EXAMPLAR

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Single Choice Correct

1*. A stone is dropped into a quiet lake and waves move in circles at the speed of 5 cm/s. At the instant when the radius of the circular wave is 8 cm, how fast is the enclosed area increasing?
(A) 80π cm^2/s (B) 90π cm^2/s (C) 85π cm^2/s (D) 89π cm^2/s

2. The momentum of a moving particle given by $p = t\ell nt$. Net force acting on this particle is defined by equation $F = \frac{dp}{dt}$. The net force acting on the particle is zero at time :
(A) $t = 0$ (B) $t = \frac{1}{e}$ (C) $t = \frac{1}{e^2}$ (D) None of these

3. An edge of a variable cube is increasing at the rate of 3 cm/s. How fast is the volume of the cube increasing when the edge is 10 cm long?
(A) 900 cm^3/s (B) 920 cm^3/s (C) 850 cm^3/s (D) 950 cm^3/s

4. If $y = \cfrac{x}{a+\cfrac{x}{b+\cfrac{x}{a+\cfrac{x}{b}.....\infty}}}$ then $\frac{dy}{dx}$ -
(A) $\frac{a}{ab+2ay}$ (B) $\frac{b}{ab+2by}$ (C) $\frac{a}{ab+2by}$ (D) $\frac{b}{ab+2ay}$

5. If $y = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + ... + \frac{x^n}{n!}$, then $\frac{dy}{dx} =$
(A) y (B) $y + \frac{x^n}{n!}$ (C) $y - \frac{x^n}{n!}$ (D) $y - 1 - \frac{x^n}{n!}$

6. If $y = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + ...\infty$, then $\frac{dy}{dx} =$
(A) y (B) $y - 1$ (C) $y + 1$ (D) None of these

7. If $y = \sin(\sqrt{\sin x + \cos x})$, then $\frac{dy}{dx} =$
(A) $\frac{1}{2}\frac{\cos\sqrt{\sin x + \cos x}}{\sqrt{\sin x + \cos x}}$ (B) $\frac{\cos\sqrt{\sin x + \cos x}}{\sqrt{\sin x + \cos x}}$
(C) $\frac{1}{2}\frac{\cos\sqrt{\sin x + \cos x}}{\sqrt{\sin x + \cos x}}.(\cos x - \sin x)$ (D) None of these

Subjetive Questions

Evaluate the following integrals.

8. Evaluate $\int \frac{3}{(2-x)^2}\,dx$

9. Evaluate $\int \sin(8z-5)\,dz$

10. $16\int_0^{\pi/4} \cos^3\theta \sin\theta\, d\theta$

11. $2\int_1^2 \frac{e^{\frac{1}{x}}}{x^2}\,dx$

12*. A carrom board (4 ft × 4 ft square) has the queen at the centre. The queen, hit by the striker moves to the front edge, rebounds and goes in the hole behind the striking line. Find the magnitude of displacement of the queen (A) from the centre to the front edge (B) from the front edge to the hole and (C) from the centre to the hole.

ANSWERS

- **Single Choice Correct**

1.	(A)	**2.**	(B)	**3.**	(A)	**4.**	(D)	**5.**	(C)
6.	(A)	**7.**	(C)						

- **Subjective Questions**

8. $\frac{3}{2-x}+C$ **9.** $-\frac{\cos(8z-5)}{8}+(C)$ **10.** (3), **11.** $2(e-\sqrt{e})$

12. [(a) $\frac{2}{3}\sqrt{10}$ ft, (b) $\frac{4}{3}\sqrt{10}$ ft, (c) $2\sqrt{2}$ ft]

RECTILINEAR MOTION

True / False

1. When a particle is in motion, its acceleration may be in any direction.

2. If a ball starts falling from the position of rest, then it travels a distance of 25m during the third second of its fall. If g = 10 ms^{-2} and air friction absent.

3. A packet dropped from a rising balloon first moves upwards and then moves downward as observed by a stationary observer on the ground.

4*. The direction of acceleration of a moving particle may be directly obtained from the trajectory of the particle.

5. Two balls of different masses are thrown vertically upwards with the same speed. They pass through the point of projection in their downward motion with the same speed (Neglect air resistance).

6. Two balls of different masses are thrown vertically upwards with the same speed. They pass through the point of projection in their downward motion with the same speed (Neglect air resistance). **[IIT-JEE 1983]**

Fill in the blanks

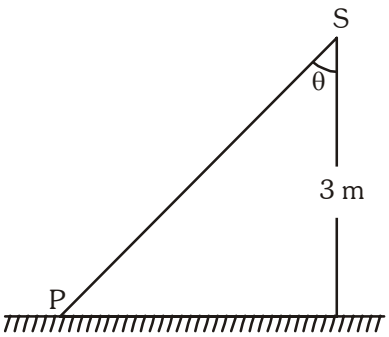
7*. A point starts moving in a straight line with some acceleration. At a time t after beginning, the acceleration suddenly reverses (without change in magnitude) The time from start in which the particle returns to the initial point is .....

8. Two stones are dropped down simultaneously from different heights. At the time of starting, the distance between them is 30 cm. After 2 sec. the distance between the two stones would be .....

9. A body falling freely from rest has a velocity v after it falls through distance h. The distance it has to fall down further, for its velocity to become doubled is ..... times h.

10. A particle moves in a circle of radius R. In half the period of revolution its displacement is ..... and distance covered is ..... **[IIT-JEE 1983]**

11. Spotlight S rotates in a horizontal plane with constant angularvelocity of 0.1 rad/s. The spot of light P moves along the wall at a distance of 3 m. The velocity of the spot P when 0 = 450 (see Fig.) is rn/s. [**IIT-JEE 1987]**



Assertion-Reason

These questions contains, Statement I (assertion) and Statement II (reason).

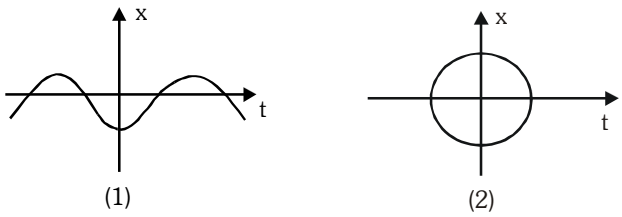
12*. **Statement I :** When velocity of a particle is zero then acceleration of particle is also zero.
because
Statement II : Acceleration is equal to rate of change of velocity.
(A) Statement–I is true, Statement–II is true ; Statement–II is correct explanation for Statement–I.
(B) Statement–I is true, Statement–II is true ; Statement–II is NOT a correct explanation for statement–I.
(C) Statement–I is true, Statement–II is false.
(D) Statement–I is false, Statement–II is true.

13. **Statement I :** A particle moves in a straight line with constant acceleration. The average velocity of this particle cannot be zero in any time interval.
because
Statement II : For a particle moving in straight line with constant acceleration, the average velocity in a time interval is $\frac{u+v}{2}$, where u and v are initial and final velocity of the particle of the given time interval.
(A) Statement–I is true, Statement–II is true ; Statement–II is correct explanation for Statement–I.
(B) Statement–I is true, Statement–II is true ; Statement–II is NOT a correct explanation for statement–I.
(C) Statement–I is true, Statement–II is false.
(D) Statement–I is false, Statement–II is true.

14. **Statement–I :** A positive acceleration can be associated with a 'slowing down' of the body.
because
Statement–II : The origin and the positive direction of an axis are a matter of choice.
(A) Statement–I is true, Statement–II is true ; Statement–II is correct explanation for Statement–I.
(B) Statement–I is true, Statement–II is true ; Statement–II is NOT a correct explanation for statement–I.
(C) Statement–I is true, Statement–II is false.
(D) Statement–I is false, Statement–II is true.

15. **Statement–I :** In a free fall, the initial velocity of a body may or may not be zero.
because
Statement–II : A heavy body falls at a faster rate as compared to a lighter body (neglect air resistance)
(A) Statement–I is true, Statement–II is true ; Statement–II is correct explanation for Statement–I.
(B) Statement–I is true, Statement–II is true ; Statement–II is NOT a correct explanation for statement–I.
(C) Statement–I is true, Statement–II is false.
(D) Statement–I is false, Statement–II is true.

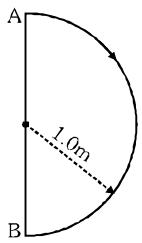
16. **Statement–I :** Graph (1) represent one dimensional motion of a particle. While graph (2) can not represent 1–D motion of the particle. (here x is position and t is time)



because
Statement–II : Particle can have only one position at an instant.
(A) Statement–I is true, Statement–II is true ; Statement–II is correct explanation for Statement–I.
(B) Statement–I is true, Statement–II is true ; Statement–II is NOT a correct explanation for statement–I.
(C) Statement–I is true, Statement–II is false.
(D) Statement–I is false, Statement–II is true.

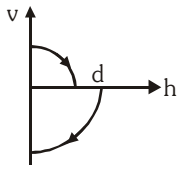
Single Choice Correct

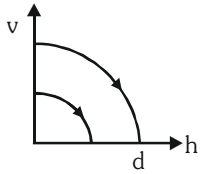
17. In 1.0s, a particle goes from point A to point B, moving in a semicircle (see figure). The magnitude of the average velocity is : **[IIT-JEE - 1999]**

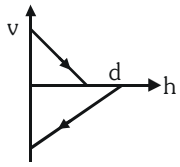


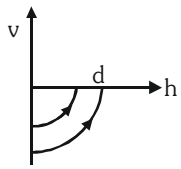
(A) 3.14 m/s
(B) 2.0 m/s
(C) 1.0 m/s
(D) zero

18. A ball is dropped vertically from a height d above the ground. It hits the ground and bounces up vertically to a height d/2. Neglecting subsequent motion and air resistance, its velocity v varies with height h above the ground as : **[IIT-JEE - 2000]**

(A) 

(B) 

(C) 

(D) 

19*. A parachutist drops freely from an aeroplane for 10 s before the parachute opens out. Then he descends with a net retardation of 2.5 m/s^2. If he bails out of the plane at a height of 2495 m and g = 10 m/s^2, hit velocity on reaching the ground will be :

(A) 5 m/s (B) 10 m/s (C) 15 m/s (D) 20 m/s

20*. A point moves in a straight line under the retardation –kv, where k is a constant. If the initial velocity is u, the distance covered in 't' seconds is :

(A) $\frac{u}{k}(1-e^{-kt})$ (B) $\frac{u}{k}(1+e^{-kt})$ (C) $\frac{u}{k}(1-e^{kt})$ (D) $\frac{u}{k}(1+e^{kt})$

21*. A particle is moving with uniform acceleration along a straight line . Its velocities at A & B are respectively 7 m/s & 17 m/s . M is mid point of AB. If t_1 is the time taken to go from A to M and t_2 the time taken to go from M to B, the ratio $\frac{t_1}{t_2}$ is equal to :

(A) 3 : 2 (B) 3 : 1 (C) 2 : 1 (D) 2 : 3

22*. A particle moves with uniform acceleration and v_1 , v_2 and v_3 denote the average velocities in the three successive intervals of time t_1, t_2 and t_3. Which of the following relations is correct ?

(A) $(v_1 - v_2) : (v_2 - v_3) = (t_1 - t_2) : (t_2 + t_3)$
(B) $(v_1 - v_2) : (v_2 - v_3) = (t_1 + t_2) : (t_2 + t_3)$
(C) $(v_1 - v_2) : (v_2 - v_3) = (t_1 - t_2) : (t_1 - t_3)$
(D) $(v_1 - v_2) : (v_2 - v_3) = (t_1 - t_2) : (t_2 - t_3)$

23. A particle is moving eastwards with a velocity of 5 m/s. In 10 s the velocity changes to 5 m/s northwards. The average acceleration in this time is **[IIT-JEE 1982]**

(A) zero
(B) $\frac{1}{\sqrt{2}}$ m/s^2 towards north-east
(C) $\frac{1}{\sqrt{2}}$ m/s^2 towards north-west
(D) $\frac{1}{\sqrt{2}}$ m/s^2 towards north

Multiple Choice Correct

24*. A particle moves with constant speed v along a regular hexagon ABCDEF in the same order . Then the magnitude of the average velocity for its motion from A to :

(A) F is $\frac{v}{5}$ (B) D is $\frac{v}{3}$ (C) C is $\frac{v\sqrt{3}}{2}$ (D) B is v .

25*. A particle moves along x–axis according to the law x = (t^3–3t^2–9t+5)m. Then :

(A) In the interval 3<t<5, the particle is moving in +x direction
(B) The particle reverses its direction of motion twice in entire motion if it starts at t=0
(C) The average acceleration from $1 \le t \le 2$ seconds is 6m/s^2.
(D) In the interval $5 \le t \le 6$ seconds, the distance travelled is equal to the displacement.

26*. Pick the correct statements :

(A) Average speed of a particle in a given time is never less than the magnitude of the average velocity.

(B) It is possible to have a situation in which $\left|\frac{d\vec{u}}{dt}\right| \neq 0$ but $\frac{d}{dt}|\vec{u}| = 0$.

(C) The average velocity of a particle is zero in a time interval. It is possible that the instantaneous velocity is never zero in the interval.

(D) The average velocity of a particle moving on a straight line is zero in a time interval. It is possible that the instantaneous velocity is never zero in the interval. (infinite acceleration is not allowed)

27*. A stone is projected vertically upwards at t = 0 second. The net displacement of stone is zero in time interval between t = 0 second to t = T seconds. Pick up the ***CORRECT*** statement :

(A) From time $t = \frac{T}{4}$ second to $t = \frac{3T}{4}$ second, the average velocity is zero.

(B) The change in velocity from time t = 0 to $t = \frac{T}{4}$ second is same as change in veolocity from $t = \frac{T}{8}$ second to $t = \frac{3T}{8}$ second.

(C) The distance travelled from t = 0 to $t = \frac{T}{4}$ second is larger than distance travelled from $t = \frac{T}{4}$ second to $t = \frac{3T}{4}$ second

(D) The distance travelled from $t = \frac{T}{2}$ second to $t = \frac{3T}{4}$ second is half the distance travelled from $t = \frac{T}{2}$ second to t = T second.

28*. A particle moves with an initial velocity v_0 and retardation βv, where v is its velocity at any time t (β is a positive constant).

(A) the particle will cover a total distance of v_0/β.

(B) the particle will continue to move for a very long time.

(C) the particle will stop shortly.

(D) the velocity of particle will become $v_0/2$ after time $1/\beta$.

29. The coordinates of a particle moving in a plane are given by x(t) = acos(pt) and y(t) = bsin(pt) where a, b (<a) and p are positive constants of appropriate dimensions. Then : **[IIT-JEE - 1999]**

(A) The path of the particle is an ellipse.

(B) The velocity and acceleration of the particle are normal to each other at $t = \pi/2p$

(C) The acceleration of the particle is always directed towards a focus.

(D) The distance travelled by the particle in time interval t = 0 to $t = \frac{\pi}{2p}$ is a

30. A particle of mass m moves on the x-axis as follows: it starts from rest at t = 0 from the point x = 0, and comes to rest at t = 1 at the point x = 1. No other information is available about its motion at intermediate time (0<t<1). If α denotes the instantaneous acceleration of the particle, then **[IIT-JEE 1993]**

(A) α cannot remain positive for all *t* in the internal $0 \le t \le 1$

(B) $|\alpha|$ cannot exceed 2 at any point in its path

(C) $|\alpha|$ must be ≥ 4 at some point or points in its path

(D) α must change sign during the motion, but no other assertion can be made with the information given

Match the Column

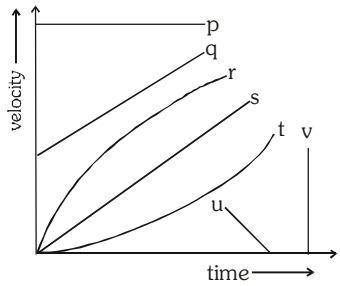
31. The equation of one dimensional motion of the particle is described in column I. At t = 0, particle is at origin and at rest. Match the column I with the statements in Column II.

Column I	**Column II**
(A) $x = (3t^2 + 2)$m	(p) Velocity of particle at t = 1s is 8 m/s
(B) v = 8t m/s	(q) Particle moves with uniform acceleration
(C) a = 16t	(r) Particle moves with variable acceleration
(D) $v = 6t - 3t^2$	(s) Particle will change its direction after some time.

32. **Column I**

(A) Zero acceleration
(B) Infinite acceleration
(C) Constant positive acceleration, with zero initial velocity
(D) Constant positive acceleration, with non–zero initial velocity
(E) Constant Negative acceleration
(F) Increasing acceleration
(G) Decreasing acceleration

Column II



33. A particle is rotating in a circle of radius 1m with constant speed 4 m/s. In time 1 s, match the following (in SI units)

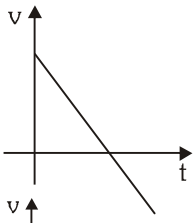
Column I	**Column II**
(A) Displacement	(p) 8sin2
(B) Distance	(q) 4
(C) Average velocity	(r) 2sin2
(D) Average acceleration	(s) 4sin2

34*. A balloon rises up with constant net acceleration of $10 m/s^2$ at t = 0. After 2 s a particle drops from the balloon. After further 2 s match the following : (Take g = 10 m/s^2)

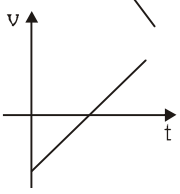
Column I	**Column II**
(A) Height of particle from ground	(p) Zero
(B) Speed of particle	(q) 10 SI units
(C) Displacement of Particle (from t = 2 sec. to t = 4 sec.)	(r) 40 SI units
(D) Acceleration of particle	(s) 20 SI units

35. The velocity time graph for a particle moving alnog a straight line is given in each situation of column-I. In the time interal $\infty > t > 0$, match the graph in column-I with corresponding statements in column-II.

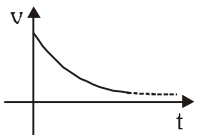
Columns I **Column II**

(A) 

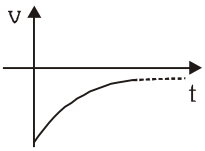
(p) speed of particle is continously decreasing.

(B) 

(q) magnitude of acceleration of particle is decreasing with time.

(C) 

(r) direction of acceleration of particle does not change.

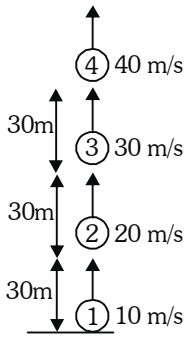
(D) 

(s) magnitude of acceleration of particle is increasing with time.
(t) magnitude of acceleration of particle does not change.

36. For a particle projected upwards with velocity 20 m/s, match the following ($g = 10\ m/s^2$)

Column I	**Column II**
(A) Distance travelled in 1st second	(p) 5 m
(B) Distance travelled in 2nd second	(q) 15 m
(C) Distance travelled in 3rd second	(r) 20 m
(D) Distance travelled in 4th second	(s) 25 m

37. Four particles are projected simultaneously upwards with velocities shown in figure. After 1s separation between ($g = 10\ m/s^2$)



Column I	**Column II**
(A) 1 and 2	(p) 40 m
(B) 2 and 3	(q) 60 m
(C) 2 and 4	(r) 30 m
(D) 1 and 4	(s) None of these

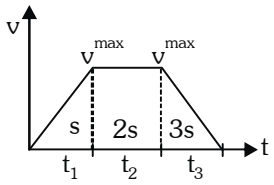
38. A particle moves in a straight line with zero initial velocity. then, match the following terms.

Column I	**Column II**
(A) 1/2 (slope of $v^2 - x$) graph	(p) Speed
(B) Slope of v – t graph	(q) Acceleration
(C) Slope of x – t graph	(r) Area under v – t graph
(D) $\sqrt{2(\text{Area under a} - \text{s graph})}$	(s) Velocity (u = 0)

Comprehension

Comprehension-1

The velocity time graph of a body moving in a straight line is shown in figure.



39. The ratio of average velocity to the maximum velocity is:

(A) $\frac{3}{5}$ (B) $\frac{2}{5}$ (C) $\frac{4}{5}$ (D) $\frac{7}{9}$

40. The time for which particle is accelerated, if average velocity is v_{av}.

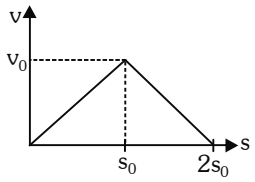
(A) $\frac{2s}{v_{av}}$ (B) $\frac{2s}{5v_{av}}$ (C) $\frac{6s}{5v_{av}}$ (D) None of these

41. The ratio of accelerated time to the retarding time is:

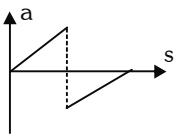
(A) $\frac{1}{3}$ (B) $\frac{1}{2}$ (C) $\frac{5}{3}$ (D) $\frac{1}{2}$

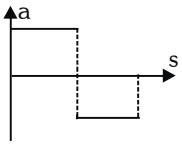
Comprehension-2

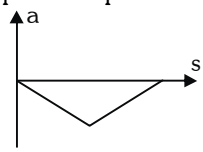
Velocity (v) versus displacement (s) graph of a particle moving in a straight line is as shown in figure. Given $v_0 = 4$ m/s and $s_0 = 20$ m.

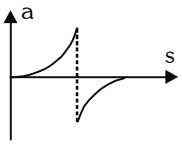


42. Corresponding acceleration (a) versus displacement (s) graph of the particle would be:

(A) 

(B) 

(C) 

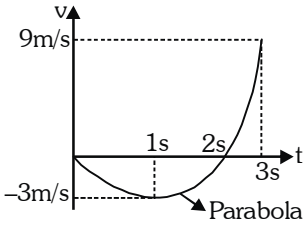
(D) 

43. At s = 30 m what is the acceleration of particle.
(A) 0.2 m/s^2 (B) 0.4 m/s^2 (C) –0.2 m/s^2 (D) –0.4 m/s^2

44. At what displacement, velocity and acceleration have same magnitudes ?
(A) At s = 5 m (B) At s = 10 m (C) At s = 30 m (D) None of these

Comprehension-3

A particle moves along x-axis. Its velocity time graph is given below.



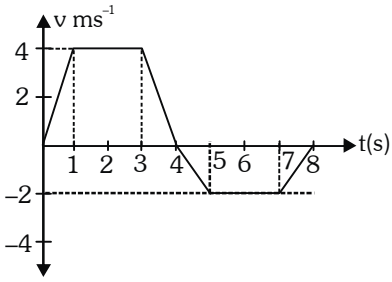
45. The displacement of the particle in 0 to 3s
(A) Zero (B) 4m (C) 8m (D) 12m

46. The distance travelled by the particle is 0 to 3s
(A) zero (B) 4m (C) 8m (D) 12m

47. The particle changes its direction of acceleration, when
(A) t > 1s (B) t = 2s (C) t > 1s (D) t ≤ 1s

Comprehension-4

The velocity-time graph of a particle in straight line motion is shown in figure. The particle state its motion from origin.



48. The distance travelled by the particle in 8s is
(A) 18 m (B) 16 m (C) 8 m (D) 6 m

49. The displacement of the particle from the origin after 8s is
(A) 18 m (B) 16 m (C) 8 m (D) 6 m

50. Find the average acceleration from 2s to 6s.
(A) –1 m/s^2 (B) –1.5 m/s^2 (C) 1.5 m/s^2 (D) 1 m/s^2

Subjetive Questions

51*. A particle is moving along x – axis with acceleration $a = a_0 (1 - t/T)$ where a_0 and T are constants. The particle at t = 0 has zero velocity. Calculate the average velocity between t = 0 and the instant when a = 0.

