) and radius \( r \) is set rolling on a table. If \( \omega \) is its angular velocity, show that its total energy \( E = mr^2\omega^2 \).
3.4 A thin metal ring of diameter 0.6m and mass 1kg starts from rest and rolls down on an inclined plane. Its linear velocity on reaching the foot of the plane is 5 m \( s^{-1} \), calculate (i) the moment of inertia of the ring and (ii) the kinetic energy of rotation at that instant.

3.5 A solid cylinder of mass 200 kg rotates about its axis with angular speed 100 \( s^{-1} \). The radius of the cylinder is 0.25 m. What is the kinetic energy associated with the rotation of the cylinder? What is the magnitude of the angular momentum of the cylinder about its axis?
3.6 Calculate the radius of gyration of a rod of mass 100 g and length 100 cm about an axis passing through its centre of gravity and perpendicular to its length.

3.7 A circular disc of mass 100 g and radius 10 cm is making 2 revolutions per second about an axis passing through its centre and perpendicular to its plane. Calculate its kinetic energy.

3.8 Starting from rest, the flywheel of a motor attains an angular velocity 100 rad/s from rest in 10 s. Calculate (i) angular acceleration and (ii) angular displacement in 10 seconds.

3.9 A disc of radius 5 cm has moment of inertia of 0.02 kg m$^2$. A force of 20 N is applied tangentially to the surface of the disc. Find the angular acceleration produced.

3.10 From the figure, find the moment of the force 45 N about A?

Problems

3.25 A person weighing 45 kg sits on one end of a seasaw while a boy of 15 kg sits on the other end. If they are separated by 4 m, how far from the boy is the centre of mass situated. Neglect weight of the seasaw.

3.26 Three bodies of masses 2 kg, 4 kg and 6 kg are located at the vertices of an equilateral triangle of side 0.5 m. Find the centre of mass of this collection, giving its coordinates in terms of a system with its origin at the 2 kg body and with the 4 kg body located along the positive X axis.

3.27 Four bodies of masses 1 kg, 2 kg, 3 kg and 4 kg are at the vertices of a rectangle of sides $a$ and $b$. If $a = 1$ m and $b = 2$ m, find the location of the centre of mass. (Assume that, 1 kg mass is at the origin of the system, 2 kg body is situated along the positive x axis and 4 kg along the y axis.)

3.28 Assuming a dumbbell shape for the carbon monoxide (CO) molecule, find the distance of the centre of mass of the molecule from the carbon atom in terms of the distance $d$ between the carbon and the oxygen atom. The atomic mass of carbon is 12 amu and for oxygen is 16 amu.

\[(1 \text{ amu} = 1.67 \times 10^{-27} \text{ kg})\]

3.29 A solid sphere of mass 50 g and diameter 2 cm rolls without sliding with a uniform velocity of 5 m s$^{-1}$ along a straight line on a smooth horizontal table. Calculate its total kinetic energy. (Note : Total $E_k = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$).

3.30 Compute the rotational kinetic energy of a 2 kg wheel rotating at 6 revolutions per second if the radius of gyration of the wheel is 0.22 m.
3.31 The cover of a jar has a diameter of 8 cm. Two equal, but oppositely directed, forces of 20 N act parallel to the rim of the lid to turn it. What is the magnitude of the applied torque?
Self evaluation

4.1 If the distance between two masses is doubled, the gravitational attraction between them
(a) is reduced to half    (b) is reduced to a quarter
(c) is doubled          (d) becomes four times

4.2 The acceleration due to gravity at a height (1/20)th the radius of the Earth above the Earth’s
surface is 9 m s\(^{-2}\). Its value at a point at an equal distance below the surface of the Earth is
(a) 0    (b) 9 m s\(^{-2}\)
(c) 9.8 m s\(^{-2}\)  (d) 9.5 m s\(^{-2}\)

4.3 The weight of a body at Earth’s surface is W. At a depth half way to the centre of the Earth, it
will be
(a) W    (b) W/2
(c) W/4  (d) W/8