52. A parachutist after bailing out falls 52 m without friction . When the parachute opens, she decelerates at 2.1 ms^{-2} & reaches the ground with a speed of 2.9 ms^{-1} .
(i) How long has been the parachutist in the air ?
(ii) At what height did the fall begin ?

53*. A driver travelling at speed 36 kmh^{-1} sees the light turn red at the intersection. If his reaction time is 0.6s, and then the car can deaccelerate at $4ms^{-2}$. Find the stopping distance of the car.

54*. A body starts with an initial velocity of 10 m/s and moves along a straight line with a constant acceleration. When the velocity of the particle is 50 m/s the acceleration is reversed in direction. Find the velocity of the particle when it reaches the starting point.

55*. An elevator is descending with uniform acceleration. To measure the acceleration , a person in the elevator drops a coin at the moment the elevator starts. The coin is 6 ft above the floor of the elevator at time it is dropped. The person observes that the coin strikes the floor in 1 second. Calculate from these data the acceleration of the elevator. [Take g = 32 ft/s^2]

56. A particle moving in straight line, traversed half the distance with a velocity v_0. The remaining part of the distance was covered with velocity v_1 for half the time and with velocity v_2 for the other half of the time. Find the mean velocity of the particle averaged over the whole time of motion.

57. The displacement of a particle moving on a straight line is given by $x = 16t - 2t^2$. Find out
(a) displacement upto 2 and 6s. (b) Distance travelled upto 2 and 6s.

58*. A particle moving in a straight line having acceleration which varies with its velocity as $a = -kv^n$. Here k is a constant. For what value of n the average value of velocity of the particle averaged over the time, till it stops, is one third the initial velocity. ($n \neq 1$ or 2)

59*. The brakes of a train which is travelling at 30 m/s are applied as the train passes point A. The brakes produce a constant retardation of magnitude 3λ m/s^2 until the speed of the train is reduced to 10 m/s. The train travels at this speed for a distance and is then uniformly accelerated at λ m/s^2 until it again reaches a speed of 30 m/s as it passes point B . The time taken by the train in travelling from A to B, a distance of 4 km, is 4 min. Sketch the speed time graph for this motion and calculate :
(i) The value of λ (ii) Distance travelled at 10 m/s .

60. A balloon starts ascending from the ground at a constant speed of 25 m/s. After 5 s, a bullet is shot vertically upwards from the ground.
(i) What should be the minimum speed of the bullet so that it may reach the balloon ?
(ii) The bullet is shot at twice the speed calculated in (i). Find the height at which it passes the balloon.

61*. A railway track runs parallel to a road until a turn brings the road to railway crossing. A cyclist rides along the road everyday at a constant speed 20 km/hr. He normally meets a train that travels in same direction at the crossing. One day he was late by 25 minutes and met the train 10 km before the railway crossing. Find the speed of the train.

62. A particle starts moving rectilinerly at time t = 0 such that its velocity 'v' changes with time 't' according to the equation $v = t^2 - t$ where t is in seconds and v is in m/s. Find the time interval for which the particle retards.

63. The velocity of a particle moving in the direction of x-axis varies as $v = \alpha . x$, where α is a constant. At the moment t = 0, the particle was located at x = 0, then find the average velocity and average acceleration over the time that the particle takes to cover first s meter of the path.

64*. A bird is at a point P (4m, -1m, 5m) and sees two points P_1 (-1m, -1m, 0m) and P_2(3m, -1m, -3m). At time t = 0, it starts flying in a plane of the three positions, with a constant speed of 2 m/s in a direction perpendicular to the strainght line P_1P_2 till it sees P_1 & P_2 collinear at time t. Find the time t.

65. The driver of a car moving with a speed of 10 m s^{-1} sees a red light ahead, applies brakes and stops after covering 10 metre distance. If the same car were moving with a speed of 20 m s^{-1}, then the same driver would have stopped the car after covering 30 m distance. Within what distance the car can be stopped if travelling with a velocity of 15 m s^{-1} ? Assume the same reaction time and the same deceleration in each case :

66. An object starts from rest at t = 0 and accelerates at a rate given by a = 6t. What is
(a) its velocity and (b) its displacement at any time t?

67. For a particle moving along x-axis, acceleration is given as $a = 2v^2$. If the speed of the particle is v_0 at x = 0, find speed as a function of x.

68. For a particle moving along x-axis, velocity is given as a function of time as $v = 2t^2 + \sin t$. At t = 0, particle is at origin. Find the position as a function of time?

69. Two particles A and B start from rest and move for equal time on a straight line. the particle A has an acceleration a for the first half of the total time and 2a for the second half. The particle B has an acceleration 2a for the first half and a for the second half. Which particle has covered larger distance ?

70. A train, travelling at 20 km/hr is approaching a platform. A bird is sitting on a pole on the platform. When the train is at a distance of 2 km from pole, brakes are applied which produce a uniform deceleration in it. At that instant the bird flies towards the train at 60 km/hr and after touching the nearest point on the train flies back to the pole and then flies towards the train and continues repeating itself. Calculate how much distance will the bird have flown before the train stops ?

71. A balloon rises from ground. When a stone is dropped from balloon at a given instant it takes a time of $\frac{2u_0}{g}$, (u_0 is constant) to reach ground irrespective of position from where it is dropped. find acceleration of balloon as a function of time.

ANSWERS

- **True and False**

1. True **2**. True **3**. True **4**. False **5**. True **6**. True

- **Fill in the Blanks**

7. $(2+\sqrt{2})\,t$ **8.** 30 cm **9.** Three **10.** 2R, πR **11.** 0.6

- **Assertion–Reason**

12. (D) **13**. (D) **14**. (A) **15**. (C) **16**. (A)

- **Single Choice Correct**

17. (B) **18.** (A) **19.** (A) **20.** (A) **21.** (A)
22. (B) **23.** (C)

- **Multiple Choice Correct**

24. (ACD) **25.** (AD) **26.** (ABC) **27.** (ABC) **28.** (AB)
29. (AB) **30.** (AC)

- **Match the Column**

31. (A)–q, (B)–p, q; (C)–p, r; (D)–r, s
32. (A)–p, (B)–v, (C)–s, (D)–q, E–u, F–t, G–r
33. (A)–r, (B)–q, (C)–r (D)–p
34. (A)–r, (B)–p, (C)–s, (D)–q
35. (A)–r, t; (B)–r, t; (C)–p, q, r; (D)–p, q, r
36. (A)–q, (B)–p, (C)–p, (D)–q
37. (A)–p, (B)–p, (C)–s, (D)–s
38. (A)–q, (B)–q, (C)–s, (D)–p

- **Comprehension**

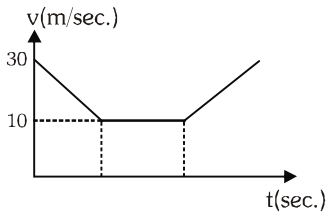
Comprehension 1 : **39.** (A) **40.** (C) **41.** (A)
Comprehension 2 : **42.** (A) **43.** (D) **44.** (D)
Comprehension 3 : **45.** (A) **46.** (C) **47.** (C)
Comprehension 4 : **48.** (A) **49.** (D) **50.** (B)

- **Subjective Questions**

51. $a_0T/3$ **52**. (i) 17.1s (ii) 293.8 m **53**. 18.5 m **54.** 70 m/s

55. 20 ft/s^2 **56.** $2v_0\left(\dfrac{v_1+v_2}{2v_0+v_1+v_2}\right)$ **57.** (a) 24m, 24 m (b) 24 m, 40 m

58. $\dfrac{1}{2}$ **59.** (i) $\lambda=\dfrac{1}{6}$, (ii) 800m



60. 75 ms^{-1}, $(437.5 \pm 62.5\sqrt{21})$m **61.** 120 km/h **62.** $\dfrac{1}{2} < t < 1$ **63.** 0, 0

64. 3.5 sec **65** 18.75 m **66.** (a) $3t^2$, (b) t^3

67. $[\,v = v_0e^{2x}\,]$ **68.** $[\,x=\dfrac{2}{3}t^3-\cos(t)+1\,]$ **69.** (B) has covered larger distance

70. 12 km **71.** $-\dfrac{g}{2}e^{-\frac{gt}{2u_0}}$

PROJECTILE MOTION

True/False

1. A projectile fired from the ground follows a parabolic path. The speed of the projectile is minimum at the top of its path. **[IIT-JEE 1984]**

2*. The normal acceleration of the projectile at its highest position is equal to g.

3. The greatest height to which a man can throw a stone is H. The greatest distance upto which he can throw the stone is H/2..

Fill in the blanks

4. The trajectory of a projectile in a vertical plane is $y = ax - bx^2$, where a, b are constants, and x and y are respectively the horizontal and vertical distances of the projectile from the point of projection. The maximwn height attained is ..... and the angle of projection from the horizontal is ..... . **[IIT-JEE 1997]**

5. The equation of a projectile is $y = \sqrt{3}x - \frac{gx^2}{2}$. The angle of projection is .....and initial velocity is .....

6. A particle is projected with initial velocity 40 m/s . The particle is located at the same height 1s and 3s after it was thrown . The time of flight of the projectile is..... The angle of projection is .....and the height at those instants is.....($g = 10$ m/s^2)

7. A stone of weight 10 kg is dropped from a cliff in a high wind . The wind exerts a steady horizontal force of 50 N on the stone as it falls .The path that the stone follows is .....

Assertion & Reason

These questions contains, Statement I (assertion) and Statement II (reason).

8. **Statement–I :** A projectile is thrown with an initial velocity of $\left(a\hat{i} + b\hat{j}\right)$ m/s. If range of projectile is maximum then a = b.
because
Statement–II : In projectile motion, angle of projection is equal to 45° for maximum range condition.
(A) Statement–I is true, Statement–II is true ; Statement–II is correct explanation for Statement–I.
(B) Statement–I is true, Statement–II is true ; Statement–II is NOT a correct explanation for statement–I.
(C) Statement–I is true, Statement–II is false.
(D) Statement–I is false, Statement–II is true.

9*. **Statement–I :** Path of a projectile is a parabola irrespective of its velocity of projection.
because
Statement–II : Trajectory of a projectile is a parabola when variation of g, (acceleration due to gravity) can be neglected.
(A) Statement–I is true, Statement–II is true ; Statement–II is correct explanation for Statement–I.
(B) Statement–I is true, Statement–II is true ; Statement–II is NOT a correct explanation for statement–I.
(C) Statement–I is true, Statement–II is false.
(D) Statement–I is false, Statement–II is true.

10. **Statement–I** : The maximum range along the inclined plane, when thrown downward is greater than that when thrown upward along the same inclined plane with same velocity.
because
Statement–II : The maximum range along inclined plane is independent of angle of inclination.
(A) Statement–I is true, Statement–II is true ; Statement–II is correct explanation for Statement–I.
(B) Statement–I is true, Statement–II is true ; Statement–II is NOT a correct explanation for statement–I.
(C) Statement–I is true, Statement–II is false.
(D) Statement–I is false, Statement–II is true.

11. **Statement–I** : Two particles of different mass, are projected with same velocity at same angles. The maximum height attained by both the particles will be same.
because
Statement–II : The maximum height of projectile is independent of particle mass
(A) Statement–I is true, Statement–II is true ; Statement–II is correct explanation for Statement–I.
(B) Statement–I is true, Statement–II is true ; Statement–II is NOT a correct explanation for statement–I.
(C) Statement–I is true, Statement–II is false.
(D) Statement–I is false, Statement–II is true.

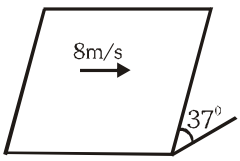
12. **Statement–I :** When a body is dropped or thrown horizontally from the same height, it would reach the ground at the same time.
because
Statement–II : Horizontal velocity has no effect on the vertical direction.
(A) Statement–I is true, Statement–II is true ; Statement–II is correct explanation for Statement–I.
(B) Statement–I is true, Statement–II is true ; Statement–II is NOT a correct explanation for statement–I.
(C) Statement–I is true, Statement–II is false.
(D) Statement–I is false, Statement–II is true.
(E) Both Statement–I and Statement–II are false.

13. **Statement–I :** When a particle is thrown obliquely from the surface of the Earth, it always moves in a parabolic path, provided the air resistance is negligible.
because
Statement–II : A projectile motion is a two dimensional motion.
(A) Statement–I is true, Statement–II is true ; Statement–II is correct explanation for Statement–I.
(B) Statement–I is true, Statement–II is true ; Statement–II is NOT a correct explanation for statement–I.
(C) Statement–I is true, Statement–II is false.
(D) Statement–I is false, Statement–II is true.

Single Choice Correct

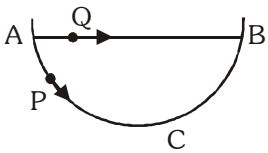
14*. The total speed of a projectile at its greatest height is $\sqrt{\frac{6}{7}}$ of its speed when it is at half of its greatest height . The angle of projection will be :
(A) 60° (B) 45° (C) 30° (D) 50°

15*. A ball is projected on smooth inclined plane in direction perpendicular to line of greatest slope with velocity of 8m/s. Find its speed after 1 sec.



(A) 10 m/s (B) 12 m/s (C) 15 m/s (D) 20 m/s

16*. A particle P is sliding down a frictionless hemispherical bowl. It passes the point A at t = 0. At this instant of time, the horizontal component of its velocity is v. A bead Q of the same mass as P is ejected from A at t = 0 along the horizontal string AB, with the speed v. Friction between the bead and the string may be neglected. Let t_P and t_Q be the respective times taken by P and Q to reach the point B. Then **[IIT-JEE 1993]**



(A) $t_P < t_Q$ (B) $t_P = t_Q$
(C) $t_P > t_Q$ (D) $\frac{t_P}{t_Q} = \frac{\text{length of arc ACB}}{\text{length of chord AB}}$

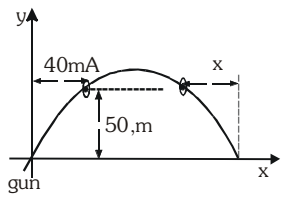
Multiple Choice Correct

17*. Two guns situated at the top of a hill of height 10 m, fire one shot each with the same speed of $5\sqrt{3}$ ms^{-1} at some interval of time. One gun fires horizontally and other fires upwards at an angle of 60° with the horizontal. The shots collide in mid air at the point P. Taking the origin of the coordinate system at the foot of the hill right below the muzzle, trajectories in x-y plane and $g = 10\ ms^{-2}$ then
(A) the first shell reaches the point P at $t_1 = 1s$ from the start
(B) the second shell reaches the point P at $t_2 = 2s$ from the start
(C) the first shell is fired 1s after the firing of the second shell
(D) they collide at P whose coordinates are given by $\left(5\sqrt{3}, 5\right)m$

18*. If T is the total time of flight, H the maximum height and R is the horizontal range of a projectile. Then x and y co–ordinates at any time t are related as :

(A) $y = 4H\left(\frac{t}{T}\right)\left(1-\frac{t}{T}\right)$ (B) $y = 4H\left(\frac{T}{t}\right)\left(1-\frac{T}{t}\right)$ (C) $y = 4H\left(\frac{x}{R}\right)\left(1-\frac{x}{R}\right)$ (D) $y = 4H\left(\frac{R}{x}\right)\left(1-\frac{R}{x}\right)$

19*. A gun is set up in such a way that the muzzle is at ground level as in figure. The hoop A is located at a horizontal distance 40m from the muzzle and is 50m above the ground level. Shell is fired with initial horizontal component of velocity as 40m/s. Which of the following is/are correct?
(A) The vertical component of velocity of the shell just after it is fired is 55m/s, if the shell has to pass through the hoop A.
(B) The shell will pass through both the hoops if x=40m.
(C) The shell will pass through both the hoops if x=20m.
(D) The vertical component of velocity of the shell just after it is fired is 45m/s, if the shell is to pass through both the hoops.



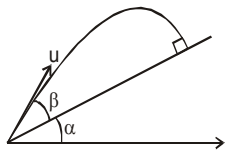
20*. A particle of mass m moves along a curve $y = x^2$. When particle has x – co–ordinate as 1/2 and x–component of velocity as 4m/s. Then :
(A) The position coordinate of particle are (1/2, 1/4)
(B) The velocity of particle will be along the line $4x - 4y - 1 = 0$
(C) The magnitude of velocity at that instant is $4\sqrt{2}$ m/s
(D) None of these

21*. A projectile is projected at an angle of elevation α. After t seconds, it appears to have an angle of elevation β as seen from the point of projection. Which of the following are correct :

(A) the y-coordinate of the position of the projectile at time t is $(v \sin \alpha)\ t - \frac{1}{2}gt^2$, where v is the velocity of projection
(B) the x-coordinate of the position of projectile at time t is $(v \cos \alpha)\ t$, where v is the velocity of projection
(C) $\tan \beta = \tan \alpha - \frac{gt}{2v \cos \alpha}$, where v is the velocity of projection
(D) velocity of projection is $\frac{gt \cos \beta}{2 \sin(\alpha - \beta)}$

Match the Column

22. Match the following.
The projectile collides perpendicularly with the inclined plane. (Refer the figure)



(A) Maximum height attained by the projectile from the ground	(p) zero
(B) Maximum height attained by the projectile from Inclined plane	(q) g
(C) Acceleration of the projectile before striking the inclined plane	(r) $\frac{u^2 \sin^2 \beta}{2\ g \cos \alpha}$
(D) Horizontal component of acceleration of the projectile.	(s) $\frac{u^2 \sin^2(\alpha+\beta)}{2\ g}$

23*. A ball is projected from the ground with velocity v such that its range is maximum.

Column-I		Column-II	
(A)	Velocity at half of the maximum height	(p)	$\frac{\sqrt{3}\,v}{2}$
(B)	Velocity at the maximum height	(q)	$\frac{v}{\sqrt{2}}$
(C)	Change in its velocity when it returns to the ground	(r)	$v\sqrt{2}$
(D)	Average velocity when it reaches the maximum height	(s)	$\frac{v}{2}\sqrt{\frac{5}{2}}$

24. The path of projectile is represented by $y = Px - Qx^2$.

Column-I		Column-II	
(A)	Range	(p)	P/Q
(B)	Maximum height	(q)	P
(C)	Time of flight	(r)	$P^2/4Q$
(D)	Tangent of angle of projection is	(s)	$\sqrt{\frac{2}{Qg}}P$

25*. In a projectile motion, horizontal component of initial velocity is a and vertical component of initial velocity is b. Let θ is the angle which initial velocity vector makes with horizontal then match the following:

Column-I		Column-II	
(A)	Time of flight	(p)	$\frac{b}{a}$
(B)	Maximum height	(q)	$\frac{2b}{g}$
(C)	Horizontal range	(r)	$\frac{2ab}{g}$
(D)	tan θ	(s)	$\frac{b^2}{2g}$

Comprehension

Comprehension-1*.

A student performs an experiment to determine how the range of a ball depends on the velocity with which it is projected. The "range" is the distance between the points where the ball lands and from where it was projected, assuming it lands at the same height from which it was projected. In each trial, the student uses the same baseball, and launches it at the same angle. Table shows the experimental results.

Trial	Launch speed (m/s)	Range (m)
1	10	8
2	20	31.8
3	30	70.7
4	40	122.5

Based on this data, the student then hypothesizes that the range, R, depends on the initial speed v_0, according to the following equation : $R=Cv_0^n$, where C is a constant and n is another constant.

26*. Based on this data, the best guess for the value of n is :

(A) $\frac{1}{2}$ (B) 1 (C) 2 (D) 3

27*. The student speculates that the constant C depends on :
(i) The angle at which the ball was launched (ii) The ball's mass (iii) The ball's diameter
If we neglect air resistance, then C actually depends on :
(A) I only (B) I and II (C) I and III (D) I, II and III

28*. The student performs another trial in which the ball is launched at speed 5.0 m/s. Its range is approximately:
(A) 1.0 m (B) 2.0 m (C) 3.0 m (D) 4.0 m

Comprehension-2

A projectile is projected with some initial velocity and some initial angle of projection. A wind is also blowing, due to which constant horizontal retardation a is imparted to the particle in the plane of motion. It is found that, the particle is at same height at two different time t_1 & t_2 and particle is at same horizontal distance at two different time t_3 & t_4.

29. Angle of projection of particle is :

(A) $\tan^{-1}\left(\frac{t_1+t_2}{t_3+t_4}\right)$ (B) $\tan^{-1}\left[\frac{a(t_1+t_2)}{g(t_3+t_4)}\right]$ (C) $\tan^{-1}\left[\frac{g(t_1+t_2)}{a(t_3+t_4)}\right]$ (D) None of these

30. Maximum height of the particle is :

(A) $\frac{g}{8}(t_1+t_2)^2$ (B) $\frac{g}{4}(t_1+t_2)^2$ (C) $\frac{g}{2}(t_1+t_2)^2$ (D) None of these

Comprehension-3

A point moves in plane X-Y according to law $x = a \sin \omega t$ and $y = (a - a \cos \omega t)$ where a is a positive constant and t is the time.

31. The magnitude of velocity of body at any instant of time t is:
(A) $a\omega \cos \omega t$ (B) $a\omega$ (C) $a\omega \sin \omega t$ (D) None

32. The trajectory represents

(A) $\sqrt{2ay}$ (B) $x = \sqrt{2ay}\sqrt{1-\frac{y}{2a}}$ (C) $x \propto y^2$ (D) None of these

33. The magnitude of acceleration of the body at any instant is :

(A) $a\omega^2$ (B) $a\omega$ (C) $\frac{a\omega^2}{2}$ (D) $\frac{a\omega}{2}$

Comprehension-4

Two projectiles are projected simultaneously from the top and bottom of a vertical tower of height h at angles 45° and 60° above horizontal respectively. Both strike at the same point on ground at distance 20 m from the foot of the tower after same time.

34. The speed of projectile projected from the bottom is :

(A) 40 m/s (B) $\frac{20}{\sqrt{3}}$ m/s (C) $40\sqrt{3}$ m/s (D) $\frac{20}{\sqrt{3}}$ m/s

35. The ratio of the speed of the projectile projected from the top and the speed of the projectile projected from the bottom of tower is

(A) $1:\sqrt{2}$ (B) $1:\sqrt{3}$ (C) $\sqrt{5}:1$ (D) $\sqrt{7}:1$

36. The time of flight of projectiles is
(A) $(3)^{1/4}$ (B) $2(3)^{1/4}$ (C) $3(3)^{1/4}$ (D) $4(3)^{1/4}$

Comprehension-5*

A particle is projected with a velocity $\vec{v} = 8\hat{i} + 6\hat{j}$ m/s from the earth's surface.

37*. The time after which it will start moving perpendicular to its initial direction of motion is :
(A) 1 s (B) 5/3 s (C) 1/2 s (D) 1.25 s

38*. The maximum height attained by the particle is :
(A) 3.2 m (B) 2 m (C) 1.8 m (D) 3.6 m

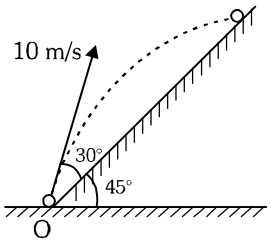
39*. The radius of curvature of the particle at its highest position is :
(A) 12.5 m (B) 1.8 m (C) 3.2 m (D) 6.4 m

40*. The time of flight of the particle for its horizontal range is :
(A) 1.2 s (B) 1.6 s (C) 1.8 s (D) None of these

Comprehension-6

A particle is projected onto the inclined plane as shown.