4.4 Force due to gravity is least at a latitude of
(a) 0°    (b) 45°
(c) 60°   (d) 90°

4.5 If the Earth stops rotating, the value of g at the equator will
(a) increase    (b) decrease
(c) remain same  (d) become zero

4.6 The escape speed on Earth is 11.2 km s\(^{-1}\). Its value for a planet having double the radius and
eight times the mass of the Earth is
(a) 11.2 km s\(^{-1}\)    (b) 5.6 km s\(^{-1}\)
(c) 22.4 km s\(^{-1}\)   (d) 44.8 km s\(^{-1}\)

4.7 If r represents the radius of orbit of satellite of mass m moving around a planet of mass M.
The velocity of the satellite is given by
(a) v\(^2\) =    (b) v =
(c) v\(^2\) =    (d) v =

4.8 If the Earth is at one fourth of its present distance from the Sun, the duration of the year will be
(a) one fourth of the present year    (b) half the present year
(c) one - eighth the present year    (d) one - sixth the present year
4.9 Which of the following objects do not belong to the solar system?
(a) Comets  (b) Nebulae
(c) Asteroids  (d) Planets

4.10 According to Kepler’s law, the radius vector sweeps out equal areas in equal intervals of

time. The law is a consequence of the conservation of
(a) angular momentum (b) linear momentum
(c) energy (d) all the above

Two mark questions

1. Why is the gravitational force of attraction between the two bodies of ordinary masses not
noticeable in everyday life?

2. State the universal law of gravitation.

3. Define gravitational constant. Give its value, unit and dimensional formula.

4. What are the factors affecting the ‘g’ value?

5. Why a man can jump higher on the moon than on the Earth?

6. Define gravitational potential.

7. Define gravitational field intensity.

8. Differentiate between inertial mass and gravitational mass.

9. The moon has no atmosphere. Why?

10. What will happen to the orbiting satellite, if its velocity varies?

11. What are the called geo-stationary satellites?

12. Why do the astronauts feel weightlessness inside the orbiting spacecraft?

13. State Helio-Centric theory.


15. What is solar system?


17. What is albedo?

18. What are asteroids?

19. What are constellations?

20. What are the special features of gravitational law.

21. State the universal law of Gravitations?

22. Define Gravitational field and Gravitational field intensity.
24. Define gravitational potential energy.
25. What are polar satellites?
26. What are the uses of Satellite communication?
27. Write about Remote sensing satellites.
28. What is astronomy?
29. Define Solar Constant.
30. What is the reason for the formation of craters on the surface of the moon?
31. What are meteors and meteorites?

**Three mark questions**

1. Define gravitational potential energy. Deduce an expression for it for a mass in the gravitational field of the Earth.
2. Obtain an expression for the gravitational potential at a point.
3. Show that the orbital radius of a geo-stationary satellite is 36000 km.
4. Deduce the law of periods from the law of gravitation.
5. State and prove the law of areas based on conservation of angular momentum.
6. Derive an expression for acceleration due to gravity at the surface of earth.
7. Explain the variation of g with latitude by considering the non-sphericity of the earth.
8. Derive an expression for gravitational potential energy.
9. Derive an expression for the time period of a satellite.
10. What is a rocket? Explain its principle with the help of a diagram.
11. Explain the method of launching a satellite.

**Five mark questions**

1. The acceleration due to gravity varies with (i) altitude and (ii) depth. Prove.
2. Discuss the variation of g with latitude due to the rotation of the Earth.
3. The acceleration due to gravity is minimum at equator and maximum at poles.
   Give the reason.
4. What is escape speed? Obtain an expression for it.
5. What is orbital velocity? Obtain an expression for it.

**Solved Problems**

4.1 Calculate the force of attraction between two bodies, each of mass 200 kg and 2 m apart on the surface of the Earth. Will the force of attraction be different, if the same bodies are placed on the moon, keeping the separation same?

4.2 The acceleration due to gravity at the moon’s surface is 1.67 m s\(^{-2}\). If the radius of the moon is 1.74 \(\times\) 10\(^6\) m, calculate the mass of the moon.