Take g = 10 m/s^2



41. The time of flight is :
(A) $\sqrt{2}$ s (B) $\frac{1}{\sqrt{2}}$ s
(C) 1 s (D) None of these

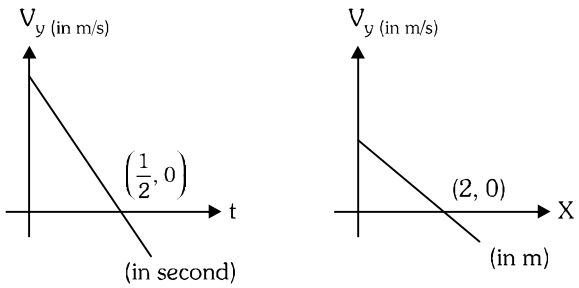
42. The speed of the particle when its velocity becomes parallel to the inclined plane is :
(A) 5 m/s (B) $\frac{5(\sqrt{3}+1)}{2\sqrt{3}}$ m/s (C) $5\sqrt{3}$ m/s (D) $5(\sqrt{3}-1)$ m/s

43. The velocity of the particle with which it strikes perpendicular to the inclined plane is :
(A) 5.5 m/s (B) $5\sqrt{3}$ m/s (C) $5\sqrt{2}$ m/s (D) 5 m/s

44. The velocity of the particle parallel to the inclined plane at the time of its sinking is :
(A) 5 m/s (B) $5(2-\sqrt{3})$ m/s (C) $5\sqrt{2}$ m/s (D) None of these

Comprehension-7

Two graphs of the same projectile motion (in the xy-plane) projected from origin are shown. x-axis is along horizontal direction and y-axis is vertically upwards. Take g = 10 ms^{-2}.



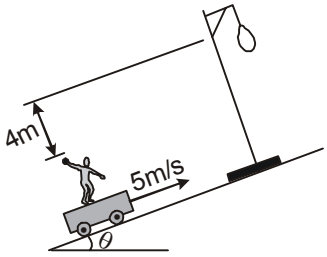
45. The projection speed is :
(A) $\sqrt{37}$ m s^{-1} (B) $\sqrt{41}$ m s^{-1} (C) $\sqrt{14}$ m s^{-1} (D) $\sqrt{40}$ m s^{-1}

46. Projection angle with the horizontal is :

(A) $\tan^{-1}\left(\frac{4}{5}\right)$ (B) $\tan^{-1}\left(\frac{2}{3}\right)$ (C) $\tan^{-1}\left(\frac{5}{4}\right)$ (D) $\tan^{-1}\left(\frac{3}{2}\right)$

Subjetive Questions

47*. A man is travelling on a flat car which is moving up a plane inclined at $\cos\theta = 4/5$ to the horizontal with a speed 5 m/s. He throws a ball towards a stationary hoop located perpendicular to the incline in such a way that the ball moves parallel to the slope of the incline while going through the centre of the hoop. The centre of the hoop is 4 m high from the man's hand calculate the time taken by the ball to reach the hoop.



48*. A shell bursts on contact with the ground and pieces from it fly in all directions with all velocities upto 80 feet per second. Show that a man 100 feet away is in danger for $\frac{5}{\sqrt{2}}$ seconds. [Use g = 32 ft/s^2]

49*. Two parallel straight lines are inclined to the horizontal at an angle α. A particle is projected from a point mid way between them so as to graze one of the lines and strikes the other at right angles. Show that if θ is the angle between the direction of projection and either of lines, then

$$\tan\theta = \left(\sqrt{2}-1\right)\cot\alpha$$

50*. Shots fired simultaneously from the top and foot of a vertical cliff at elevations of 30° and 60° respectively, strike an object simultaneously which is at a height of 100 meters from the ground and at a horizontal distance of $200\sqrt{3}$ meters from the cliff. Find the height of the cliff, the velocities of projection of the shots and the time taken by the shots to hit the object. (g = 10 m/sec^2.) **[REE-2000]**

51. Two guns situated on the top of a hill of height 10 m, each fired shots with the same speed $5\sqrt{3}$ m/s at some interval of time. One gun fires horizontally and other fires upwards at an angle of 60° with the horizontal. the shots collide in air at a point P. Find:

(i) the time interval between the firings and

(ii) the coordinates of the point P. Take origin of the coordinate system at the foot of the hill right below the muzzle and trajectories in x-y plane. **[JEE-96]**

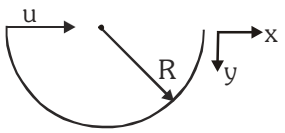
52*. A vertical pole has a red mark at some height. A stone is projected from a fixed point on the ground. When projected at an angle of 45° it hits the pole orthogonally 1m above the mark. When projected with a different velocity at an angle of $\tan^{-1}(3/4)$, it hits the pole orthogonally 1.5 m below the mark. Find the velocity and angle of projection so that it hits the mark orthogonally to the pole. [g = 10 m/sec^2] **[JEE-96]**

53. The velocity of a particle when it is at its greatest height is $\sqrt{\frac{2}{5}}$ of its velocity when it is at its half the maximum height . The angle of projection is.....and the velocity vector angle at half the maximum height is .....

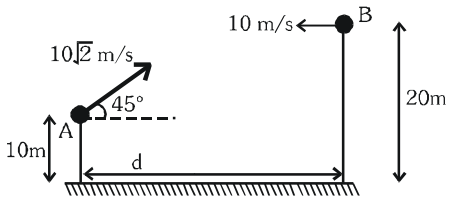
54. A body falling freely from a given height H hits an inclined plane in its path at a height h. As a result of this impact the direction of the velocity of the body becomes horizontal. For what value of (h / H) the body will take maximum time to reach the ground? **[IIT-JEE 1986]**

55*. A particle is projected horizontally as shown from the rim of a large hemispherical bowl. The displacement of the particle when it strikes the bowl the first time is R. Find the velocity of the particle at that instant and the time taken.

56*. A food packet was dropped from an aircraft flying horizontally. 6 s before it hit the ground, it was at a height of 780 m, and had travelled a distance of 1 km horizontally. Find the speed and the altitude of the aircraft.

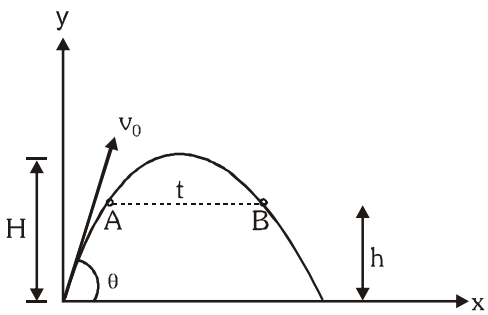


57. A body falls freely from some altitude H. At the moment the first body starts falling another body is thrown from the earth's surface which collides with the first at an altitude h = H/2. The horizontal distance is ℓ. Find the initial velocity and the angle at which it was thrown.



58*. In the figure shown, the two projectiles are fired simultaneously. What should be the initial speed of the left side projectile for the two projectile to hit in the mid-air ?

59*. The figure shows two position A and B at the same height h above the ground. If the maximum height of the projectile is H, Then determine the time t elapsed between the positions A and B in terms of H and h.



60*. A ball is thrown horizontally with a velocity $v_0 = \sqrt{2gH}$ from certain height H. Find the

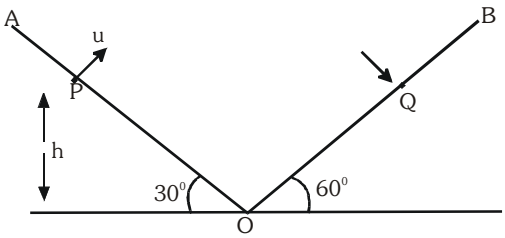
(a) displacement, when horizontal component of velocity is equal to vertical component of velocity in magnitude.

(b) velocity, when horizontal displacement is equal to vertical displacement in magnitude

(c) average velocity averaged over total time of flight.

61*. A shell is fired from a point O at an angle of 60° with a speed of 40 m/s & it strikes a horizontal plane through O, at a point A. The gun is fired a second time with the same angle of elevation but a different speed v. If it hits the target which starts to rise vertically from A with a constant speed $9\sqrt{3}$ m/s at the same instant as the shell is fired, find v .

62*. Two inclined planes OA and OB having inclinations 30^0 and 60^0 respectively, intersect each other at O as in figure. A particle is projected from point P with velocity $u = 10\sqrt{3} m/s$ along a direction perpendicular to plane OA. If the particle strikes the plane OB perpendicularly at Q. Calculate



(i) Time of flight.
(ii) Velocity with which particle strikes the plane OB.
(iii) Vertical height of P from O.
(iv) Maximum height from O attained by the particle .
(v) Distance PQ.

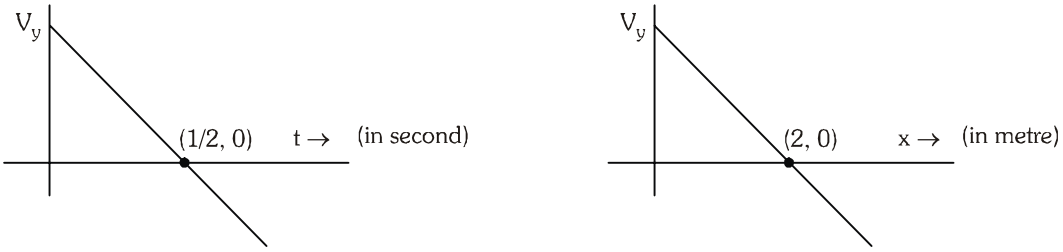
63*. A stone is projected from the point of a ground in such a direction so as to hit a bird on the top of a telegraph post of height h and then attain the maximum height 2h above the ground. If at the instant of projection, the bird were to fly away horizontally with a uniform speed, find the ratio between the horizontal velocities of the bird and the stone, if the stone still hits the bird while descending.

64*. A projectile is launched at an angle α from a cliff of height H above the sea level. If it falls into the sea at a distance D from the base of the cliff, show that its maximum height above the sea level is $\left[H+\frac{D^2\tan^2\alpha}{4(H+D\tan\alpha)}\right]$.

65*. A particle is projected with a velocity $2\sqrt{ag}$ so that it just clears two walls of equal height 'a'. which are at a distance 2a apart. Show that the time of passing between the walls is $2\sqrt{a/g}$.

66. A truck starts from origin, accelerating with 'a' m/sec^2 in positive x-axis direction. After 2 seconds a man standing at the starting point of the truck projected a ball at an angle 30° with velocity 'v' m/s. Find the relation between 'a' and 'v' such that ball hits the truck. (assume truck is moving on horizontal plane and man projected the ball from the same horizontal level of truck)

67. Two graphs of the same projectile motion (in the xy plane) projected from origin are shown. X axis is along horizontal direction & Y axis is vertically upwards. Take g = 10 m/s^2.

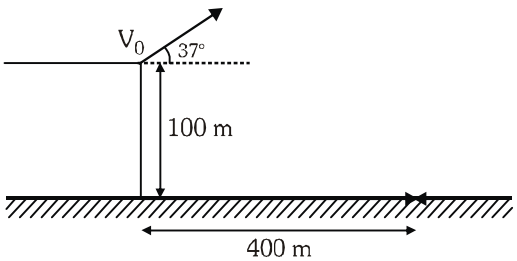


Find : (i) Y component of initial velocity and
(ii) X component of intial velocity

68. A stone is dropped from a height of 45 m from horizontal level ground. There is horizontal wind blowing due to which horizontal acceleration of the stone becomes 10 m/s^2. (Take g = 10 m/s^2)
(a) Find time taken by stone to reach the ground.
(b) Find the net horizontal displacement of the stone from time it is dropped and till it reaches ground.

69*. A regular hexagon stands with one side on the ground and a particle projected so as to graze its four upper vertices. Show that the ratio of its maximum velocity to that of its minimum velocity is $\sqrt{\frac{31}{3}}$.

70. A projectile is fired into the air from the edge of a 100 m high cliff at an angle of 37° above the horizontal. The projectile hits a target 400 m away from the base of the cliff. What is the initial velocity of the projectile, v_0? (Neglect air friction and assume x - axis to be horizontal and y-axis to be vertical).



ANSWERS

- **True and False**

1. True **2.** True **3.** False

- **Fill in the Blanks**

2. $a^2/4b$, $\tan^{-1}(a)$ **5.** 60^0, $2ms^{-1}$ **6.** 4s, 30^0, 15 m **7.** Straight line

- **Assertion–Reason**

8. (A) **9.** (D) **10.** (C) **11.** (A) **12.** (A) **13.** (D)

- **Single Choice Correct**

14. (C) **15.** (A) **16.** (B)

- **Multiple Choice Correct**

17. (A,B,C,D) **18.** (A,C) **19.** (A,B) **20.** (A,B,C) **21.** (A,B,C,D)

- **Match the Column**

22. (A) s (B) r (C) q (D) p
23. (A) p; (B) q; (C) r; (D) s
24. (A) p; (B) r; (C) s; (D) q
25. (A) q; (B) s; (C) r; (D) p

- **Comprehension**

Comprehension 1 : **26.** (C) **27.** (A) **28.** (B)
Comprehension 2 : **29.** (C) **30.** (A)
Comprehension 3 : **31.** (B) **32.** (B) **33.** (A)
Comprehension 4 : **34.** (D) **35.** (A) **36.** (B)
Comprehension 5 : **37.** (B) **38.** (C) **39.** (D) **40.** (A)
Comprehension 6 : **41.** (A) **42.** (D) **43.** (D) **44.** (B)
Comprehension 7 : **45.** (B) **46.** (C)

- **Subjective Questions**

47. 1s

50. 400 m, $V_T = 40$ m/s , $V_F = 40\sqrt{3}$ m/s, T = 10 s.

51. (i) 1s (ii) $\left(5\sqrt{3}, 5\right)$

52. $\frac{\sqrt{3620}}{3}$ m/s, $\tan^{-1}\left(\frac{9}{10}\right)$

53. 60^0, $\tan^{-1}\left(\sqrt{\frac{3}{2}}\right)$

54. $\frac{1}{2}$

55.. $u\hat{i} + \sqrt{\sqrt{3}Rg}\,\hat{j}$, $\sqrt{\frac{\sqrt{3}R}{g}}$

56. 360 km/hr, 1.28 km

57. $v_0 = \sqrt{gH\left(1+\frac{\ell^2}{H^2}\right)}$, $\tan\alpha = \frac{H}{\ell}$

58. $20\sqrt{\frac{2}{3}}$

59. $\sqrt{\frac{8(H-h)}{g}}$

60. (a) $(2\hat{i}-\hat{j})H$, (b) $\sqrt{2gH}\,(\hat{i}-2\hat{j})$, (c) $\sqrt{\frac{gH}{2}}(2\hat{i}-\hat{j})$ (along horizontal x-axis).

61. 50 ms^{-1}

62. (i) 2s (ii) 10 ms^{-1} (iii) 5m (iv) 16.25 m (v) 20 m

63. $\frac{2}{\sqrt{2}+1}$

66. $\frac{\sqrt{3}v^2}{g} = a\left(2+\frac{v}{g}\right)^2$

67. (i) 5 m/s (ii) 4 m/s

68. (a) 3 sec. (b) 45 m

70. $v_0 = 25\sqrt{5}$ m/s

RELATIVE MOTION

True / False

1. Two bodies A and B are moving along same line and same direction with A ahead of B and $v_A > v_B$. If v_A is decreasing and v_B is increasing, before collision the separation between them will be maximum at the instant when $v_A = v_B$.

2. Two bodies A and B are moving along the same line and same direction with A ahead of B and $v_A < v_B$. v_A is increasing and v_B is decreasing and the two bodies do not collide. The minimum distance will be at the instant when $v_A = v_B$.

3. The distance between two particles will be constant if the relative velocity vector is always perpendicular to the line joining the two particles.

4. If separation between two particles does not change then their relative velocity will be zero.

5. If speed of two particles is increasing at the same rate then their relative velocity will be constant.

Fill in the Blanks

6. Four persons K, L, M, N are initially at the four corners of a square of side d. Each person now moves with a uniform speed v in such a way that K always moves directly towards L, L directly towards M, M directly toward N and N directly towards K. The four persons will meet at a time ..... **[IIT-JEE 1984]**

7. For two particles A and B (moving with constant velocity) to collide, the direction of $\vec{r}_{AB}$ and $\vec{v}_{AB}$ must be ..... .

8. Two runners start simultaneously from the same point on a circular track of radius 140 m in the same direction. Their speeds are 11 m/s & 2.2 m/s they will meet again after ..... .

Assertion & Reason

These questions contains, Statement I (assertion) and Statement II (reason).

(A) Statement–I is true, Statement–II is true ; Statement–II is correct explanation for Statement–I.

(B) Statement–I is true, Statement–II is true ; Statement–II is NOT a correct explanation for statement–I.

(C) Statement–I is true, Statement–II is false.

(D) Statement–I is false, Statement–II is true.

9. **Statement–I** : If two particles, moving with constant velocities are to meet, the relative velocity must be along the line joining the two particles.

because

Statement–II : Relative velocity means velocity of one particle as viewed from the other.

10. **Statement–I** : Two balls are dropped one after the other from a tall tower. The distance between them increases linearly with time (elapsed after the second ball is dropped and before the first hits ground).

because

Statement–II : Relative acceleration is zero, whereas relative velocity is non–zero in the above situation.

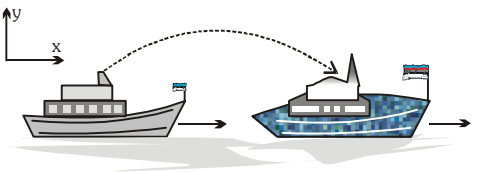
11. **Statement–I** : A man can cross the river of width d in minimum time t. On increasing river velocity, minimum time to cross the river by man will remain unchanged.

because

Statement–II : Velocity of river is perpendicular to width of river. So minimum time to cross the river is independent of velocity of river.

Single Choice Correct

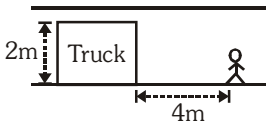
12*. From a motorboat moving downstream with a velocity 2 m/s with respect to river, a stone is thrown. The stone falls on an ordinary boat at the instant when the motorboat collides with the ordinary boat. The velocity of the ordinary boat with respect to the river is equal to zero. The river flow velocity is given to be 1 m/s. The initial velocity vector of the stone with respect to earth is :-



Take the value of g = 10 m/s^2
Initial separation between the two boats is 20m.

(A) $2\hat{i}+20\hat{j}$ (B) $3\hat{i}+40\hat{j}$
(C) $3\hat{i}+50\hat{j}$ (D) $2\hat{i}+50\hat{j}$

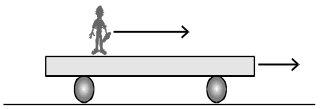
13*. A 2m wide truck is moving with a uniform speed of 8 m/s along a straight horizontal road. A pedestrian starts crossing the road at an instant when the truck is 4 m away from him. The minimum constant velocity with which he should run to avoid an accident is :



(A) $1.6\sqrt{5}$ m/s (B) $1.2\sqrt{5}$ m/s (C) $1.2\sqrt{7}$ m/s (D) $1.6\sqrt{7}$ m/s

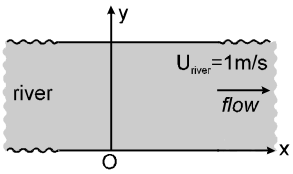
14*. A trolley is moving horizontally with a constant velocity of v m/s w.r.t. earth. A man starts running from one end of the trolley with a velocity 1.5v m/s w.r.t. to trolley. After reaching the opposite end, the man return back to starting end and continues running with a velocity of 1.5 v m/s w.r.t. the trolley in the backward direction. If the length of the trolley is L then the displacement of the man with respect to earth during the process will be :

(A) 2.5L (B) 1.5 L
(C) $\frac{5L}{3}$ (D) $\frac{4L}{3}$

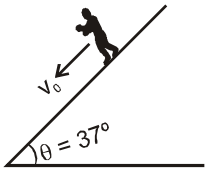


15*. A man can swim in still water with a speed of 3 m/s. x and y axis are drawn along and normal to the bank of river flowing to right with a speed of 1 m/s. The man starts swimming from origin O at t = 0 second. Assume size of man to be negligible. Find the equation of locus of all the possible points where man can reach at t = 1 sec.

(A) $(x-1)^2 + y^2 = 3$
(B) $(x-1)^2 + y^2 = 9$
(C) $x^2 + (y-1)^2 = 3$
(D) $x^2 + (y-1)^2 = 9$



6*. A man is moving downward on an inclined plane ($\theta = 37^o$) with velocity v_0 and rain drops appear to him moving in horizontal direction with velocity $2v_0$ towards him. If man increases his velocity to $2v_0$ him velocity of rain drops as observed by man is :



(A) $\sqrt{\frac{41}{5}}\,v_0$ (B) $\sqrt{39}\,v_0$
(C) $7\,v_0$ (D) $6\,v_0$

17. A river is flowing from west at a speed of 5 m/min. A man on the south bank of the river, capable of swimming at 10 m/min in still water, wants to swim across the rive in the shortest time. He should swim in a direction **[IIT-JEE 1983]**

(A) due north (B) 30° east of north (C) 30° west of north (D) 60° east of north

18. A boat which has a speed of 5 km/h in still water crosses a river of width 1 kmalong the shortest possible path in 15 min. The velocity of the river water in km/h is **[IIT-JEE 1988]**

(A) 1 (B) 3 (C) 4 (D) $\sqrt{41}$

19. A man in a balloon, throws a stone downwards with a speed of 5 m/s with respect to balloon. The balloon is moving upwards with a constant acceleration of 5 m/s2. Then velocity of the stone relative to the man after 2 second is :

(A) 10 m/s (B) 30 m/s (C) 15 m/s (D) 35 m/s

20. A projectile A is projected from ground. An observer B running on ground with uniform velocity of magnitude 'v' observes A to move along a straight line. The time of flight of A as measured by B is T. Then the range R of projectile on ground is :

(A) R = vT (B) R < vT
(C) R > vT (D) information insufficient to draw inference.

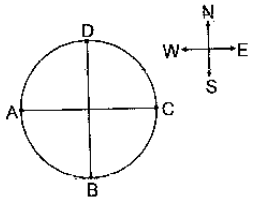
21. Two aeroplanes fly from their respective position 'A' and 'B' starting at the same time and reach of point 'C' (along straight line) simultaneously when wind was not blowing. On a windy day they head towards 'C' but both reach the point 'D' simultaneously in the same time which they took to reach 'C'. Then the wind is blowing in:

(A) North-East direction

(B) North-West direction

(C) Direction making an angle $0 < \theta < 90$ with North towards West.

(D) North direction



22. A particle is thrown up inside a stationary lift of sufficient height. The time of flight is T. Now it is thrown again with same initial speed v_0 with respect to lift. At the time of second throw, lift is moving up with speed v_0 and uniform acceleration g upward (the acceleration due to gravity). The new time of flight is:

(A) $\frac{T}{4}$ (B) $\frac{T}{2}$ (C) T (D) 2T

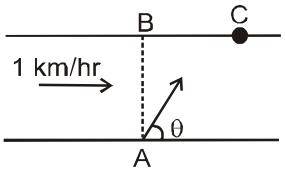
23. Consider a collection of a large number of particles each with speed v. The direction of velocity is randomly distributed in the collection. The magnitude of the relative velocity between a pair of particles average over all the pairs in the collection is :

(A) greater than v (B) less than v (C) equal to v (D) we can't say anything

Multiple Choice Correct

24*. A river is flowing with a speed of 1 km/hr. A swimmer wants to go to point 'C' starting from 'A'. He swims with a speed of 5 km/hr, at angle θ, w.r.t. the river. If AB = BC = 400 m. Then :

(A) the value of θ is 53°
(B) time taken by the man is 6 min
(C) time taken by the man is 8 min
(D) the value of θ is 45°



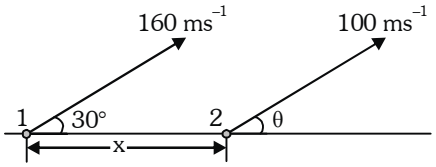
25*. A swimmer who can swim in a river with speed mv (with respect to still water) where v is the velocity of river current, jumps into the river from one bank to cross the river.