4.3 Calculate the height above the Earth’s surface at which the value of acceleration due to gravity reduces to half its value on the Earth’s surface. Assume the Earth to be a sphere of radius 6400 km.

4.4 Determine the escape speed of a body on the moon. Given: radius of the moon is 1.74 \(\times\) 10\(^6\) m and mass of the moon is 7.36 \(\times\) 10\(^{22}\) kg.

4.5 The mass of the Earth is 81 times that of the moon and the distance from the centre of the Earth to that of the moon is about 4 \(\times\) 10\(^{3}\) km. Calculate the distance from the centre of the Earth where the resultant gravitational force becomes zero when a spacecraft is launched from the Earth to the moon.

4.6 A stone of mass 12 kg falls on the Earth’s surface. If the mass of the Earth is about 6 \(\times\) 10\(^{24}\) kg and acceleration due to gravity is 9.8 m s\(^{-2}\), calculate the acceleration produced on the Earth by the stone.

4.7 The maximum height up to which astronaut can jump on the Earth is 0.75 m. With the same effort, to what height can he jump on the moon? The mean density of the moon is (2/3) that of the Earth and the radius of the moon is (1/4) that of the Earth.

4.8 Three point masses, each of mass \(m\), are placed at the vertices of an equilateral triangle of side \(a\). What is the gravitational field and potential due to the three masses at the centroid of the triangle.

4.9 A geo-stationary satellite is orbiting the Earth at a height of 6R above the surface of the Earth. Here R is the radius of the Earth. What is the time period of another satellite at a height of 2.5R from the surface of the Earth?
4.41 Two spheres of masses 10 kg and 20 kg are 5 m apart. Calculate the force of attraction between the masses.

4.42 What will be the acceleration due to gravity on the surface of the moon, if its radius is \( \frac{1}{81} \) the radius of the Earth and its mass is \( \frac{1}{81} \) the mass of the Earth? (Take \( g \) as 9.8 m s\(^{-2}\))

4.43 The acceleration due to gravity at the surface of the moon is 1.67 m s\(^{-2}\). The mass of the Earth is about 81 times more massive than the moon. What is the ratio of the radius of the Earth to that of the moon?

4.44 If the diameter of the Earth becomes two times its present value and its mass remains unchanged, then how would the weight of an object on the surface of the Earth be affected?

4.45 Assuming the Earth to be a sphere of uniform density, how much would a body weigh one fourth down to the centre of the Earth, if it weighed 250 N on the surface?

4.46 What is the value of acceleration due to gravity at an altitude of 500 km? The radius of the Earth is 6400 km.

4.47 What is the acceleration due to gravity at a distance from the centre of the Earth equal to the diameter of the Earth?

4.48 What should be the angular velocity of the Earth, so that bodies lying on equator may appear weightless? How many times this angular velocity is faster than the present angular velocity? (Given : \( g = 9.8 \) m s\(^{-2}\); \( R = 6400 \) km)

4.49 Calculate the speed with which a body has to be projected vertically from the Earth’s surface, so that it escapes the Earth’s gravitational influence. (\( R = 6.4 \times 10^3 \) km; \( g = 9.8 \) m s\(^{-2}\))

4.50 Jupiter has a mass 318 times that of the Earth and its radius is 11.2 times the radius of the Earth. Calculate the escape speed of a body from Jupiter’s surface.

4.51 A satellite is revolving in circular orbit at a height of 1000 km from the surface of the Earth. Calculate the orbital velocity and time of revolution. The radius of the Earth is 6400 km and the mass of the Earth is \( 6 \times 10^{24} \) kg.

4.52 An artificial satellite revolves around the Earth at a distance of 3400 km. Calculate its orbital velocity and period of revolution. Radius of the Earth = 6400 km; \( g = 9.8 \) m s\(^{-2}\).
4.53 A satellite of 600 kg orbits the Earth at a height of 500 km from its surface. Calculate its (i) kinetic energy (ii) potential energy and (iii) total energy \( (M = 6 \times 10^{24} \text{ kg} ; R = 6.4 \times 10^6 \text{ m}) \)

4.54 A satellite revolves in an orbit close to the surface of a planet of density 6300 kg m\(^{-3}\). Calculate the time period of the satellite. Take the radius of the planet as 6400 km.

4.55 A spaceship is launched into a circular orbit close to the Earth’s surface. What additional velocity has to be imparted to the spaceship in the orbit to overcome the gravitational pull.
\( (R = 6400 \text{ km}, g = 9.8 \text{ m s}^{-2}) \)
5.1 If the length of the wire and mass suspended are doubled in a Young’s modulus experiment, then, Young’s modulus of the wire
(a) remains unchanged  (b) becomes double
(c) becomes four times  (d) becomes sixteen times

5.2 For a perfect rigid body, Young’s modulus is
(a) zero  (b) infinity
(c) 1  (d) –1

5.3 Two wires of the same radii and material have their lengths in the ratio 1 : 2. If these are stretched by the same force, the strains produced in the two wires will be in the ratio
(a) 1 : 4  (b) 1 : 2
(c) 2 : 1  (d) 1 : 1

5.4 If the temperature of a liquid is raised, then its surface tension is
(a) decreased  (b) increased
(c) does not change  (d) equal to viscosity

5.5 The excess of pressure inside two soap bubbles of diameters in the ratio 2 : 1 is
(a) 1 : 4  (b) 2 : 1
(c) 1 : 2  (d) 4 : 1

5.6 A square frame of side l is dipped in a soap solution. When the frame is taken out, a soap film is formed. The force on the frame due to surface tension T of the soap solution is
(a) 8 Tl  (b) 4 Tl
(c) 10 Tl  (d) 12 Tl

5.7 The rain drops falling from the sky neither hit us hard nor make holes on the ground because they move with
(a) constant acceleration  (b) variable acceleration
(c) variable speed  (d) constant velocity

5.8 Two hail stones whose radii are in the ratio of 1 : 2 fall from a height of 50 km. Their terminal velocities are in the ratio of
(a) 1 : 9  (b) 9 : 1
(c) 4 : 1  (d) 1 : 4
5.9 Water flows through a horizontal pipe of varying cross-section at the rate of 0.2 m$^3$s$^{-1}$. The velocity of water at a point where the area of cross-section of the pipe is 0.01 m$^2$ is
(a) 2 ms$^{-1}$  
(b) 20 ms$^{-1}$
(c) 200 ms$^{-1}$  
(d) 0.2 ms$^{-1}$

5.10 An object entering Earth’s atmosphere at a high velocity catches fire due to
(a) viscosity of air  
(b) the high heat content of atmosphere
(c) pressure of certain gases  
(d) high force of g.

Two mark questions

1. State Hooke’s law.
2. Which is more elastic, rubber or steel? Support your answer.
3. What is Reynold’s number?
4. Why aeroplanes and cars have streamline shape?
5. What is terminal velocity?
6. Define cohesive force and adhesive force. Give examples
7. Define i) molecular range ii) sphere of influence iii) surface tension.
8. How do insects run on the surface of water?
9. Why hot water is preferred to cold water for washing clothes?
10. Why the blood pressure in humans is greater at the feet than at the brain?
11. Why two holes are made to empty an oil tin?
12. A person standing near a speeding train has a danger of falling towards the train. Why?
13. Why a small bubble rises slowly through a liquid whereas the bigger bubble rises rapidly?
14. What are the interactions observed when the atoms come closer?
15. Define inter atomic force.
16. What are fluids?
17. State Pascals law
18. What is viscosity?
19. Why mercury does not wet glass?
20. Give few examples for the decreases of surface tension of water.
21. Water rises and mercury falls in a capillary tube. Why?
22. What is meant by capillarity?
Three mark questions
1. Define: i) elastic body ii) plastic body iii) stress iv) strain v) elastic limit vi) restoring force
2. State and prove Pascal’s law without considering the effect of gravity.
3. Taking gravity into account, explain Pascal’s law.
4. What is critical velocity of a liquid?
5. Describe an experiment to determine viscosity of a liquid.
6. Explain Stoke’s law.
7. Derive an expression for terminal velocity of a small sphere falling through a viscous liquid.
8. Explain surface tension on the basis of molecular theory.
9. Establish the relation between surface tension and surface energy.
10. Give four examples of practical application of surface tension.
11. Verify Hookes law with the help of an experiment.
12. Discuss the relationship between stress applied to a body and strain developed in it.
13. Explain the application of Pascals law in the working of hydraulic lift.
15. Explain any four applications of Bernoullis theorem.