(A) If $m \le 1$ he can not reach a point on other bank directly opposite to his starting point.
(B) If $m < 1$ he can not cross the river.
(C) Only if $m > 1$ he can reach a point on other bank.
(D) He can reach the other bank at some point, whatever be the value of m other then zero.

26. Two cities A and B are connected by a regular bus service with buses plying in either direction every T seconds. The speed of each bus is uniform and equal to V_b. A cyclist cycles from A to B with a uniform speed of V_c. A bus goes past the cyclist in T_1 second in the direction A to B and every T_2 second in the direction B to A. Then

(A) $T_1 = \frac{V_b T}{V_b + V_c}$ (B) $T_2 = \frac{V_b T}{V_b - V_c}$ (C) $T_1 = \frac{V_b T}{V_b - V_c}$ (D) $T_2 = \frac{V_b T}{V_b + V_c}$

27*. Suppose two particles 1 and 2 are projected in vertical plane simultaneously.



Their angles of projection are 30° and θ, respectively, with the horizontal. Let they collide after a time t in air. Then

(A) $\theta = \sin^{-1}(4/5)$ and they will have same speed just before the collision.

(B) $\theta = \sin^{-1}(4/5)$ and they will have different speed just before the collision.

(C) $x < 1280\sqrt{3} - 960$ m.

(D) It is possible that the particles collide when both of them are at their highest point.

28. Positions of lion A, lion B and a deer running on X axis are (-10m,0m) ,(10m,0m) and (0m,0m) at some instant of time. Velocities of lion A, lion B and a deer are $(20\hat{i})$ m/s, $(-10\hat{i})$ m/s and $(30\hat{i})$ m/s Choose the correct option(s):

(A) distance between lion A and lion B is decreasing at 30m/s

(B) distance between deer and lion B is decreasing at 40m/s

(C) distance between lion A and lion B is increasing at 30m/s

(D) if all three continue to move with uniform velocities lion A will nab deer before lion B as its speed is greater.

29. A man is standing on a road and observes that rain is falling at angle 45° with the vertical. The man starts running on the road with constant acceleration 0.5 m/s^2. After a certain time from the start of the motion, it appear to him the rain is still falling at angle 45° with the vertical, with speed $2\sqrt{2}$ m/s. Motion of the man is in the same vertical plane in which the rain is falling. Then which of the following statement(s) are true :

(A) It is not possible

(B) Speed of the rain relative to the ground is 2 m/s

(C) Speed of the man when he finds rain to be falling at angle 45° with the vertical, is 4 m/s.

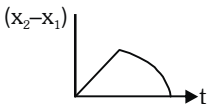
(D) The man has travelled a distance 16 m on the road by the time he again finds rain to be falling at angle 45°.

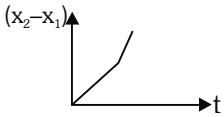
30. Two stones are thrown vertically upwards simultaneously from the same point on the ground with initial speed $u_1 = 30$ m/sec and $u_2 = 50$ m/sec. Which of the curve represents correct variation (for the time interval in which both reach the ground) of

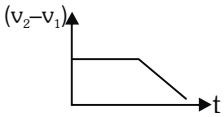
$(x_2 - x_1)$ = the relative position of second stone with respect to first with time (t).

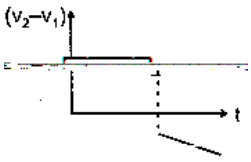
$(v_2 - v_1)$ = the relative velocity of second stone with respect to first with time (t).

Assume that stones do not rebound after hitting : 6

(A) 

(B) 

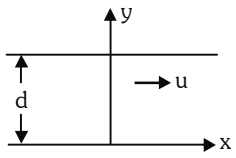
(C) 

(D) 

Comprehension

Comprehension -1

We know that when a boat travels in water, its net velocity w.r.t. ground is the vector sum of two velocities. First is the velocity of boat itself in river and other is the velocity of water w.r.t. ground. Mathematically.



$\vec{v}_{boat} = \vec{v}_{boat,water} + \vec{v}_{water}$

Now given that velocity of water w.r.t. ground in a river is u. Width of the river is d.

A boat starting from rest aims perpendicular to the river with an acceleration of a = 5t, where t is time. the boat starts from point (1, 0) of the coordinate system as shown in figure. Assume SI units.

31. Obtain the total time taken to cross the river.

(A) $(3d/5)^{1/3}$ (B) $(6d/5)^{1/3}$ (C) $(6d/5)^{1/2}$ (D) $(2d/3)^{1/3}$

32. Find the equation of trajectory of the boat.

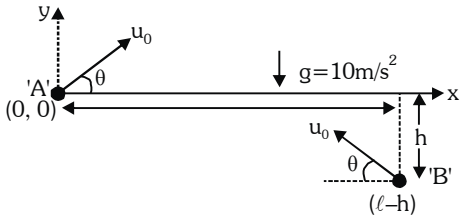
(A) $x-1=\left(\frac{3y}{5}\right)^{1/3}$ (B) $x=u\left(\frac{6y}{5}\right)^{1/3}$ (C) $x-1=u\left(\frac{6y}{5}\right)^{1/3}$ (D) None of these

33. Find the drift of the boat when it is in the middle of the river.

(A) $u\left(\frac{3d}{5}\right)^{1/3}$ (B) $u\left(\frac{3d}{5}\right)^{1/3}+1$ (C) $u\left(\frac{6d}{5}\right)^{1/3}$ (D) None of these

Comprehension -2

Two particles 'A' and'B' are projected in the vertical plane with same intial velocity u_0 from point (0, 0) and (l, - h) towards each other as shown in figure at t = 0.



34. The path of particle 'A' with respect to particle 'B' will be :

(A) parabola (B) straight line parallel to x - axis.
(C) straight line parallel to y-axis (D) none of these.

35. Minimum distance between particle A and B during motion will be :

(A) ℓ (B) h (C) $\sqrt{\ell^2+b^2}$ (D) $\ell + h$

36. The time when separation between A and B is minimum is :

(A) $\frac{x}{u_0\cos\theta}$ (B) $\sqrt{\frac{2h}{g}}$ (C) $\frac{l}{2u_0\cos\theta}$ (D) $\frac{2\ell}{u_0\cos\theta}$

Comprehension - 3

Raindrops are falling with a velocity $10\sqrt{2}$ m/s making an angle of 45° with the vertical. The drops appear to be falling vertically to a man running with constant velocity. The velocity of rain drops change such that the rain drops now appear to be falling vertically with $\sqrt{3}$ times the velocity it appeared earlier to the same person running with same velocity.

37. The magnitude of velocity of man with respect to ground is :

(A) $10\sqrt{2}$ m/s (B) $10\sqrt{3}$ m/s (C) 20 m/s (D) 10 m/s

38. After the velocity of rain drops change, the magnitude of velocity of raindrops with respect to ground is:

(A) 20 m/s (B) $20\sqrt{3}$ (C) 20 m/s (D) $10\sqrt{3}$ m/s

39. The angle (in degrees) between the initial and the final velocity vectors of the raindrops with respect to the ground is:

(A) 8 (B) 15 (C) 22.5 (D) 37

Subjetive Questions

40*. A cart is moving along x-direction with a velocity of 4 rn/s. A person on the cart throws a stone with a velocity of 6 m/s relative to himself. In the frame of reference of the cart the stone is thrown in y-z plane making an angle of 30° with vertical z-axis. At the highest point of its trajectory the stone hits an object of equal mass hung vertically from branch of a tree by means of a string of length L A completely inelastic collision occurs, in which the stone gets embedded in the object. Determine : ($g = 9.8$ m/s^2) **[IIT-JEE 1997]**

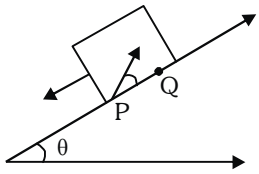
(a) the speed of the combined mass immediately after the collision with respect to an observer on the ground.

(b) the length L of the string such that tension in the string becomes zero when the string becomes horizontal during the subsequent motion of the combined mass.

41*. A large heavy box is sliding without friction down a smooth plane of inclination θ. From a point P on the bottom of the box, a particle is projected inside the box. The initial speed of the particle with respect to the box is u and the direction of projection makes an angle a with the bottom as shown in the figure. **[IIT-JEE 1998]**

(a) Find the distance along the bottom of the box between the point of projection P and the point Q where the particle lands (Assume that the particle does not hit any other surface of the box. Neglect air resistance.)

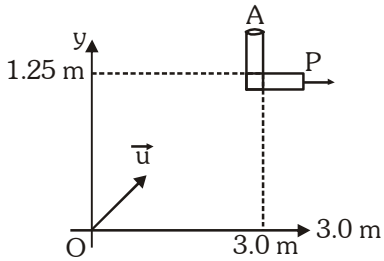
(b) If the horizontal displacement of the particle as seen by an observer on the ground is zero, find the speed of the box with respect to the ground at the instant when the particle was projected.



42*. An object A is kept fixed at the point x = 3 m and y = 125m on a plank P raised above the ground. At time t = 0 the plank starts moving along the +x-direction with an acceleration 1.5 m/s^2. At the same instant a stone is projected from the origin with a velocity $\vec{u}$ as shown.

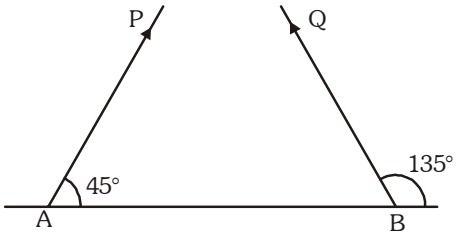
A stationary person on the ground observes the stone hitting the object during its downward motion at an angle of 45° to the horizontal. All the motions are in x-y plane.

Find $\vec{u}$ and the time after which the stone hits the object. (Take g = 10 m/s^2). **[IIT-JEE 2000]**



43. Particles P and Q of mass 20 g and 40 g respectively are simultaneously projected from points A and B on the ground. The initial velocities of F and Q make 45° and 135° angles respectively with the horizontal AR as shown in the figure. Each particle has an initial speed of 49 m/s. The separation AB is 245 m.

Both particles travel in the same vertical plane and undergo a collision. After the collision, P retraces its path. Determine the position Q where it hits the ground. How much time after the collision does the particle Q take to reach the ground? (Take g = 9.8m/s^2).

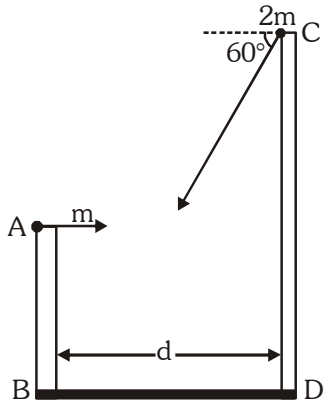


[IIT-JEE 1982]

44*. Two towers AB and CD are situated a distance d apart as shown in figure. AB is 20 m high and CD is 30 m high from the ground. An object of mass m is thrown from the top of AR horizontally with a velocity of 10 rn/s towards CD. Simultaneously another object of mass 2m is thrown from the top of CD at an angle of 60° to the horizontal towards AR with the same magnitude of initial velocity as that of the first object. The two objects move in the same vertical plane, collide in mid-air and stick to each other. **[IIT-JEE 1994]**

(a) Calculate the distance d between the towers.

(b) Find the position where the objects hit the ground.



45*. Two guns situated on the top of a hill of height 10 m fire one shot each with the same speed $5\sqrt{3}$ m/s at some interval of time. One gun fires horizontally and other fires upwards at an angle of 60° with the horizontal. The shots collide in air at point P find : (g = 10 m/s^2) **[IIT-JEE 1996]**

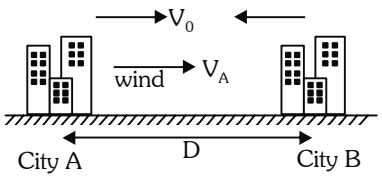
46. During a rainy day, rain is failling vertically with a velocity 2m/s. A boy at rest starts his motion with a constant acceleration of 2 m/s2 along a straight road. Find the rate at which the angle of the axis of umbrella with vertical should be changed sothat the rain always falls parallel to the axis of the umbrella.

47. A swimmer jumps from a bridge over a canal and swims 1 km upstream. After that first km, he passes a floating cork. He continues swimming for half an hour and then turns around and swims back to the bridge. The swimmer and the cork reach the bridge at the same time. The swimmer has been swimming at a constant speed. How fast does the water in the canal flow ?

48. Two swimmers 'A' & 'B' one located on one side and other on the another side of a river are situated at a distance 'D' from each other. Line joining them is making an angle θ with the direction perpendicular to flow. The speed of each swimmer with respect to still water is 'u' & speed of river flow is v_r. Both A & B start swimming at the same time in the direciton parallel to line AB towards each other and they keep on swimming in same direction. Then,
(a) Find the time after which they will meet.
(b) Find the speed of river (v_r) in terms of 'u' so that path of the two swimmers with respect to the ground becomes perpendicular to each other.

49. Hailstones falling vertically with a speed of 10 m/s, hit the wind screen (wind screen makes an angle 30° with the horizontal) of a moving car and rebound elastically. Find the velocity of the car if the driver finds the hailstones rebound vertically after striking.

50. An airplane flies between two cities separated by a distance D. Assume the wind blows directly from one city to the other at a speed V_A (As shown) and the speed of the airplane is V_0 relative to the air.

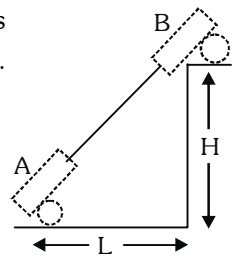


(a) Find the time taken by the airplane to make a round trip between the two cities (that is, to fly from city A to city B and then back to City A)?
(b) To an oberver on the ground, find the average speed of the airplane for such a round trip?
(c) To an observer on the ground, find the average velocity for the round trip?

51*. 'n' number of particles are located at the vertices of a regular polygon of n sides having the edge length 'a'. They all start moving simultaneously with equal constant speed 'v' heading towards each other all the time. How long will the particles take to collide ?

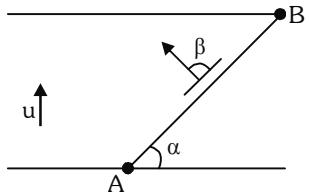
52*. Two swimmers 'A' & 'B', one located on one side and other on the another side of a river are situated at a distance 'D' from each other. Line joining them is making an angle θ with the direction perpendicular to flow. The speed of each swimmer with respect to still water is 'u' & speed of river flow is v_r. Both A & B start swimming at the same time in the direction parallel to line AB towards each other and they keep on swimming in same direction. Then,
(a) Find the time after which they will meet.
(b) Find the speed of river (v_r) in terms of 'u' so that the path of the two swimmers with respect to the ground becomes perpendicular to each other.

53*. Cannon A is located on a plane a distance L from a wall of height H. On top of this wall is an identical cannon (cannon B). Ignore air resistance throughout this problem. Also ignore the size of the cannons relative to L and H. The two groups of gunners aim the cannons directly at each other. They fire at each other simultaneously, with equal muzzle speed v_0. What is the value of v_0 for which the two cannon balls collide just as they hit the ground ?



54*. A massive plate is moving with uniform velocity $-10\hat{i}$ m/s. A dust particle travelling with velocity $-10\hat{i}$ m/s collides normally with plate. An observer moving with plate finds that dust particle's direction of motion gets reversed while it loses half its speed due to collision. Find speed of dust particle after collision relative to ground.

55*. A launch travels across a river from a point A to a point B of the opposite bank along the line AB forming angle α with the bank. The flag on the mast of the launch makes an angle β with its direction of motion. Determine the speed of the launch w.r.t. the bank. The velocity of wind is u perpendicular to the stream.



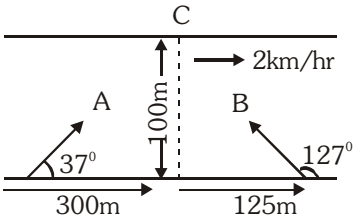
56*. A ship is moving at a constant speed of 10 km/hr in the direction of the unit vector $\hat{i}$. Initially, its position vector, relative to a fixed origin is $10\left(-\hat{i}+\hat{j}\right)$ where $\hat{i}$ & $\hat{j}$ are perpendicular vectors of length 1 km . Find its position vector relative to the origin at time t hours later. A second ship is moving with constant speed u km/hr parallel to the vector $\hat{i}+2\hat{j}$ and is initially at the origin.

(i) If $u = 10\sqrt{5}$ km/h . Find the minimum distance between the ships and the corresponding value of t

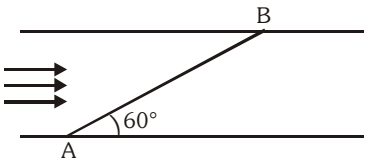
(ii) Find the value of u for which the ships are on a collision course and determine the value of t at which the collision would occur if no avoiding action were taken .

57*. Two bodies move towards each other in a straight line at initial velocities v_1 & v_2 & with constant accelerations a_1 & a_2 directed against the corresponding velocities at the initial instant . What must be the maximum initial separation ℓ_{max} between the bodies for which they meet during the motion ?

58. Two swimmers start a race. One who reaches the point C first on the other bank wins the race. A makes his strokes in a direction of 37^0 to the river flow with velocity 5km/hr relative to water. B makes his strokes in a direction 127^0 to the river flow with same relative speed. River is flowing with speed of 2km/hr and is 100m wide. Who will win the race? Compute the time taken by A and B to reach the point C if the speeds of A and B on the ground are 8 km/hr and 6 km/hr respectively.



59*. A swimmer starts to swim from point A to cross a river. He wants to reach point B on the opposite side of the river. The line AB makes an angle 60° with the river flow as shown. The velocity of the swimmer in still water is same as that of the water



(i) In what direction should he try to direct his velocity? Calculate angle between his velocity and river velocity.

(ii) Find the ratio of the time taken to cross the river in this situation to the minimum time in which he can cross this river.

60. Two particles start simultaneously from the same point and move along two straight lines making an angle α with each other. One move with uniform velocity u and the other with constant acceleration a and initial velocity 0.

(a) Find the least relative velocity of one with respect to other.

(b) At the same time, find the distance between the two particles.

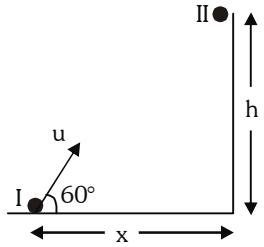
61*. Find the time an aeroplane having velocity v(relative to air), takes to fly around a square with side a and the wind blowing at a velocity u, in the two cases,

(a) if the direction of wind is along one side of the square.

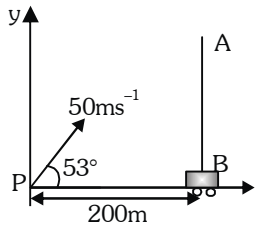
(b) if the direction of wind is along one of the diagonals of the square

62. An airplane is observed by two observers traveling at 60 kmh^{-1} in two vehicles moving in opposite directions on a straight road. To an observer in one vehicle, the plane appears to cross the road track at right angles while to the other appears to be 45°. At what angle does the plane actually cross the road track and what is its speed relative to ground?

63. Ball I is thrown towards a tower at an angle of 60° with the horizontal with unknown speed(u).
At the same moment, ball II is released from the top of tower as shown in figure. Balls collide after 2s and at the moment of collision, the velocity of ball I is horizontal. Find the
(a) Speed u
(b) Distance of point of projection of ball I from base of tower (x)
(c) Height of tower

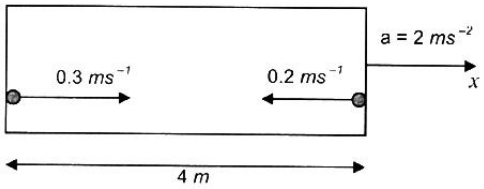


64. A ball is fired from point P, with an initial speed of 50 ms^{-1} at an angle of 53°, with the horizontal. At the same time, a long wall AB at 200 m from point P starts moving toward P with a constant speed of 10 ms^{-1}. Find
(a) The time when the ball collides with wall AB.
(b) The coordinate of point C, where the ball collides, taking point P as origin.



65*. A boy on a train of height h_1 projects a coin to his friend of height h_2 standing on the same train, with a velocity v relative to the train, at an angle θ with horizontal. If the train moves with a constant velocity v' in the direction of x-motion of the coin, find the (a) distance between the boys so that the second boy can catch the coin, (b) maximum height attained by the coin, and (c) speed with which the second boy catches the coin relative to himself (train) and ground.

66*. A rocket is moving in a gravity free spece with a constant acceleration of 2 ms^{-2} along +x direction (see figure). The length of a chamber inside the rocket is 4 m. A ball is thrown from the left end of the chamber in +x direction with a speed of 0.3 ms^{-1} relative to the rocket. As the same time, another ball is thrown in –x direction with a speed of 0.2 ms^{-1} from its right end relative to the rocket. The time in seconds when the two balls hit each other is– **[JEE(Adv.) 2014]**



ANSWERS

- **True and False**

1. True **2.** True **3.** True **4.** False **5.** False

- **Fill in the Blanks**

6. d/v **7.** opposite **8.** 100 sec.

- **Assertion–Reason**

9. (B) **10.** (A) **11.** (A)

- **Single Choice Correct**

12. (C) **13.** (A) **14.** (D) **15.** (B) **16.** (A)
17. (A) **18.** (B) **19.** (D) **20.** (A) **21.** (B)
22. (B) **23.** (A)

- **Multiple Choice Correct**

24. (AB) **25.** (AD) **26.** (CD) **27.** (BCD) **28.** (AB)
29. (CD) **30.** (AD)

- **Comprehension**

Comprehension -1 **31.** (B) **32.** (C) **33.** (A)
Comprehension -2 **34.** (B) **35.** (B) **36.** (C)
Comprehension -3 **37.** (D) **38.** (A) **39.** (B)

- **Subjective Questions**

40. (a) 2.5 m/s (b) 0.32 m

41. (a) $\frac{u^2 \sin 2\alpha}{g\cos\theta}$ (b) $\frac{u\cos(\alpha+\theta)}{\cos\theta}$ (down the plane)

42. $\vec{u} = (3.75\hat{i} + 6.25\hat{j})$m/s, 1s

43. Just midway between A and B, 3.53s

44. (a) Approximately 17.32 m; (b) 11.55 m from B

45. (a) 1 s (b) ($5\sqrt{3}$ m , 5m)

46. $\frac{d\theta}{dt} = \frac{1}{1+t^2}$

47. u = 1 km/h

48. (a) $t = \frac{D}{2u}$ (b) $\Rightarrow v_r = u$

49. $10\sqrt{3}$ m/s

50. (a) $t = \frac{D}{V_0 - V_A} + \frac{D}{V_0 + V_A} = \frac{2DV_0}{V_0 - V_A}$

(b) Average speed $= \frac{\text{Total distance}}{\text{Total time}} = \frac{V_0^2 - V_A^2}{V_0}$

(c) Average velocity is zero.

51. $\frac{a}{v\left(1 - \cos\frac{2\pi}{n}\right)}$

52. (a) $\frac{D}{2u}$; (b) $v_r = u$

53. $\sqrt{\frac{g(L^2+H^2)}{4H}}$

54. 20 m/s

55. $\frac{u\sin(\alpha+\beta-\pi/2)}{\sin\beta}$

56. $\vec{s} = 10(t-1)\hat{i}+10\hat{j}$ (a) $t = \frac{1}{2}h, 10km$ (b) $\frac{10\sqrt{5}}{3}$, $t = \frac{3}{2}$ hr

57. $\frac{(v_1+v_2)^2}{2(a_1+a_2)}$

58. B, $t_A = 165$ s, $t_B = 150$ s

59. (a) 120^0 (b) $2/\sqrt{3}$

60. (a) $u\sin\alpha$, (b) $\frac{u^2\cos\alpha}{2a}\sqrt{1+3\sin^2\alpha}$

61. (a) $\frac{2a}{v^2-u^2}\left(v+\sqrt{v^2-u^2}\right)$, (b) $2\sqrt{2}a\left(\frac{\sqrt{2v^2-u^2}}{v^2-u^2}\right)$

62. 134.16 kmh^{-1}; $\tan^{-1}2$

63. (a) $\frac{40}{\sqrt{3}}ms^{-1}$; (b) $\frac{40}{\sqrt{3}}$ m; (c) 40 m

64. 5s; 150 m ; 75 m

65. (a) $h_2-h_1 = x\tan\theta-\frac{gx^2}{2v^2\cos^2\theta}$ From here we will get two values of x, both can be valid;

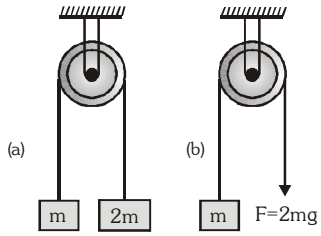
(b) $H = h_1+\frac{v^2\sin^2\theta}{2g}$

(c) $\sqrt{v^2-2g(h_2-h_1)}$

66. (2) OR (8)

True / False

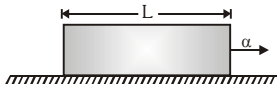
1. The pulley arrangements of figure (a) and (b) are identical. The mass of the rope is negligible. In (a) the mass m is lifted up by attaching a mass 2m to the other end of the rope. In (b), m is lifted up by pulling the other end of the rope with a constant downward force F = 2mg. The acceleration of m is the same in both cases.



2. A car with closed windows makes a left turn. A helium filled balloon in the car will be pushed to the left side.

Fill in the blanks

3. A uniform rod of length L & density ρ is being pulled along a smooth floor with a horizontal acceleration α (see figure) The magnitude of the stress (force/area) at the transverse cross–section through the mid–point of the rod is .....



Assertion & Reason

(A) Statement–I is true, Statement–II is true ; Statement–II is correct explanation for Statement–I.
(B) Statement–I is true, Statement–II is true ; Statement–II is NOT a correct explanation for statement–I
(C) Statement–I is true, Statement–II is false
(D) Statement–I is false, Statement–II is true

4. **Statement–I :** A stationary object placed on ground may experience a pseudo force as observed by the reference frame attached to the ground.
because
Statement–II : Earth (a rotating body) is a non–inertial frame.

5. **Statement–I :** A man who falls from a height on a cement floor receive more injury than when he falls from the same height on a heap of sand.
because
Statement–II : The impulse applied by a cement floor is more than the impulse by sand floor.

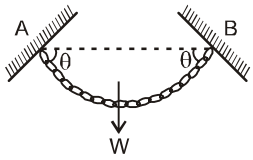
6. **Statement–I :** In Karate a brick is broken with a bare hand.
because
Statement–II : In this process the impulse is sharp.

7. **Statement–I :** Aeroplanes always fly at low altitudes.
because
Statement–II : According to Newton's third law of motion, for every action there is an equal and opposite reaction.

8. **Statement–I :** Two teams having a tug of war always pull equally hard on one another.
because
Statement–II : The team that pushes harder against the ground, in a tug of war, wins.

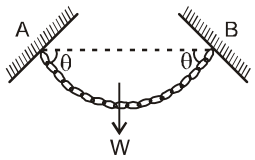
Single Choice Correct

9. A flexible chain of weight W hangs between two fixed points A and B at the same level. The inclination of the chain with the horizontal at the two points of support is θ. What is the tension of the chain at the endpoint ?



(A) $\frac{W}{2}$ cosec θ
(B) $\frac{W}{2}$ sec θ
(C) W cos θ
(D) $\frac{W}{2}$ sin θ

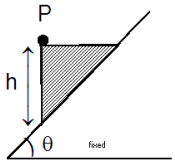
10. What is the tension mid point in the previous question ?



(A) $\frac{W}{2}$ cosec θ (B) $\frac{W}{2}$ sec θ

(C) $\frac{W}{2}$ cot θ (D) $\frac{W}{2}$ sin θ

11. A wedge of height h is released from rest with a light particle P placed on it as shown. The wedge slides down an incline which makes an angle θ with the horizontal. All the surfaces are smooth , find the time after P will reach the surface of the incline.

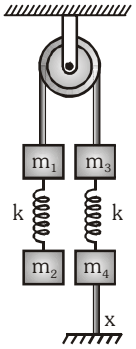


(A) $\sqrt{\frac{2h}{g\sin^2\theta}}$ (B) $\sqrt{\frac{h}{g\sin^2\theta}}$ (C) $\sqrt{\frac{h}{2g\sin^2\theta}}$ (D) $\sqrt{\frac{h}{g\sin\theta}}$

12. A block is kept on a smooth inclined plane of angle of inclination 30° that moves with a constant acceleration so that the block does not slide relative to the inclined plane. Let F_1 be the contact force between the block and the plane. Now the inclined plane stops and let F_2 be the contact force between the two in this case. Then F_1/F_2 is

(A) 1 (B) $\frac{4}{3}$ (C) 2 (D) $\frac{3}{2}$

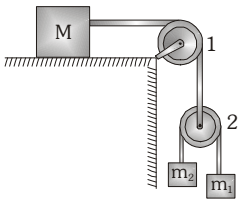
13. For the system (in equilibrium) shown in the figure, the acceleration of the mass m_4 immediately after the lower thread x is cut will be, (assume that the threads are weightless and inextensible, the spring are weightless, the mass of pulley is negligible and there is no friction)



(A) 0 (B) $\left(\frac{m_1+m_2-m_3}{m_4}\right)g$

(C) $\left(\frac{m_1+m_2-m_3-m_4}{m_4}\right)g$ (D) $\frac{g}{4}$

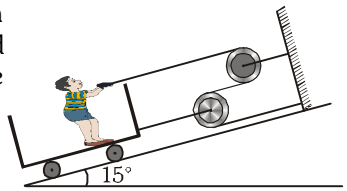
14. In the arrangement shown in figure m_1 = 1kg, m_2 = 2kg. Pulleys are massless and strings are light. For what value of M the mass m_1 moves with constant velocity (Neglect friction)



(A) 6 kg (B) 4 kg

(C) 8 kg (D) 10 kg

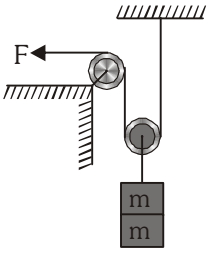
15. A trolley is being pulled up an incline plane by a man sitting on it (as shown in figure). He applies a force of 250 N. If the combined mass of the man and trolley is 100 kg, and both move together, the acceleration of the trolley will be [sin15° = 0.26]

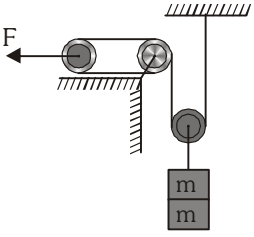


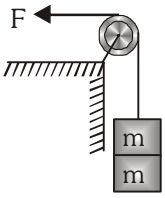
(A) 2.4 m/s^2 (B) 9.4 m/s^2

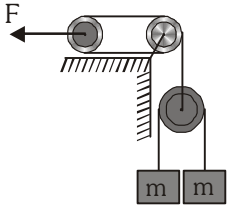
(C) 6.9 m/s^2 (D) 4.9 m/s^2

16. A man thinks about 4 arrangements as shown to raise two small bricks each having mass m. Which of the arrangement would take minimum time?

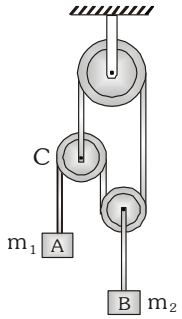
(A)


(B)


(C)


(D)


17. In the arrangement shown in figure neglect the masses of the pulley and string and also friction. The accelerations of blocks A and B are



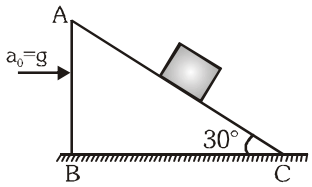
(A) g, g/2

(B) g/2, g

(C) 3g/2, 3g/4

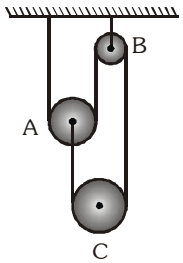
(D) g, g

18. A block is placed on an inclined plane moving towards right horizontally with an acceleration $a_0 = g$. The length of the plane AC = 1m. Friction is absent everywhere. The time taken by the block to reach from C to A is ($g = 10\ m/s^2$)



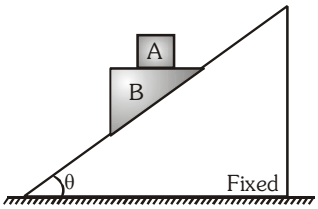
(A) 1.2 s (B) 0.74 s
(C) 2.56 s (D) 0.42 s

19. In the arrangement shown in figure pulley A and B are massless and the thread is inextensible. Mass of pulley C is equal to m. If friction in all the pulleys is negligible, then



(A) tension in thread is equal to 1/2 mg
(B) acceleration of pulley C is equal to g/2 (downward)
(C) acceleration of pulley A is equal to g/2 (upward)
(D) acceleration of pulley A is equal to 2g (upward)

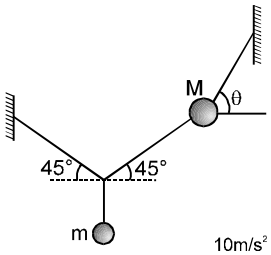
20. Block A of mass m is placed over a wedge B of same mass m. Assuming all surfaces to be smooth. The displacement of block A in 1 s if the system is released from rest is



(A) $g\dfrac{(1+\sin^2\theta)}{(1-\sin^2\theta)}$ (B) $\dfrac{g\sin\theta}{2}$

(C) $g\dfrac{\cos^2\theta}{1+\sin^2\theta}$ (D) $g\dfrac{\sin^2\theta}{1+\sin^2\theta}$

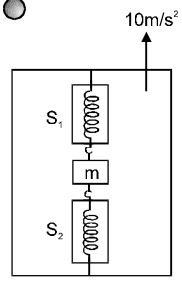
21. Two masses m and M are attached with strings as shown. For the system to be in equilibrium we have



(A) $\tan\theta = 1 + \dfrac{2M}{m}$ (B) $\tan\theta = 1 + \dfrac{2m}{M}$

(C) $\tan\theta = 1 + \dfrac{M}{2m}$ (D) $\tan\theta = 1 + \dfrac{m}{2M}$

22. Reading shown in two spring balances S_1 and S_2 is 90 kg and 30 kg respectively and lift is accelerating upwards with acceleration 10 m/s^2. The mass is stationary with respect to lift. Then the mass of the block will be :

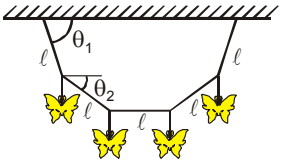


(A) 60 kg (B) 30 kg
(C) 120 kg (D) None of these

23. Five persons A, B, C, D & E are pulling a cart of mass 100 kg on a smooth surface and cart is moving with acceleration 3 m/s^2 in east direction. When person 'A' stops pulling, it moves with acceleration 1m/s^2 in the west direction. When person 'B' stops pulling, it moves with acceleration 24 m/s^2 in the north direction. The magnitude of acceleration of the cart when only A & B pull the cart keeping their directions same as the old directions, is :

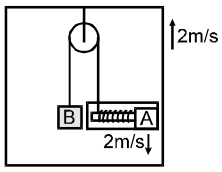
(A) 26 m/s^2 (B) $3\sqrt{71}\ m/s^2$ (C) 25 m/s^2 (D) 30 m/s^2

24. Four identical metal butterflies are hanging from a light string of length 5ℓ at equally placed points as shown. The ends of the string are attached to a horizontal fixed support. The middle section of the string is horizontal. The relation between the angle θ_1 and θ_2 is given by :



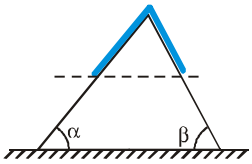
(A) $\sin\theta_1 = 2\sin\theta_2$
(B) $2\cos\theta_1 = \sin\theta_2$
(C) $\tan\theta_1 = 2\tan\theta_2$
(D) $\theta_2 < \theta_1$ and no other conclusion can be derived.

25. In the figure shown the velocity of lift is 2 m/s while string is winding on the motor shaft with velocity 2 m/s and block A is moving downwards with a velocity of 2 m/s, then find out the velocity of block B.



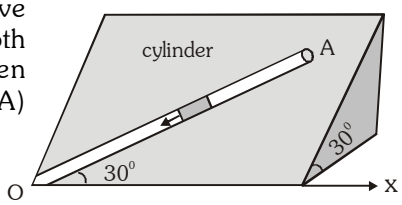
(A) 2 m/s ↑
(B) 2 m/s ↓
(C) 4 m/s ↑
(D) 8 m/s ↑

26. A uniform rope of length L and mass M is placed on a smooth fixed wedge as shown. Both ends of rope are at same horizontal level. The rope is initially released from rest, then the magnitude of initial acceleration of rope is :



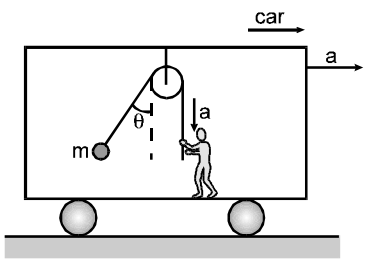
(A) Zero
(B) $M(\cos\alpha - \cos\beta)g$
(C) $M(\tan\alpha - \tan\beta)g$
(D) None of these

27. An inclined plane makes an angles 30° with the horizontal. A groove OA=5m cut in the plane makes an angle 30° with OX. A short smooth cylinder is free to slide down the influence of gravity. The time taken by the cylinder to reach from A to O is (if released from rest from A) ($g = 10\ m/s^2$)



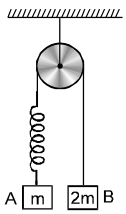
(A) 4s
(B) 2s
(C) $2\sqrt{2}$ s
(D) 1s

28. A bob is hanging over a pulley inside a car through a string . The second end of the string is in the hand of a person standing in the car . The car is moving with constant acceleration 'a' directed horizontally as shown in figure . Other end of the string is pulled with constant acceleration ' a ' (relative to car) vertically. The tension in the string is equal to (assuming θ remains constant)



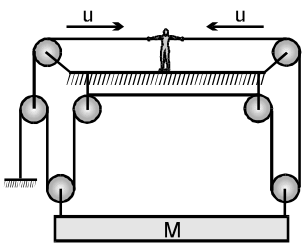
(A) $m\sqrt{g^2 + a^2}$
(B) $m\sqrt{g^2 + a^2} - ma$
(C) $m\sqrt{g^2 + a^2} + ma$
(D) $m(g + a)$

29. In the figure a block 'A' of mass 'm' is attached at one end of a light spring and the other end of the spring is connected to another block 'B' of mass 2m through a light string. 'A' is held and B is in static equilibrium. Now A is released. The acceleration of A just after that instant is 'a'. In the next case, B is held and A is in static equilibrium. Now when B is released, its acceleration immediately after the release is 'b'. The value of a/b is :
(Pulley, string and the spring are massless)



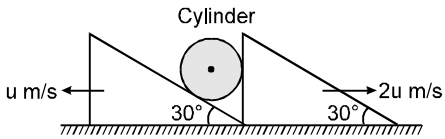
(A) 0
(B) undefined
(C) 2
(D) $\frac{1}{2}$

30. System is shown in the figure and man is pulling the rope from both sides with constant speed ' u'. Then the speed of the block will be:



(A) $\frac{3u}{4}$
(B) $\frac{3u}{2}$
(C) $\frac{u}{4}$
(D) none of these

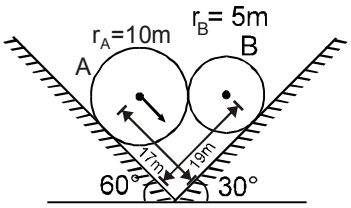
31. System is shown in the figure. Assume that cylinder remains in contact with the two wedges. The velocity of cylinder is



(A) $\sqrt{19-4\sqrt{3}}\,\frac{u}{2}$ m/s (B) $\frac{\sqrt{13}\,u}{2}$ m/s

(C) $\sqrt{3}\,u$ m/s (D) $\sqrt{7}\,u$ m/s

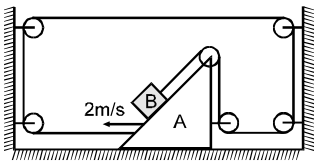
32. System is shown in the figure. Velocity of sphere A is 9 m/s. Then speed of sphere B at the given instant will be :



(A) 9 m/s (B) 12 m/s

(C) $\frac{45}{4}$ m/s (D) none of these

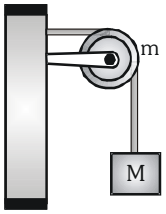
33. System is shown in figure and wedge is moving towards left with speed 2 m/s. Then velocity of the block B will be:



(A) $\sqrt{3}$ m/s (B) 1 m/s

(C) 2 m/s (D) 0 m/s

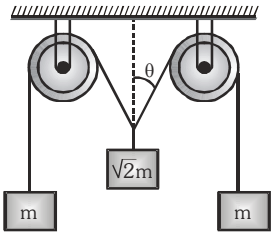
34. A string of negligible mass going over a clamped pulley of mass m supports a block of mass M as shown in the figure. The force on the pulley by the clamp is given by :– **[IIT-JEE 2001]**



(A) $\sqrt{2}$ Mg (B) $\sqrt{2}$ mg

(C) $\sqrt{(M+m)^2+m^2}g$ (D) $\left(\sqrt{(M+m)^2+M^2}\right)g$

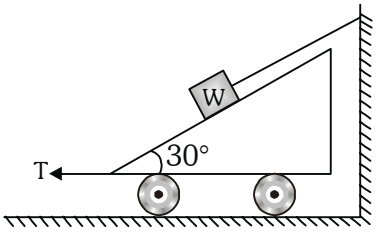
35. The pulleys and strings shown in the figure are smooth and of negligible mass. For the system to remain in equilibrium, the angle θ should be : **[IIT-JEE 2001]**



(A) 0° (B) 30°

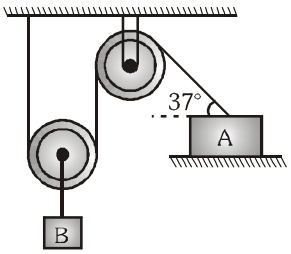
(C) 45° (D) 60°

36. Find the tension T needed to hold the cart equilibrium, if there is no friction



(A) $\frac{\sqrt{3}}{4}W$ (B) $\frac{\sqrt{2}}{2}W$ (C) $\frac{2}{\sqrt{3}}W$ (D) $\frac{4}{\sqrt{3}}W$

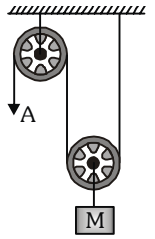
37. In the figure shown block B moves down with a velocity 10 m/s. The velocity of A in the position shown is



(A) 12.5 m/s (B) 25 m/s

(C) 6.25 m/s (D) None of these

38. A load of mass M = 100 kg is supported is a vertical plane by a string and pulleys. If the free end A of the string is pulled vertically downward with an acceleration a = 2 m/s^2, the tension in string is:

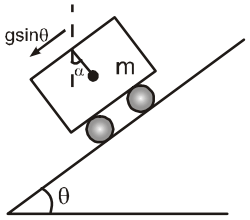


(A) 500 N (B) 550 N

(C) 600 N (D) 1000 N

Multiple Choice Correct

39. A trolley is accelerating down an incline of angle θ with acceleration g$\sin\theta$. Which of the following is correct. (α is the angle made by the string with vertical).



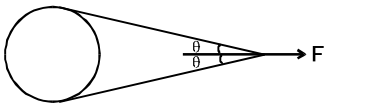
(A) $\alpha = \theta$

(B) $\alpha = 0^0$

(C) Tension in the string, T = mg

(D) Tension in the string, T = mg sec θ

40. A string is wrapped round a log of wood and it is pulled with a force F as shown in the figure .



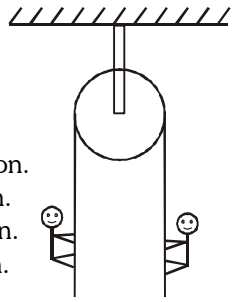
(A) tension T in the string increases with increase in θ

(B) tension T in the string decreases with increase in θ

(C) tension T > F if $\theta > \pi/3$

(D) tension T > F if $\theta > \pi/4$

41. Two men of unequal masses hold on to the two sections of a light rope passing over a smooth light pulley. Which of the following is/are possible.



(A) The lighter man is stationary while the heavier man slides down with some acceleration.

(B) The heavier man is stationary while the lighter man climbs up with some acceleration.

(C) The heavier man is stationary while the lighter man slips down with some acceleration.

(D) The lighter man is stationary while the heavier man climbs up with some acceleration.

42. If the resultant of three forces $\mathbf{F}_1 = p\mathbf{i} + 3\mathbf{j} - \mathbf{k}$, $\mathbf{F}_2 = -5\mathbf{i} + \mathbf{j} + 2\mathbf{k}$ and $\mathbf{F}_3 = 6\mathbf{i} - \mathbf{k}$ acting on a particle has magnitude equal to 5 units, then the value(s) of p is (are)

(A) -6 (B) -4 (C) 2 (D) 4

43. Select the incorrect statement :

(A) A powerful man pushes a wall and the wall gets deformed. The magnitude of force exerted by the wall on man will be equal to the magnitude of force exerted by man on the wall.

(B) Ten person are pulling horizontally an object on a smooth horizontal surface in different directions. The resultant acceleration of the object is zero. Then the pull of each man is equal to the pull of the other nine men.

(C) A massless object cannot exert force on any other object.

(D) All contact forces are electromagnetic in nature.

44. A block of weight 9.8N is placed on a table. The table surface exerts an upward force of 10 N on the block. Assume g = 9.8 m/s^2.

(A) The block exerts a force of 10N on the table (B) The block exerts a force of 19.8N on the table

(C) The block exerts a force of 9.8N on the table (D) The block has an upward acceleration.

45. A ball of mass m is attached to the lower end of a light vertical spring of force constant *k*. The upper end of the spring is fixed. The ball is released from rest with the spring at its normal length, and comes to rest again after descending through a distance x :

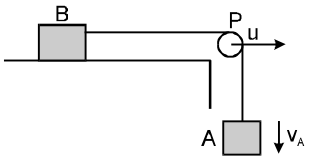
(A) x = mg/k

(B) x = 2mg/k

(C) The ball will have no acceleration at the position where it has descended through x/2

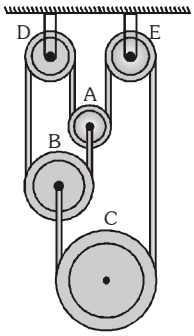
(D) The ball will have an upward acceleration equal to g at its lowermost position.