Five mark questions
1. Explain the three moduli of elasticity.
2. Describe Searle’s Experiment.
3. Explain the principle, construction and working of hydraulic brakes.
4. Derive an expression for the total energy per unit mass of a flowing liquid.
5. State and prove Bernoulli’s theorem.
6. Derive an expression for surface tension by capillary rise method.

Solved Problems
5.1 A 50 kg mass is suspended from one end of a wire of length 4 m and diameter 3 mm whose other end is fixed. What will be the elongation of the wire? Take q = 7 × 10^{10} N m^{-2} for the material of the wire.
5.2 A sphere contracts in volume by 0.01% when taken to the bottom of sea 1 km deep. If the density of sea water is 10^3 kg m^{-3}, find the bulk modulus of the material of the sphere.
5.3 A hydraulic automobile lift is designed to lift cars with a maximum mass of 3000 kg. The area of cross-section of the piston carrying the load is $425 \times 10^{-4} \text{ m}^2$. What maximum pressure would the piston have to bear?

5.4 A square plate of 0.1 m side moves parallel to another plate with a velocity of 0.1 m s$^{-1}$, both plates being immersed in water. If the viscous force is $2 \times 10^{-3} \text{ N}$ and viscosity of water is $10^{-3} \text{ N s m}^{-2}$, find their distance of separation.

5.5 Determine the velocity for air flowing through a tube of $10^{-2} \text{ m}$ radius. For air $\rho = 1.3 \text{ kg m}^{-3}$ and $\eta = 187 \times 10^{-7} \text{ N s m}^{-2}$.

5.6 Fine particles of sand are shaken up in water contained in a tall cylinder. If the depth of water in the cylinder is 0.3 m, calculate the size of the largest particle of sand that can remain suspended after 40 minutes. Assume density of sand = 2600 kg m$^{-3}$ and viscosity of water = $10^{-3} \text{ N s m}^{-2}$.

5.7 A circular wire loop of 0.03 m radius is rested on the surface of a liquid and then raised. The pull required is 0.003 kg wt greater than the force acting after the film breaks. Find the surface tension of the liquid.

5.8 Calculate the diameter of a capillary tube in which mercury is depressed by 2.219 mm. Given $T$ for mercury is 0.54 N m$^{-1}$, angle of contact is 140$^\circ$ and density of mercury is 13600 kg m$^{-3}$.

5.9 Calculate the energy required to split a water drop of radius $1 \times 10^{-3} \text{ m}$ into one thousand million droplets of same size. Surface tension of water = 0.072 N m$^{-1}$.

5.10 Calculate the minimum pressure required to force the blood from the heart to the top of the head (a vertical distance of 0.5 m). Given density of blood = 1040 kg m$^{-3}$. Neglect friction.

**Problems**

5.39 A wire of diameter 2.5 mm is stretched by a force of 980 N. If the Young’s modulus of the wire is $12.5 \times 10^{10} \text{ N m}^{-2}$, find the percentage increase in the length of the wire.

5.40 Two wires are made of same material. The length of the first wire is half of the second wire and its diameter is double that of second wire. If equal loads are applied on both the wires, find the ratio of increase in their lengths.

5.41 The diameter of a brass rod is 4 mm. Calculate the stress and strain when it is stretched by 0.25% of its length. Find the force exerted. Given $q = 9.2 \times 10^{10} \text{ N m}^{-2}$ for brass.
5.42 Calculate the volume change of a solid copper cube, 40 mm on each side, when subjected to a pressure of \(2 \times 10^7\) Pa. Bulk modulus of copper is \(1.25 \times 10^{11}\) N m\(^{-2}\).