46. In the Figure, the pulley P moves to the right with a constant speed u. The downward speed of A is v_A, and the speed of B to the right is v_B.



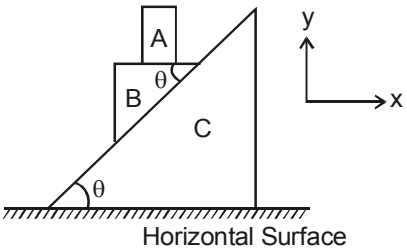
(A) $v_B = v_A$
(B) $v_B = u + v_A$
(C) $v_B + u = v_A$
(D) the two blocks have accelerations of the same magnitude

47. In the pulley system shown in figure the movable pulleys A,B and C are of mass 1 kg each. D and E are fixed pulleys. The strings are light and inextensible. Choose the correct alternative(s). All pulleys are frictionless.



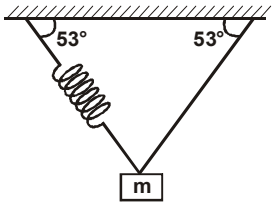
(A) tension in the string is 20/3 N
(B) acceleration of pulley A is g/3 downward
(C) acceleration of pulley B is g/6 upward
(D) acceleration of pulley C is g/3 upward

48. In the figure shown all the surface are smooth. All the blocks A, B and C are movable, x-axis is horizontal and y-axis vertical as shown. Just after the system is released from the position as shown.



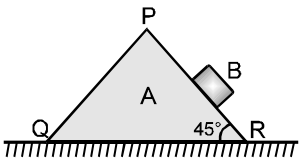
(A) Acceleration of 'A' relative to ground is in negative y-direction
(B) Acceleration of 'A' relative to B is in positive x-direction
(C) The horizontal acceleration of 'B' relative to ground is in negative x-direction.
(D) The acceleration of 'B' relative to ground directed along the inclined surface of 'C' is greater than g sin θ.

49. A block is attached with an ideal spring and string, and is in equilibrium as shown in figure. The acceleration of the block just after breaking the string is a_1 and just after breaking the spring is a_2. Then



(A) $a_1 = \frac{5g}{8}$
(B) $a_2 = \frac{3g}{5}$
(C) $a_1 = \frac{g}{2}$
(D) $a_2 = g$

50. A block B of mass 0.6 kg slides down the smooth face PR of a wedge A of mass 1.7 kg which can move freely on a smooth horizontal surface. The inclination of the face PR to the horizontal is 45°. Then :



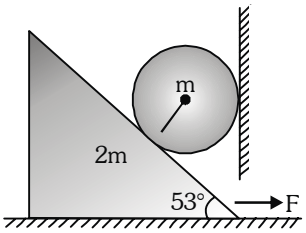
(A) the acceleration of A is 3 g/20
(B) the vertical component of the acceleration of B is 23 g/40
(C) the horizontal component of the acceleration of B is 17 g/40
(D) none of these

51. A reference frame attached to the earth : **[IIT-JEE 1986]**
(A) is an inertial frame by definition
(B) cannot be an inertial frame because the earth is revolving round the sun
(C) is an inertial frame because Newton's laws and applicable in this frame
(D) cannot be an inertial frame because the earth is rotating about its own axis.

Comprehension

Comprehension 1

In the given situation wedge is moving towards right with an acceleration 5 m/s^2 with the help of external force F. (Neglect friction) (m = 1kg)



52. Acceleration of sphere is

(A) $\frac{20}{3}$ m/s^2 (B) 5 m/s^2 (C) 4 m/s^2 (D) $\frac{10}{3}$ m/s^2

53. Normal between sphere and wedge is

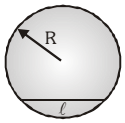
(A) $\frac{50}{3}$N (B) $\frac{250}{9}$N (C) $\frac{400}{3}$N (D) $\frac{500}{3}$N

54. Value of F is

(A) $\frac{290}{9}$N (B) $\frac{250}{3}$N (C) $\frac{400}{3}$N (D) None of these

Comprehension 2

A rod of length ℓ(< 2R) is kept horizontally inside a smooth spherical shell as shown in figure. Mass of the rod is m.



55. Keeping mass to be constant if length of the rod is increased (but always < 2R) the normal reactions at two ends of the rod.

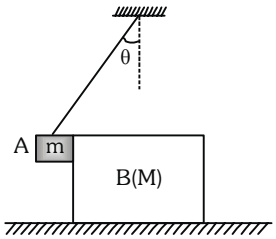
(A) Will remain constant (B) Will increase (C) Will decrease (D) May increase or decrease

56. The normal reaction when ℓ = R is :–

(A) $\frac{mg}{2}$ (B) $\frac{mg}{4}$ (C) $\frac{mg}{2\sqrt{3}}$ (D) $\frac{mg}{\sqrt{3}}$

Comprehension 3

In the arrangement shown, a small block A of mass m is suspended from a peg with the help of light inextensible cord and block B of mass of mass M is held motionless on horizontal table top. The cord makes an angle θ with the vertical. All surface are smooth.



57. Acceleration of block A immediately after it is released is

(A) $\frac{mg\sin\theta}{m+M\cos^2\theta}$ (B) $\frac{mg\sin\theta}{2(m+M\cos^2\theta)}$ (C) $\frac{mg\sin\theta}{M+m\cos^2\theta}$ (D) $\frac{mg\sin\theta}{2(M+m\cos^2\theta)}$

58. Acceleration of block B immediately after block A is released is

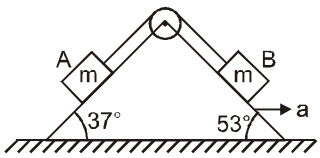
(A) $\frac{mg\sin 2\theta}{2(M\cos^2\theta+m)}$ (B) $\frac{mg\sin 2\theta}{(M\cos^2\theta+m)}$ (C) $\frac{mg\sin 2\theta}{2(M+m\cos^2\theta)}$ (D) $\frac{mg\sin 2\theta}{(M+m\cos^2\theta)}$

59. Normal force between A and B just after system in released is

(A) $\frac{mMg\sin 2\theta}{2(M\cos^2\theta+m)}$ (B) $\frac{mMg\sin 2\theta}{(M\cos^2\theta+m)}$ (C) $\frac{mMg\sin 2\theta}{3(m+M\cos^2\theta)}$ (D) None of these

Comprehension 4

Two blocks A and B of equal masses m kg each are connected by a light thread, which passes over a massless pulley as shown. Both the blocks lie on wedge of mass m kg. Assume friction to be absent everywhere and both the blocks to be always in contact with the wedge. The wedge lying over smooth horizontal surface is pulled towards right with constant acceleration a (m/s^2). (g is acceleration due to gravity).



60. Normal reaction (in N) acting on block B is

(A) $\frac{m}{5}(3g + 4a)$ (B) $\frac{m}{5}(3g - 4a)$ (C) $\frac{m}{5}(4g + 3a)$ (D) $\frac{m}{5}(4g - 3a)$

61. Normal reaction (in N) acting on block A.

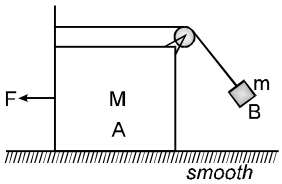
(A) $\frac{m}{5}(3g + 4a)$ (B) $\frac{m}{5}(3g - 4a)$ (C) $\frac{m}{5}(4g + 3a)$ (D) $\frac{m}{5}(4g - 3a)$

62. The maximum value of acceleration a (in m/s^2) for which normal reactions acting on the block A and block B are nonzero.

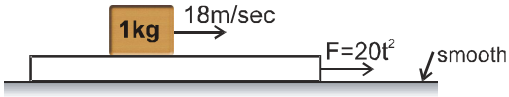
(A) $\frac{3}{4}g$ (B) $\frac{4}{3}g$ (C) $\frac{3}{5}g$ (D) $\frac{5}{3}g$

Subjetive Questions

63. A force F is applied on block A of mass M so that the tension in light string also becomes F when block B of mass m acquires an equilibrium state with respect to block A. Find the force F. Give your answer in terms of m, M and g.

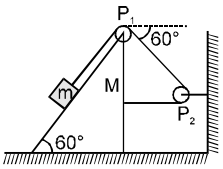


64. A small block of mass 1kg starts moving with constant velocity 18 m/sec on smooth long plank of mass 10 kg which is also pulled by a horizontal force $F = 20\,t^2$ N, where t is in seconds and F is in newtons (Initial velocity of the plank is zero)

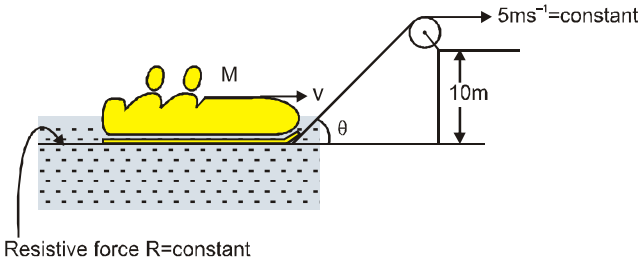


(a) Find the displacement of 1 kg block with respect to the plank at the instant when both have the same velocity.
(b) Find the magnitude of displacement of block with respect to plank when acceleration of plank is $4m/s^2$.

65. In the arrangement shown in the Fig., the block of mass m = 2 kg lies on the wedge of mass M = 8 kg. Find the initial acceleration of the wedge if the surfaces are smooth

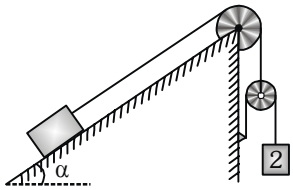


66. A boat of mass M moving with the help of an ideal string which is being pulled with 5 m/s as shown in figure.A Constant resistive force R is applied by the water opposite to the direction o motion of boat. Then at the given instant when string makes an angle θ with the horizontal. (Assume that boat does not lift up.)

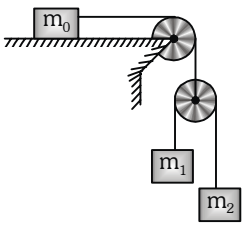


(a) Find the acceleration of the boat at the given instant.
(b) Find the tension in the string at the given instant.

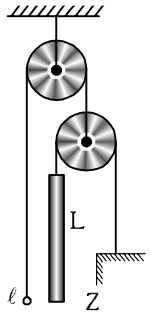
67. Find the acceleration w of body 2 in the arrangement shown in figure, if its mass in η times as great as the mass of bar 1 and the angle that the inclined plane forms with the horizontal is equal to α. The masses of the pulleys and the threads, as well as the friction, are assumed to be negligible. Look into possible cases.



68. In the arrangement shown in figure the bodies have masses m_0, m_1, m_2, the friction is absent, the masses of the pulleys and the threads are negligible. Find the acceleration of the body m_1. Look into possible cases.



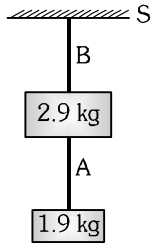
69. In the arrangement shown in figure the mass of ball 1 is $\eta = 1.8$ times as great as that of rod 2. The length of the latter is $\ell = 100$ cm. The masses of the pulleys and the threads, as well as the friction, are negligible. The ball is set on the same level as the lower end of the rod and then released. How soon will the ball be opposite the upper end of the rod ?



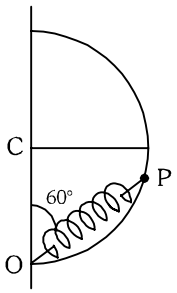
70. Two blocks of masses 2.9 kg and 1.9 kg are suspended from a rigid support S by two inextensible wires, each of length 1m, see in figure. The upper wire has negligible mass and the lower wire has a uniform mass of 0.2 kg/m. The whole system of blocks, wires and support have an upward acceleration of 0.2 m/s^2, acceleration due to gravity is 9.8 m/s^2. **[IIT-JEE 1989]**

(a) Find the tension at the mid-point of the lower wire.

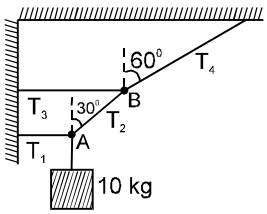
(b) Find the tension at the mid-point of the upper wire.



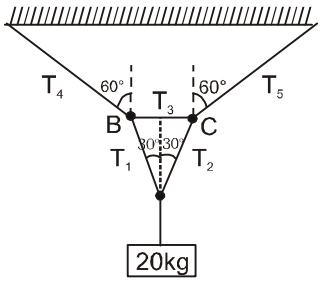
71. A smooth semicircular wire-track of radius R is fixed in a vertical plane. One end of a massless spring of natural length 3R/4 is attached to the lowest point O of the wire-track. A small ring of mass m, which can slide on the track, is attached to the other end of the spring. The ring is held stationary at point P such that the spring makes an angle of 60° with the vertical. The spring constant K = mg/R. Consider the instant when the ring is released, and (i) draw the free body diagram of the ring, (ii) determine the trangential acceleration of the ring and the normal reaction. **[IIT-JEE 1996]**



72. The system shown in figure is in equilibrium. Find the magnitude of tension in each string ; T_1, T_2, T_3 and T_4. ($g = 10$ m/s^{-2})



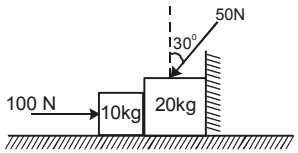
73. The system shown in figure is in equilibrium, find the tension in each string ; T_1, T_2, T_3, T_4 and T_5.



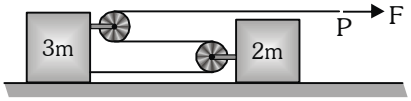
74. Two blocks are kept in contact as shown in figure. Find (Surfaces in contact are smooth)

(a) forces exerted by floor on 20 kg.

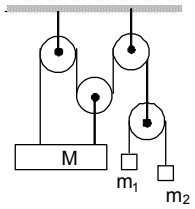
(b) contact force between two blocks.



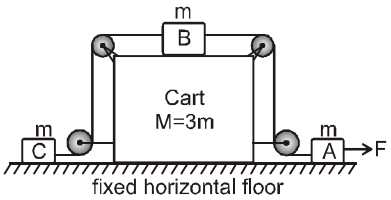
75. In the setup shown, blocks of masses 3m and 2m are placed on frictionless horizontal ground and the free end P of the thread is being pulled by a constant force F. Find acceleration of the free end P.



76. In arrangement shown in the figure, find the acceleration of M. The pulleys are light. The strings are massless. Neglect the dimension of pulleys and masses.

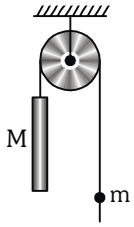


77. A block B is placed over a cart which in turn lies over a smooth horizontal floor. Block A and block C are connected to block B with light inextensible strings passing over light frictionless pulleys fixed to the cart as shown. Initially the blocks and the cart are at rest. All the three blocks have mass m and the cart has mass M(M = 3m). Now a constant horizontal force of magnitude F is applied to block A towards right. (Assuming friction to be absent everywhere)

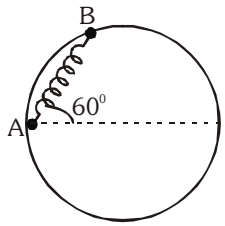


(a) Find the magnitude of acceleration of cart at the shown instant.
(b) Find the magnitude of tension in the string connecting block B and block C.

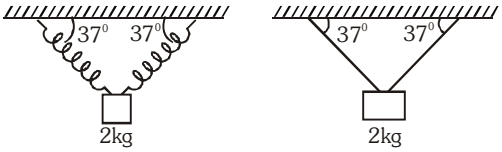
78. In the arrangement shown in figure the mass of the rod M exceeds the mass m of the ball. The ball has an opening permitting it to slide along the thread with some friction. The mass of the pulley and the friction in its axle are negligible. At the initial moment the ball was located opposite the lower end of the rod. When set free, both bodies began moving with constant accelerations. Find the friction force between the ball and the thread if t seconds after the beginning of motion the ball got opposite the upper end of the rod. The rod length equals ℓ.



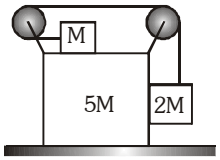
79. A bead of mass m is attached to one end of a spring of natural length $\sqrt{3}$ R and spring constant k = $\frac{(\sqrt{3}+1)mg}{R}$. The other end of the spring is fixed at point A on a smooth fixed vertical ring of radius R as shown in the figure. What is the normal reaction at B just after the bead is released?



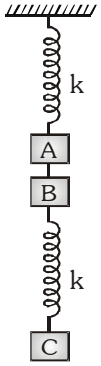
80. The blocks are of mass 2 kg shown is in equilibrium. At t=0 right spring in figure(i) and right string in figure (ii) breaks. Find the ratio of instantaneous acceleration of blocks ?



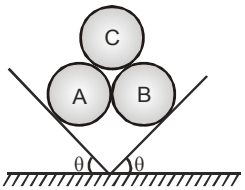
81. In the system shown. Find the initial acceleration of the wedge of mass 5M. The pulleys are ideal and the chords are inextensible. (There is no friction anywhere)



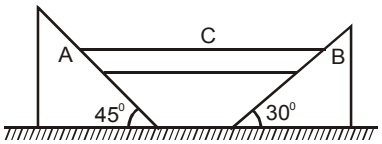
82. The system shown is in equilibrium. Find the acceleration of the blocks A, B & C all of equal masses m at the instant when (Assume springs to be ideal)
(i) the spring between ceiling & A is cut.
(ii) The string (inextensible) between A & B is cut.
(iii) The spring between B & C is cut.
Also find the tension in the string when the system is at rest and in the above 3 cases.



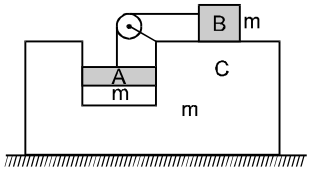
83*. Three identical rigid cylinders A,B and C are arranged on smooth inclined surfaces as shown in figure. Find the least value of θ that prevent the arrangement from collapse.



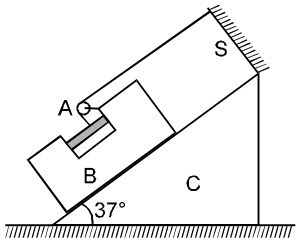
84. Block C descends vertically at 1 m/s. Find the velocity of A relative to B.



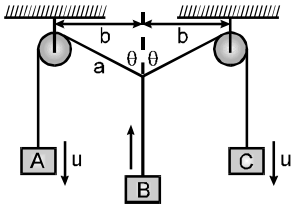
85. A block 'C' of mass m rests on a smooth table . Two blocks A and B each of mass m, are attached to the end of a light inextensible string passing over a smooth pulley fixed to C as shown in the figure. B rests on C and A can move in a frictionless vertical shaft. Find the acceleration of C.



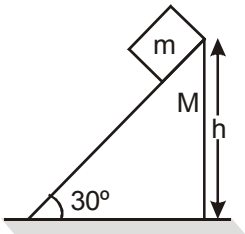
86*. In the figure shown C is a fixed wedge. A block B is kept on the inclined surface of the wedge C. Another block A is inserted in a slot in the block B as shown in figure. A light inextensible string passes over a light pulley which is fixed to the block B through a light rod. One end of the string is fixed and other end of the string is fixed to A.S is a fixed support on the wedge. All the surfaces are smooth. Masses of A and B are same. Find the magnitude of acceleration of A and B. (sin 37° = 3/5)



87*. In the figure shown the blocks A & C are pulled down with constant velocities u . Find the acceleration of block B at the given moment.



88*. A block of mass *m* is released on a smooth inclined wedge of inclination 30° and mass *M*. Height of the block varies with time as $h = 1.5 - 1.5t^2$. (*h* in metre and *t* = time in second). The acceleration of M is $\frac{x}{\sqrt{3}}$ m/s^2. Find the value of x :



ANSWERS

- **True and False**

1. False **2.** True

- **Fill in the Blanks**

3. $\frac{\rho L\alpha}{2}$

- **Assertion–Reason**

4. (A)	**5.** (C)	**6.** (A)	**7.** (A)	**8.** (B)

- **Single Choice Correct**

9. (A)	**10.** (C)	**11.** (A)	**12.** (B)	**13.** (C)
14. (C)	**15.** (D)	**16.** (A)	**17.** (D)	**18.** (B)
19. (D)	**20.** (D)	**21.** (A)	**22.** (B)	**23.** (C)
24. (C)	**25.** (D)	**26.** (A)	**27.** (B)	**28.** (C)
29. (C)	**30.** (A)	**31.** (D)	**32.** (B)	**33.** (C)
34. (D)	**35.** (C)	**36.** (A)	**37.** (B)	**38.** (B)

- **Multiple Choice Correct**

39. (A)	**40.** (AC)	**41.** (AB)	**42.** (BC)	**43.** (C)
44. (AD)	**45.** (BCD)	**46.** (BD)	**47.** (ABD)	**48.** (ABCD)
49. (AB)	**50.** (ABC)	**51.** (BD)		

- **Comprehension**

Comprehension-1.	**52.** (A)	**53.** (B)	**54.** (A)
Comprehension-2.	**55.** (B)	**56.** (D)	
Comprehension-3	**57.** (A)	**58.** (A)	**59.** (A)
Comprehension-4	**60.** (A)	**61.** (D)	**62.** (B)

- **Subjective Questions**

63. $F = \dfrac{mg}{\sqrt{1-\left(\dfrac{m}{m+M}\right)^2}}$

64. (a) $\frac{81}{2}$ m (b) $2\left[9\sqrt{2}-\frac{1}{3}\right]$ m

65. $a = \dfrac{30\sqrt{3}}{23}$ m/s^2

66. (a) $\frac{5}{2}\tan^3\theta$, (b) $\left(\frac{5}{2}M\tan^3\theta + R\right)\sec\theta$

67. $\dfrac{w = 2g(2\eta - \sin\alpha)}{(4\eta+1)}$

68. $w_1 = \dfrac{4m_1m_2 + m_0(m_1 - m_2)}{4m_1m_2 + m_0(m_1 + m_2)}g$

69. $t = \sqrt{\dfrac{2\ell(4+\eta)}{3g(2-\eta)}} = 1.4$ s

70. (a) 20 N, (b) 50.0 Newton

71. (i) $(5\sqrt{3/8})g$, (ii) $(3/8)mg$

72. $T_1 = \frac{100}{\sqrt{3}}$ N. $T_2 = \frac{200}{\sqrt{3}}$ N, $T_3 = \frac{200}{\sqrt{3}}$ N, $T_4 = 200$ N

73. $T_1 = T_2 = \frac{200}{\sqrt{3}}$ N, $T_4 = T_5 = 200$ N, $T_3 = \frac{200}{\sqrt{3}}$ N.

74. (a) 243.30 N, (b) 100 N

75. $\frac{5F}{m}$ N

76. $g\left[1-\frac{48}{\frac{M}{m_1}+\frac{M}{m_2}+36}\right]\downarrow$

77. (a) 0 (b) $\frac{F}{3}$

78. $F_{fr} = \frac{2\ell mM}{(M-m)t^2}$

79. $\left(1-\frac{\sqrt{3}}{2}\right)mg$

80. $\frac{25}{24}$

81. $\frac{2g}{23}$

82. (i) $a_A = a_B = \frac{3g}{2}\downarrow$, $a_C = 0$ (ii) $a_A = 2g\uparrow$, $a_B = 2g\downarrow$, $a_C = 0$ (iii) $a_A = a_B = \frac{g}{2}\uparrow$, $a_C = g\downarrow$

83. $\theta = \tan^{-1}\left(\frac{1}{3\sqrt{3}}\right)$

84. $\left(1+\sqrt{3}\right)ms^{-1}$ towards left

85. $\frac{g}{5}$

86. $a_B = \frac{4}{3}$ m/s^2, $a_A = \frac{4}{3}\sqrt{2}$ m/s^2.

87. $\frac{u^2}{b}\tan^3\theta$

88. 2

FRICTION

True / False

1. When a person walks on a rough surface, the frictional force exerted by the surface on the person is opposite to the direction of his motion.

2. The force of friction on a body may be zero even if it on a rough surface.

3. The frictional force is always in a direction opposite to the direction in which the body tends to move relative to the other.

Fill in the blanks

4. A block of mass 1 kg lies on a horizontal surface in a truck. The coefficient of static friction between the block and the surface is 0.6. If the acceleration of the truck is 5 m/s^2, the frictional force acting on the block is ..... newtons.

5. A block of mass 1 kg lies on a horizontal surface in a truck. The coefficient of static friction between the block and the surface is 0.6. If the acceleration of the truck is 5 m/s^2, the frictional force acting on the block is ..... newtons. ***[IIT-JEE 1984]***

Assertion-Reason

(A) Statement–I is true, Statement–II is true ; Statement–II is correct explanation for Statement–I.
(B) Statement–I is true, Statement–II is true ; Statement–II is NOT a correct explanation for statement–I
(C) Statement–I is true, Statement–II is false
(D) Statement–I is false, Statement–II is true

6. ***Statement–I :*** A larger or equal force is required to start the motion than to maintain it.
because
Statement–II : Kinetic friction coefficient is always less than (or equal to) static friction coefficient.

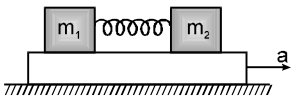
7. ***Statement–I :*** When brakes are applied on a wet road , a car is likely to skid.
because
Statement–II : Because brakes prevent rotation of the wheels, and there is not sufficient friction between the road and the wheels.

8. ***Statement–I :*** Pulling a lawn roller is easier than pushing it.
because
Statement–II : Pushing increases the apparent weight and hence the force of friction.

9. ***Statement–I :*** A block of mass m is kept at rest on an inclined plane, the net force applied by the surface to the block will be mg.
because
Statement–II : Contact force is the resultant of normal contact force and friction force.

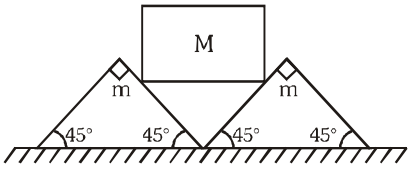
Single Choice Correct

10*. Two block of masses m_1 and m_2 are connected with a massless unstretched spring and placed over a plank moving with an acceleration 'a' as shown in figure. The coefficient of friction between the blocks and platform is μ.



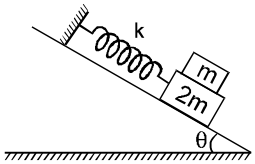
(A) spring will be stretched if $a > \mu g$
(B) spring will be compressed if $a \le \mu g$
(C) spring will neither be compressed nor be stretched for $a \le \mu g$
(D) spring will be in its natural length under all conditions

11*. Two wedges, each of mass m, are placed next to each other on a flat horizontal floor. A cube of mass M is balanced on the wedges as shown in figure. Assume no friction between the cube and the wedges, but a coefficient of static friction $\mu < 1$ between the wedges and the floor. What is the largest M that can be balanced as shown without motion of the wedges ?



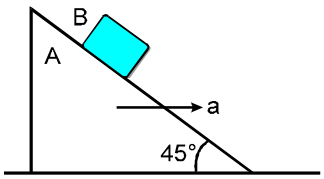
(A) $\frac{m}{\sqrt{2}}$ (B) $\frac{\mu m}{\sqrt{2}}$ (C) $\frac{\mu m}{1-\mu}$ (D) $\frac{2\mu m}{1-\mu}$

12*. The coefficient of friction between block of mass m and 2m is $\mu = 2\tan\theta$. There is no friction between block of mass 2m and inclined plane. The maximum displacement from equilibrium of two block system for which there is no relative motion between both the blocks.



(A) $g\sin\theta\sqrt{\frac{k}{m}}$ (B) $\frac{mg\sin\theta}{k}$ (C) $\frac{3mg\sin\theta}{k}$ (D) None of these

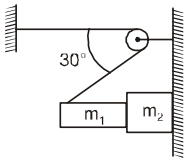
13. If the coefficient of friction between A and B is μ, the maximum horizontal acceleration of the wedge A for which B will remain at rest w.r.t the wedge is :



(A) $g\left(\frac{1-\mu}{1+\mu}\right)$ (B) $g\left(\frac{1+\mu}{1-\mu}\right)$

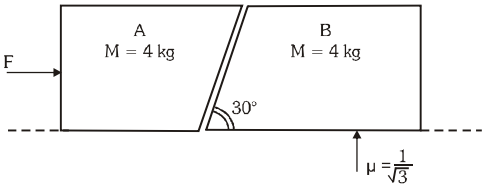
(C) $\frac{g}{2}\left(\frac{1-\mu}{1+\mu}\right)$ (D) $\frac{g}{2}\left(\frac{1+\mu}{1-\mu}\right)$

14. Two blocks with masses m_1 and m_2 of 10 kg and 20 kg respectively are placed as in fig. $\mu_s = 0.2$ between all surfaces, then tension in string and acceleration of m_2 block at this moment will be :



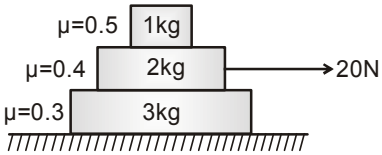
(A) 250 N, 3 m/s^2 (B) 200 N, 6 m/s^2
(C) 306 N, 4.7 m/s^2 (D) 400 N, 6.5 m/s^2

15. Two blocks A and B are placed in contact on a horizontal surface. Faces of blocks A and B, which are in contact, are inclined at 30° with the horizontal, as shown. There is no friction between block A and any surface which is in contact with this whereas friction coefficient between block B and the surface is $\frac{1}{\sqrt{3}}$. A force F is applied in horizontal direction on block A. What is the minimum value of F at which the block B just start moving rightwards?



(A) $\frac{40}{\sqrt{3}}$N (B) $\frac{80}{\sqrt{3}}$N
(C) 100 N (D) For any value of F, motion will not start

16. In the figure shown find the acceleration of block A.

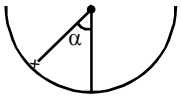


(A) 5 m/s^2 (B) 8/3 m/s^2 (C) zero (D) none of these

17. A block of mass 0.1 kg is held against a wall applying a horizontal force of 5 N on the block. If the coefficient of friction between the block and the wall is 0.5m, the magnitude of the frictional force acting on the block is : ***[IIT-JEE 1994]***

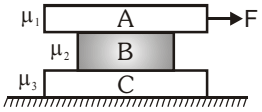
(A) 2.5 N (B) 0.98 N (C) 4.9 N (D) 0.49 N

18. A insect crawls up a hemispherical surface very slowly (see the figure). The coefficient of friction between the surface and the insect is 1/3. If the line joining the centre of the hemispherical surface to the insect makes an angle α with the vertical, the maximum possible value of α is given :– ***[IIT-JEE 2001]***



(A) $\cot \alpha = 3$ (B) $\tan \alpha = 3$ (C) $\sec \alpha = 3$ (D) $\operatorname{cosec} \alpha = 3$

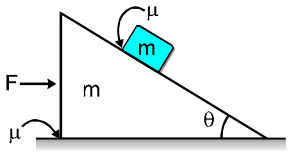
19. Given $m_A = 30$ kg, $m_B = 10$ kg, $m_C = 20$ kg. The coefficient of friction between A and B, $\mu_1 = 0.3$, between B and C, $\mu_2 = 0.2$ and between C, and ground, $\mu_3 = 0.1$. The least horizontal force F to start motion of any part of the system of three blocks resting upon one another as shown in figure is ($g = 10$ m/s^2)



(A) 60 N (B) 90 N (C) 80 N (D) 150 N

Multiple Choice Correct

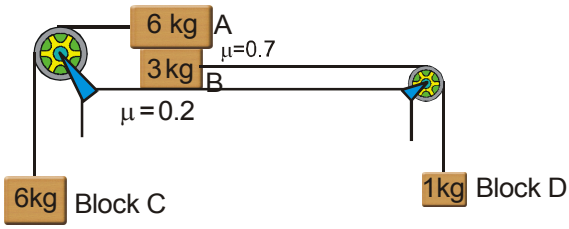
20. In the situation shown in figure a wedge of mass m is placed on a rough surface, on which a block of equal mass is placed on the inclined plane of wedge. Friction coefficient between wedge and the block and also between the ground and the wedge (μ). An external force F is applied horizontally on the wedge towards right, (assuming block does not slide on the wedge)



(A) The value of F at which wedge will start slipping is $> 2\mu mg$
(B) The value of F at which wedge will start slipping is $> \mu mg$
(C) The value of F at which no friction will act on block by the inclined plane, is $2\mu mg + 2mg\tan\theta$
(D) The value of F at which no friction will act on block on inclined plane, is $2\mu mg + mg\sin\theta$

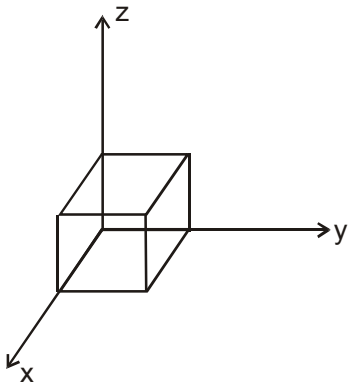
21. The force F_1 that is necessary to move a body up an inclined plane is double the force F_2 that is necessary to just prevent it from sliding down, then :
Where ϕ = angle of friction; θ = angle of inclined plane; w = weight of the body
(A) $F_2 = w\sin(\theta - \phi)\sec\phi$ (B) $F_1 = w\sin(\theta + \phi)\sec\phi$
(C) $\tan\phi = 3\tan\theta$ (D) $\tan\theta = 3\tan\phi$

22*. An arrangement of the masses and pulleys is shown in the figure. Strings connecting masses A and B with pulleys are horizontal and all pulleys and strings are light. Friction coefficient between the surface and the block B is 0.2 and between blocks A and B is 0.7. The system is released from rest. (use $g = 10$ m/s^2)



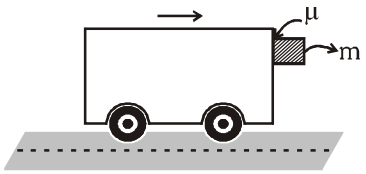
(A) The magnitude of acceleration of the system is 2 m/s^2 and there is no slipping between block A and block B.
(B) The magnitude of friction force between block A and block B is 42 N.
(C) Acceleration of block C is 1 m/s^2 downwards.
(D) Tension in the string connecting block B and block D is 12 N.

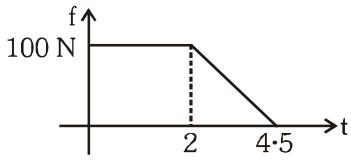
23. A solid cube of mass 5 kg is placed on a rough horizontal surface, in xy-plane as shown. The friction coefficient between the surface and the cube is 0.4. An external force $\vec{F} = 6\hat{i} + 8\hat{j} + 20\hat{k}$ N is applied on the cube. (use g = 10 m/s^2)



(A) The block starts slipping over the surface
(B) The friction force on the cube by the surface is 10 N.
(C) The friction force acts in xy-plane at angle 127° with the positive x-axis in clockwise direction.
(D) The contact force exerted by the surface on the cube is $10\sqrt{10}$ N.

24. The Van is moving on a horizontal ground along a straight road as shown in figure.





The velocity of Van is given as :

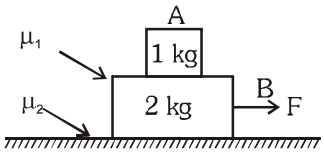
$$v = (9t - t^2 + 10) \text{ m/s}, \quad \text{where t is in second}$$

Coefficient of friction between the wall of van and block of m kg is μ. The block is at rest w.r.t. van initially. The friction time graph between block and van is given as (g = 10 m/s^2).

(A) The value of mass of block is 10 kg
(B) The coefficient of friction (μ) is 2
(C) The acceleration of block at t = 3 sec is 5 m/sec.^{2}
(D) The coefficient of friction (μ) is 1

Match the Column

25. The two blocks A and B as shown in figure are at rest initially. Now a horizontal force F is applied on the block B, then match the following (the coefficient of friction between A & B is μ_1 and μ_2 is coeficient of friction between B & ground).



Column–I	***Column–II***
(A) F = 5N, μ_1 = 0, μ_2 = 0.2	(p) $a_A = a_B$
(B) F = 5N, μ_1 = 0.2, μ_2 = 0	(q) $a_A > a_B$
(C) F = 10 N, μ_1 = 0, μ_2 = 0.2	(r) $a_A < a_B$
(D) F = 10 N, μ_1 = 0.2, μ_2 = 0	(s) Slipping Start between A and B
	(t) Slipping Start between B and ground

Comprehension

Comprehension 1.

Experiment 1 : The student pushes horizontally (rightward) on the crate and gradually increases the strength of this push force. The crate does not begin to move until the push force reaches 400 N.

Experiment 2 : The student applies a constant horizontal (rightward) push force for 1.0 s and measures how far the crate moves during that time interval. In each trial the crate starts at rest, and the student stops pushing after the 1.0 s interval. The following table summarizes the results.

Trial	Push force (N)	Distance (m)
1	500	1.5
2	600	2
3	700	2.5

26. The coefficient of static friction between the crate and floor is approximately :
(A) 0.25 (B) 0.40 (C) 2.5 (D) 4.0

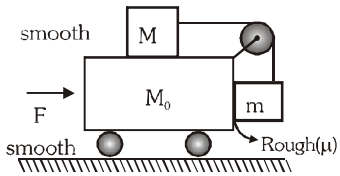
27. In experiment 1, when the rightward push force was 50N the crate didn't move. Why didn't it move ?
(A) The push force was weaker than the frictional force on the crate
(B) The push force had the same strength as the gravitational force on the crate
(C) The push force was stronger than the frictional force on the crate
(D) The push force had the same strength as the frictional force on the crate

28. The coefficient of kinetic friction between the crate and the floor is approximately :
(A) 0.20 (B) 2.0 (C) 3.0 (D) 5.0

29. In trial 3, what is the crate's speed at the moment the student stops pushing it ?
(A) 1.0 m/s (B) 2.0 m/s (C) 3.0 m/s (D) 5.0 m/s

Comprehension 2.

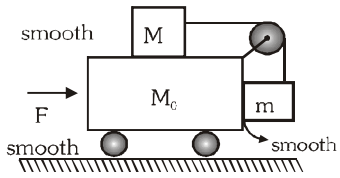
Imagine a situation in which the horizontal surface of block M_0 is smooth and its vertical surface is rough with a coefficient of friction μ .



30. Identify the correct statement(s)
(A) If F = 0, the blocks cannot remain stationary
(B) for one unique value of F, the blocks M and m remain stationary with respect to M_0
(C) the limiting friction between m and M_0 is independent of F
(D) there exist a value of F at which friction force is equal to zero

31*. In above problem, choose the correct value(s) of F which the blocks M and m remain stationary with respect to M_0
(A) $(M_0 + M + m)\dfrac{g}{\mu}$ (B) $\dfrac{m(M_0+M+m)g}{M-\mu m}$ (C) $(M_0 + M + m)\dfrac{mg}{M}$ (D) None of these

32. Consider a special situation in which both the faces of the block M_0 are smooth, as shown in adjoining figure. Mark out the correct statement(s)

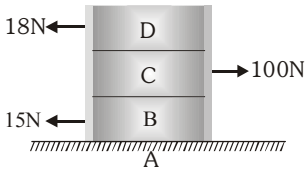


(A) If F = 0, the blocks cannot remain stationary
(B) for one unique value of F, the blocks M and m remains stationary with respect to block M_0
(C) there exist as a range of F for which blocks M and m remain stationary with respect to block M_0
(D) since there is no friction, therefore, blocks M and m cannot be in equilibrium with respect to M_0

33. In above problem, the value(s) of F for which M and m are stationary with respect to M_0
(A) $(M_0 + M + m)g$ (B) $(M_0 + M + m)\dfrac{mg}{M}$ (C) $(M_0 + M + m)\dfrac{Mg}{m}$ (D) None of these

Comprehension 3

Each of the three plates has a mass of 10 kg. If the coefficients of static and kinetic friction at each surface of contact are $\mu_s = 0.3$ and $\mu_k = 0.2$, respectively ($g=10\ ms^{-2}$)



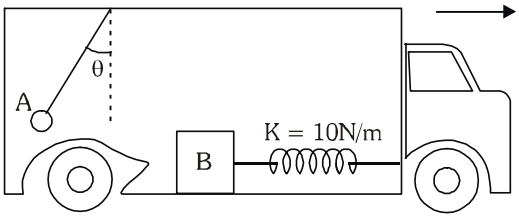
34. The acceleration of block B is
(A) zero (B) 3.336 m/s^2 (C) 4.11 m/s^2 (D) 5 m/s^2

35. The acceleration of block C is :
(A) zero (B) 3.336 m/s^2 (C) 4 m/s^2 (D) 5 m/s^2

36. The acceleration of block D is :
(A) 2 m/s^2 (B) 0.2 m/s^2 (C) 5 m/s^2 (D) 3.36 m/s^2

Subjetive Questions

37. Figure shows a moving truck, in which there is a bob 'A' and a block 'B' attached to a spring kept on the rough floor of truck. With respect to truck ($g = 10$ m/sec^2) (Assume spring is massless)



(a) If bob A is in equilibrium w.r.t. truck at $\theta = 30°$, the spring is in its natural state and the block B (mass $= \sqrt{3}$ kg) is also in equilibrium w.r.t truck, find the minimum value of the coefficient of static friction between the block and the floor of truck.

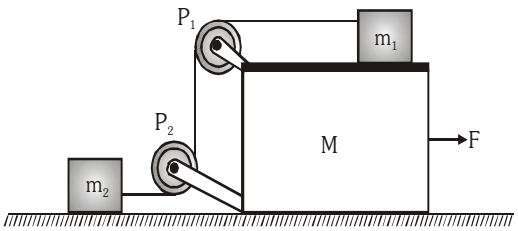
(b) If now the acceleration of truck is changed so that the new angular position of A for which it is again in equilibrium w.r.t truck at $\theta = 45°$, find the minimum elongation in spring when block B is in equilibrium w.r.t truck assuming the value of the coefficient of static friction as that calculated in part (a).

38. Block A of mass m and block B of mass 2m are placed on fixed triangular wedge by means of a massless, inextensible string and a frictionless pulley as shown in figure. The wedge is inclined at 45° to the horizontal on both sides. The coefficient of friction between block A and the wedge is 2/3 and that between block B and the wedge is 1/3. If the system of A and B is released from rest then find

(a) the acceleration of A

(b) the magnitude and direction of the force of friction acting on A ***[IIT-JEE 1997]***

39. In the figure masses m_1, m_2 and M are 20 kg, 5 kg and 50 kg respectively. The coefficient of friction between M and ground is zero. The coefficient of friction between m_1 and M and that between m_2 and ground is 0.3. The pulleys and the strings are massless. The string is perfectly horizontal between P_1 and m_1 and also between P_2 and m_2. The string is perfectly vertical between P_1 and P_2. An external horizontal force F is applied to the mass M. Take $g = 10$ m/s^2. ***[IIT-JEE 2000]***



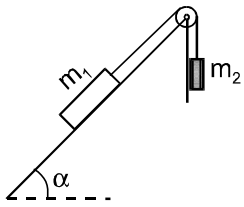
(i) Draw a free body diagram of mass M, clearly showing all the forces.

(ii) Let the magnitude of the force of friction between m_1 and M be f_1 and that between m_2 and ground be f_2. For a particular force F it is found that $f_1 = 2f_2$. Find f_1 and f_2. Write equations of motion of all the masses. Find F, tension in the string and acceleration of the masses.

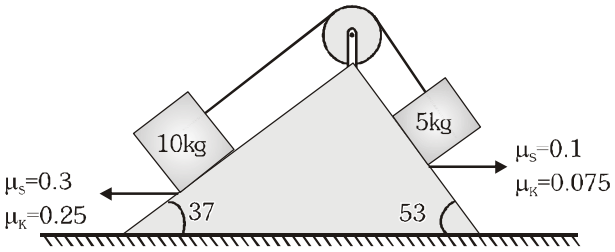
40. A small body was launched up an inclined plane set at an angle $\alpha = 15°$ against the horizontal. Find the coefficient of friction, if the time of the ascent of the body is $\eta = 2.0$ times less than the time of its descent.

41. The following parameters of the arrangement of Fig. are available: the angle α which the inclined plane forms with the horizontal and the coefficient of friction k between the body m_1 and the inclined plane. The masses of the pulley and the threads, as well as the friction in the pulley are negligible. Assuming both bodies to be motionless at the initial moment, find the mass ratio m_2/m_1 at which the body m_2

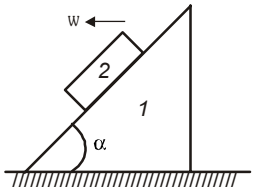
(a) starts coming down; (b) starts going up; (c) is at rest.



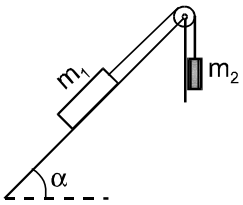
42. A system of two blocks and a light string are kept on two inclined faces (rough) as shown in the figure below. All the required data are mentioned in the diagram. Pulley is light and frictionless. (Take g = 10 m/s^2, sin 37° = 3/5) If the system is released from rest then what is the range of the tension in the string?



43. Prism 1 with bar 2 of mass m placed on it gets a horizontal acceleration w directed to the left (Fig.). At what maximum value of this acceleration will the bar be still stationary relative to the prism, if the coefficient of friction between them k < cot α ?

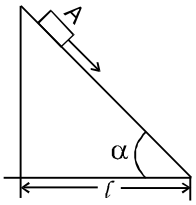


44. The inclined plane of Fig. forms an angle α = 30° with the horizontal. The mass ratio $m_2/m_1 = \eta = 2/3$. The coefficient of friction between the body m_1 and the inclined plane is equal to k = 0.10. The masses of the pulley and the threads are negligible. Find the magnitude and the direction of acceleration of the body m_2 when the formerly stationary system of masses starts moving.

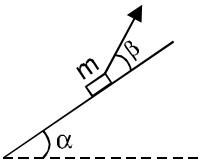


45. A plank of mass m_1 with a bar of mass m_2 placed on it lies on a smooth horizontal plane. A horizontal force growing with time t as F = at (a is constant) is applied to the bar. Find how the accelerations of the plank w_1 and of the bar w_2 depend on t, if the coefficient of friction between the plank and the bar is equal to k. Draw the approximate plots of these dependences.

46. A small body A starts sliding down from the top of a wedge (Fig.) whose base is equal to l = 2.10 m. The coefficient of friction between the body and the wedge-surface is k = 0.140. At what value of the angle α will the time of sliding be the least ? What will it be equal to ?