5.43 In a hydraulic lift, the piston \(P_2\) has a diameter of 50 cm and that of \(P_1\) is 10 cm. What is the force on \(P_2\) when 1 N of force is applied on \(P_1\)?

5.44 Calculate the mass of water flowing in 10 minutes through a tube of radius \(10^{-2}\) m and length 1 m having a constant pressure of 0.2 m of water. Assume coefficient of viscosity of water \(= 9 \times 10^{-4}\) N s m\(^{-2}\) and \(g = 9.8\) m s\(^{-2}\).

5.45 A liquid flows through a pipe of \(10^{-3}\) m radius and 0.1 m length under a pressure of 103 Pa. If the coefficient of viscosity of the liquid is \(1.25 \times 10^{-3}\) N s m\(^{-2}\), calculate the rate of flow and the speed of the liquid coming out of the pipe.

5.46 For cylindrical pipes, Reynold’s number is nearly 2000. If the diameter of a pipe is 2 cm and water flows through it, determine the velocity of the flow. Take \(\eta\) for water \(= 10^{-3}\) N s m\(^{-2}\).

5.47 In a Poiseuille’s flow experiment, the following are noted. i) Volume of liquid discharged per minute \(= 15 \times 10^{-6}\) m\(^3\)

ii) Head of liquid \(= 0.30\) m

iii) Length of tube \(= 0.25\) m

iv) Diameter \(= 2 \times 10^{-3}\) m

v) Density of liquid \(= 2300\) kg m\(^{-3}\).

Calculate the coefficient of viscosity.

5.48 An air bubble of 0.01 m radius raises steadily at a speed of \(5 \times 10^{-3}\) m s\(^{-1}\) through a liquid of density 800 kg m\(^{-3}\). Find the coefficient of viscosity of the liquid. Neglect the density of air.

5.49 Calculate the viscous force on a ball of radius 1 mm moving through a liquid of viscosity 0.2 N s m\(^{-2}\) at a speed of 0.07 m s\(^{-1}\).

5.50 A U shaped wire is dipped in soap solution. The thin soap film formed between the wire and a slider supports a weight of \(1.5 \times 10^{-2}\) N. If the length of the slider is 30 cm, calculate the surface tension of the film.

5.51 Calculate the force required to remove a flat circular plate of radius 0.02 m from the surface of water. Assume surface tension of water is 0.07 N m\(^{-1}\).

5.52 Find the work done in blowing up a soap bubble from an initial surface area of \(0.5 \times 10^{-4}\) m\(^2\) to an area \(1.1 \times 10^{-4}\) m\(^2\). The surface tension of soap solution is 0.03 N m\(^{-1}\).
5.53 Determine the height to which water will rise in a capillary tube of $0.5 \times 10^{-3}$ m diameter. Given for water, surface tension is 0.074 N m$^{-1}$.

5.54 A capillary tube of inner diameter 4 mm stands vertically in a bowl of mercury. The density of mercury is 13,500 kg m$^{-3}$ and its surface tension is 0.544 N m$^{-1}$. If the level of mercury in the tube is 2.33 mm below the level outside, find the angle of contact of mercury with glass.

5.55 A capillary tube of inner radius $5 \times 10^{-4}$ m is dipped in water of surface tension 0.075 N m$^{-1}$. To what height is the water raised by the capillary action above the water level outside. Calculate the weight of water column in the tube.

5.56 What amount of energy will be liberated if 1000 droplets of water, each of diameter $10^{-8}$ m, coalesce to form a big drop. Surface tension of water is 0.075 N m$^{-1}$.

5.57 Water flows through a horizontal pipe of varying cross-section. If the pressure of water equals $2 \times 10^{-2}$ m of mercury where the velocity of flow is $32 \times 10^{-2}$ m s$^{-1}$ find the pressure at another point, where the velocity of flow is $40 \times 10^{-2}$ m s$^{-1}$.