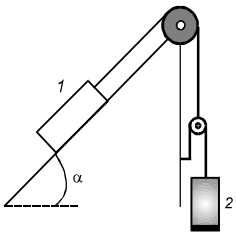


47. A bar of mass m is pulled by means of a thread up an inclined plane forming an angle α with the horizontal (fig.). The coefficient of friction is equal to k. Find the angle β which the thread must from with the inclined plane for the tension of the thread to be minimum. What is it equal to ?



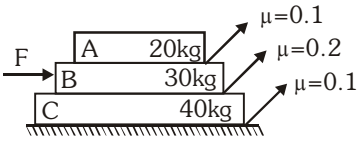
48. A horizontal plane with the coefficient of friction k supports two bodies : a bar and an electric motor with a battery on a block. A thread attached to the bar is wound on the shaft of the electric motor. The distance between the bar and the electric motor is equal to ℓ.When the motor is switched on, the bar, whose mass is twice as great as that of the other body, starts moving with a constant acceleration ω. How soon will the bodies collide?

49. Find the acceleration w of body 2 in the arrangement shown in fig , if its mass is η times as great as the mass of bar 1 and the angle that the inclined plane forms with the horizontal is equal to α .The masses of the pulleys and the threads, as well as the friction, are assumed to be negligible. Look into possible cases.

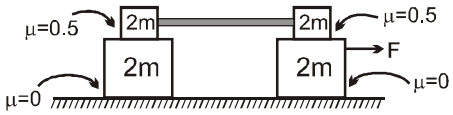


50. A 2 kg block is placed over a 4 kg block and the both are placed on a smooth horizontal surface . The cofficient of friction between the blocks is 0.20. Find the acceleration of the two blocks if a horizontal force of 12 N is applied to (a) the upper block, (b) the lower block. Take g = 10 m/s^2.

51. A system of masses is shown in the figure with masses & coefficients of friction indicated. Calculate :
(i) the maximum value of F for which there is no slipping anywhere
(ii) the minimum value of F for which B slides on C
(iii) the minimum value of F for which A slips on B.



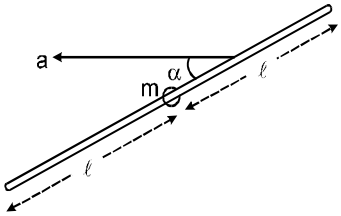
52*. Consider the arrangement shown in figure. Friction coefficient for all the surfaces are shown in the figure and the rod connecting two upper blocks is horizontal.



What is the minimum value F so that the rear two blocks start sliding with each other :

53. A thin rod of length 1 m is fixed in a vertical position inside a train, which is moving horizontally with constant acceleration 4 m/s^2. A bead can slide on the rod, and friction coefficient between them is 1/2. If the bead is released from rest at the top of the rod, find the time when it will reach at the bottom. (g=10m/s^2)

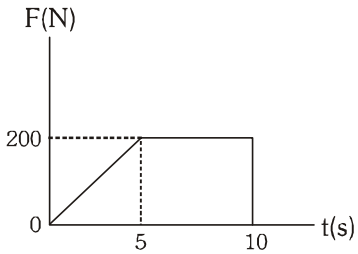
54. A bead of mass 'm' is fitted onto a rod with a length of 2ℓ, and can move on it with friction having the coefficient of friction μ. At the initial moment the bead is in the middle of the rod. The rod moves translatory in a horizontal plane with an acceleration 'a' in the direction forming an angle α with the rod as shown in figure find the time when the bead will leave the rod : (Neglect the weight of the bead).

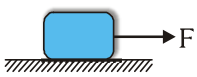


55. A block of mass 5 kg is placed on a rough horizontal surface of a moving compartment. It is seen by an observer sitting inside the compartment, that a force of 10 N is required in horizontal direction to move the box in a direction parallel to the motion of compartment while a force of 20 N is required in horizontal direction to move the box in opposite direction. Find the coefficient of friction between the surface of the block and the surface.

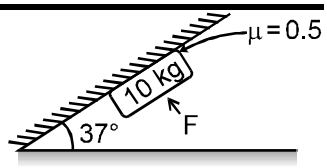
56. A particle of mass m rests on a horizontal floor with which it has a coefficient of static friction μ. If is desired to make the body move by applying the minimum possible force F. Find the magnitude of F and the direction in which it has to be applied.

57. A 20 kg block is originally at rest on a horizontal surface for which the coefficient of friction is 0.6. If a horizontal force F is applied such that it varies with time as shown. The speed of the block after 10s is [24+(0.1)X]m/sec. Find value of X (g = 10 m/s^2) :

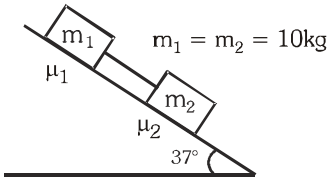




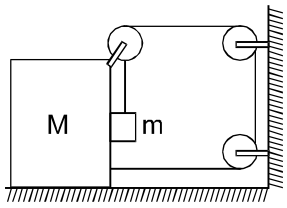
58. In the figure shown, the minimum force F to be applied perpendicular to the incline so that the block does not slide is equal to 50X newton. Find X : (The block is always in contact with the incline)



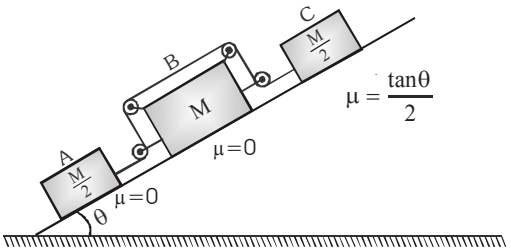
59. Two blocks of same mass are sliding on an incline. The coefficients of kinetic friction between the blocks and the incline are different, $\mu_1 = 0.5$ and $\mu_2 = 0.4$ respectively. Find the tension in string in newton.



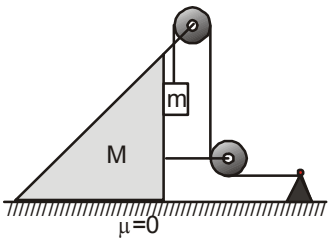
60. Find the acceleration of the block of mass M in the situation of figure. The cofficient of friction between the two blocks is μ_1 and that between the bigger block and the ground is μ_2.



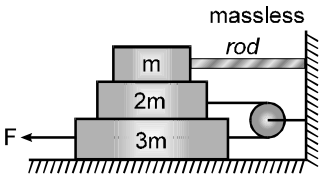
61*. As shown in the figure blocks of masses $\frac{M}{2}$, M and $\frac{M}{2}$ are connected through a light string as shown, pulleys are light and smooth. Friction is only between block C and floor. System is released from rest. Find the acceleration of blocks A, B and C.



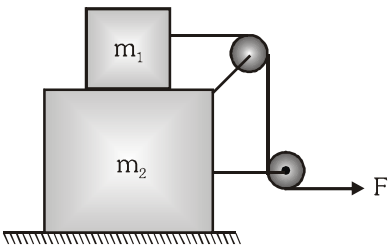
62. In the arrangement shown in Fig. the masses of the wedge M and the body m are known. The appreciable friction exists only between the wedge and the body m, the friction coefficient being equal to μ. The masses of the pulley and the thread are negligible. Find the acceleration of the body m relative to the horizontal surface on which the wedge Slides.



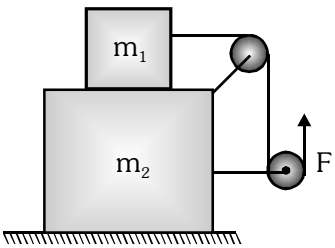
63*. Three blocks are connected as shown in the figure. Calculate the minimum force required to move the body with constant velocity. The co-efficient of friction at all surfaces is 0.25.
[Assume that rod doesnot exert force in vertical direction]



64. If $m_1 = 20$ kg, $m_2 = 30$ kg, m_2 is on smooth surface. Surface between m_1 and m_2 has $\mu_s = 0.5$ and $\mu_k = 0.3$
Find the acceleration of m_1 and m_2 for the following figures, when for
figure (a) : (i) F = 160 N (ii) F = 175 N
figure (b) : F = 160 N



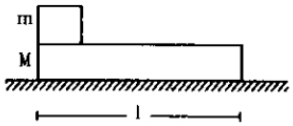
(a)



(b)

65*. A car begins to move at time t = 0 and then accelerates along a straight track with a speed given by $V(t) = 2t^2\ ms^{-1}$ for $0 \le t \le 2$. After the end of acceleration, the car continues to move at a constant speed. A small block initially at rest on the floor of the car begins to slip at t = 1 sec. and stops slipping at t = 3 sec. Find the coefficient of static and kinetic friction between the block and the floor. ($g = 10 m/s^2$)

66*. Figure shows a small block of mass m kept at the left end of a larger block of mass M and length ℓ. The system can slide on a horizontal road. The system is started towards right with an initial velocity v. The friction coefficient between the road and the bigger block is μ and that between the blocks is $\mu/2$. Find the time elapsed before the smaller block separates from the bigger block.



ANSWERS

- ***True and False***

1. F **2.** T **3.** T

- ***Fill in the Blanks***

4. 5 **5.** 5N

- ***Assertion–Reason***

6. A **7.** A **8.** A **9.** A

- ***Single Choice Correct***

10.	D	**11.**	D	**12.**	C	**13.**	B	**14.**	C
15.	D	**16.**	B	**17.**	B	**18.**	A	**19.**	A

- ***Multiple Choice Correct***

20.	AC	**21.**	ABD	**22.**	AD	**23.**	BCD	**24.**	ABC

- ***Match the Column***

25. (A) p; (B) p,t; (C) r,s.t; (D) r,s,t

- ***Comprehension***

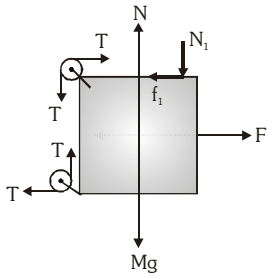
Comprehension 1:	**26.**	B	**27.**	D	**28.**	A	**29.**	D
Comprehension 2 :	**30.**	A,D	**31.**	B,C	**32.**	A,B	**33.**	B
Comprehension 3 :	**34.**	A	**35.**	C	**36.**	B		

- ***Subjective Questions***

37. (a) $\frac{1}{\sqrt{3}}$ (b) $\left(\sqrt{3}-1\right)$

38. (a) a = 0; (b) $2\sqrt{2}\frac{mg}{3}$; (c) $\frac{mg}{3\sqrt{2}}$ (downwards)

39. (i)



(ii) 60N, 18N, $\frac{3}{5}$ ms^{-2}

40. $k = [(\eta^2 - 1) / (\eta^2 + 1)] \tan\alpha = 0.16]$

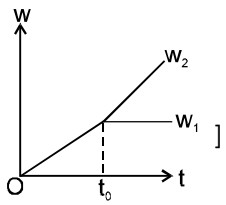
41. (a) $m_2 / m_1 > \sin\alpha + k\cos\alpha$; (b) $m_2 / m_1 < \sin\alpha - k\cos\alpha$; (c) $\sin\alpha - k\cos\alpha < m_2 / m_1 < \sin\alpha + k\cos\alpha$]

42. 40 N to 43 N

43. $w_{max} = g(1 + k\cot\alpha) / \cot\alpha - k)$]

44. $w_2 = g(\eta - \sin\alpha - k\cos\alpha) / (\eta + 1) = 0.05$ g.]

45. When $t \le t_0$, the accelerations $w_1 = w_2 = at / (m_1 + m_2)$; when $t \ge t_0$ $w_1 = kgm_2 / m_1$, $w_2 = (at - km_2g) / m_2$. Here $t_0 = kgm_2 (m_1 + m_2) / am$.



]

46. $\tan 2\alpha = -1/k$, $\alpha = 49^o$, $t_{min} = 1.0s$]

47. $\tan\beta = k$; , $T_{min} = mg(\sin\alpha + k\cos\alpha)/\sqrt{1+k^2}$.

48. $\tau = \sqrt{2\ell(3\omega + kg)}$

49. $w = 2g(2\eta - \sin\alpha)/(4\eta + 1)$]

50. (a) upper block 4 m/s^2, lower block 1 m/s^2, (b) both blocks 2 m/s^2]

51. (i) 90N (ii) 112.5 N (iii) 150 N

52. For all values of F both the rear blocks will move together

53. $\frac{1}{2}$ s

54. $\sqrt{\frac{2\ell}{a(\cos\alpha - \mu\sin\alpha)}}$

55. 0.3

56. $\frac{\mu mg}{\sqrt{1+\mu^2}}$, $\tan^{-1}\mu$

57. 0

58. 4

59. 4 N

60. $\frac{[2m - \mu_2(M+m)g]}{M + m[5 + 2(\mu_1 - \mu_2)]}$

61. $a_A = a_C = \frac{3}{4} g\sin\theta$, $g_B = g\sin\theta$

62. $\frac{g\sqrt{2}}{\mu + 2 + (M/m)}$

63. F = 13/4 m g

64. (a) (i) $a_{m_1} = a_{m_2} = 3.2ms^{-2}$ (ii) $a_{m_1} = 5.75ms^{-2}$, $a_{m_2} = 2ms^{-2}$ (b) $a_{m_1} = 5ms^{-2}$, $a_{m_2} = \frac{-10}{3} ms^{-2}$

65. $\mu_s = 0.4$, $\mu_k = 0.3$

66. $\sqrt{\frac{4Ml}{(M+m)\mu g}}$

WORK, POWER & ENERGY

True or False

1. Mechanical energy of a body cannot be negative.

2. Net work done by external forces on a moving body is same as observed from different inertial frames.

3. Work done by a non-conservative force is always negative.

4. Work done by all internal conservative forces is required to change in its potential energy.

Fill in the Blanks

5. The work done in holding a 15 kg suitcase while waiting for a bus for 15 minute is.....

6. A body of mass M tied to a string is lowered at a constant acceleration of (g/4) through a vertical distance h. The work done by the string will be.....

7. An open knife edge of mass M is dropped from a height h on a wooden floor. If the blade penetrates 's' into the wood, the average resistance offered by the wood to the blade is.....

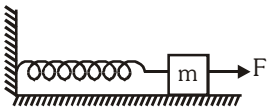
8. The power of a pump which raises 100 kg of a water in 10 s to a height 100 m is..... kW.

Assertion & Reason

(A) Statement–I is true, Statement–II is true ; Statement–II is correct explanation for Statement–I.
(B) Statement–I is true, Statement–II is true ; Statement–II is NOT a correct explanation for statement–I
(C) Statement–I is true, Statement–II is false
(D) Statement–I is false, Statement–II is true

9. ***Statement 1 :*** The work done in pushing a block is more than the work done in pulling the block in a rough surfac for same horizontal displacement.
and
Statement 2 : In the pushing condition more normal reaction increases the frictional force.

10. ***Statement 1 :*** One end of ideal massless spring is connected to fixed vertical wall and other end to a block of mass m initially at rest on smooth horizontal surface. The spring is initially in natural length. Now a horizontal force F acts on block as shown. Then the maximum extension in spring is equal to maximum compression in spring.



and
Statement 2 : To compress or to expand an ideal unstretched spring by equal amount, same work is to done on spring.

11. ***Statement 1 :*** The work done by friction is always negative.
and
Statement 2 : If frictional force acts on a body its kinetic energy may decrease.

12. ***Statement 1 :*** A particle is rotated in a vertical circle with the help of a string. Power produced by tension in the string on the particle is zero.
and
Statement 2 : Tension is always perpendicular to instantaneous velocity.

13. ***Statement–1 :*** A body can have energy without having momentum.
and
Statement–2 : A body can have momentum without having mechanical energy.

14. ***Statement–1 :*** If the internal forces are conservative, the work done by the external force is equal to the change in mechanical energy.
and
Statement–2 : Work done on a system by all the (external and internal) force is equal to the change in its kinetic energy and the change in the potential energy of a system corresponding to conservative internal forces is equal to negative of the work done by these forces.

15. ***Statement–1 :*** When a gas is allowed to expand, work done by gas is positive.
and
Statement–2 : In expansion of a gas the force due to gaseous pressure and displacement (of piston) are in the same direction.

16. ***Statement–1 :*** A body at rest may be in equilibrium.
and
Statement–2 : A body in equilibrium is at rest.

Single Choice Correct

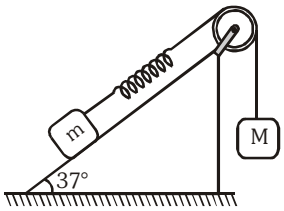
17*. A particle is projected along a horizontal field whose coefficient of friction varies as $\mu = \frac{A}{r^2}$ where r is the distance from the origin in meters and A is a positive constant. The initial distance of the particle is 1 m from the origin and its velocity is radially outwards. The minimum initial velocity at this point so that particle never stops is :

(A) ∞ (B) $2\sqrt{gA}$ (C) $\sqrt{2gA}$ (D) $4\sqrt{gA}$

18. A single conservative force F(x) acts on a 1 kg particle that moves along the x axis. The potential energy U(x) is given $U(x) = 20 + (x-2)^2$ joules. Where x is in meters. At x = 5m, the particle has a kinetic energy of 20 joules. The greatest value of x(in meters) to which particle can move. (data given $\sqrt{29} = 5.38$) is

(A) 2.2 (B) 5.4 (C) 7.38 (D) 9.2

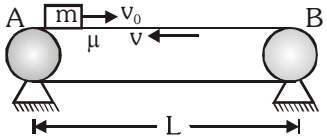
19*. A block of mass m is attached with a massless spring of force constant k. The block is placed over a rough inclined surface for which the coefficient of friction is $\mu = 3/4$. The minimum value of M required to move the block up the plane is : (Neglect mass of string and pulley and friction in pulley)



(A) $\frac{3}{5}$ m (B) $\frac{4}{5}$ m

(C) 2 m (D) $\frac{3}{2}$ m

20*. With what minimum velocity v_0 should block be projected from left end A towards end B such that it reaches the other end B of conveyer belt moving with constant velocity v ? Friction coefficient between block and belt is μ.



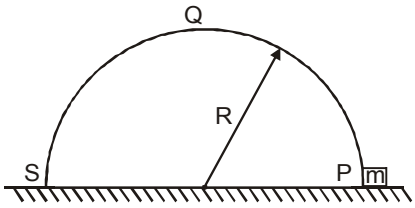
(A) $\sqrt{\mu gL}$ (B) $\sqrt{2\mu gL}$

(C) $\sqrt{3\mu gL}$ (D) $2\sqrt{\mu gL}$

21. The potential energy for a force field $\vec{F}$ is given by U(x, y) = sin (x + y). The magnitude of force acting on the particle of mass m at $\left(0, \frac{\pi}{4}\right)$ is

(A) 1 (B) $\sqrt{2}$ (C) $\frac{1}{\sqrt{2}}$ (D) 0

22. A small block of mass m is taken slowly up a fixed hemisphere from P to Q and then slowly down along its surface from Q to S by force F, which at each point of the surface, is tangential to the surface. If the coefficient of friction is μ, then the work performed by the force F in taking the block from P to S along the hemispherical surface of radius R is :

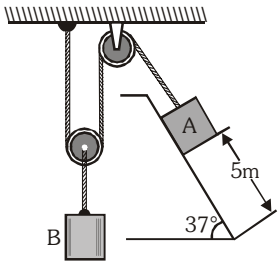


(A) 2μmgR (B) μmgR (C) πμmgR (D) None of these

23. An engine can pull 4 coaches at a maximum speed of 20 m/s. Mass of the engine is twice the mass of every coach. Assuming resistive forces proportional to the weight, approximate maximum speeds of the engine when it pulls 12 and 6 coaches are :

(A) 8.5 m/s and 15 m/s respectively (B) 6.5 m/s and 8 m/s respectively
(C) 8.5 m/s and 13 m/s respectively (D) 10.5 m/s and 15 m/s respectively

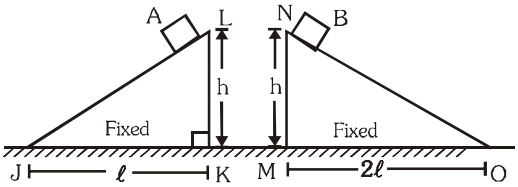
24. The blocks A and B shown in the figure have masses M_A = 5 kg and M_B = 4 kg. The system is released from rest. The speed of B after A has travelled a distance 1 m along the incline is :



(A) $\frac{\sqrt{3}}{2}\sqrt{g}$ (B) $\frac{\sqrt{3}}{4}\sqrt{g}$

(C) $\frac{\sqrt{g}}{2\sqrt{3}}$ (D) $\frac{\sqrt{g}}{2}$

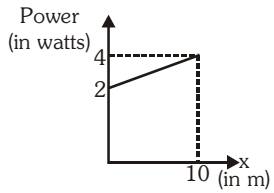
25. Two identical blocks A and B are placed on two inclined planes as shown in diagram. Neglect air resistance and other friction. Choose the correct statement :



Statement I: Kinetic energy of 'A' on sliding to J will be greater than the kinetic energy of B on falling to M.
Statement II: Acceleration of 'A' will be greater than acceleration of 'B' when both are released to slide on inclined plane.
Statement III : Work done by external agent to move block slowly from position B to O is negative

(A) only statement I is true (B) only statement II is true
(C) statement I and III are true (D) statement II and III are true

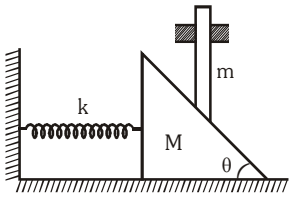
26. A particle 'A' of mass $\frac{10}{7}$ kg is moving in the positive x–direction. Its initial position is x = 0 & initial velocity is 1 m/s. The velocity at x = 10m is : (use the graph given)



(A) 4 m/s (B) 2 m/s

(C) $3\sqrt{2}$m/s (D) 100/3 m/s

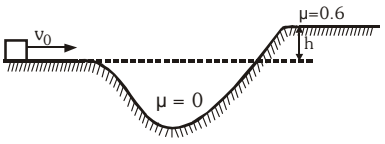
27. A wedge of mass M fitted with a spring of stiffness 'k' is kept on a smooth horizontal surface. A rod of mass m is kept on the wedge as shown in the figure. System is in equilibrium. Assuming that all surfaces are smooth, the potential energy stored in the spring is:



(A) $\frac{mg^2 \tan^2\theta}{2k}$ (B) $\frac{m^2 g \tan^2\theta}{2k}$

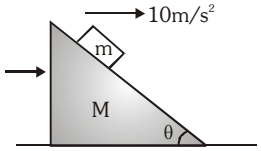
(C) $\frac{m^2 g^2 \tan^2\theta}{2k}$ (D) $\frac{m^2 g^2 \tan^2\theta}{k}$

28. In the figure, a block slides along a track from one level to a higher level, by moving through an intermediate valley. The track is frictionless untill the block reaches the higher level. There a frictional force stops the block in a distance d. The block's initial speed v_0 is 6 m/s, the height difference h is 1.1 m and the coefficient of kinetic friction μ is 0.6. The value of d is



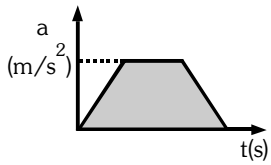
(A) 1.17 m (B) 1.71 m (C) 7.11 m (D) 11.7 m

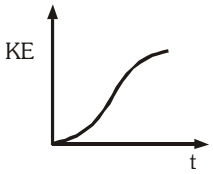
29. In the figure shown all the surfaces are frictionless, and mass of the block, m = 1 kg. The block and wedge are held initially at rest. Now wedge is given a horizontal acceleration of 10 m/s^2 by applying a force on the wedge, so that the block does not slip on the wedge. Then work done by the normal force in ground frame on the block in $\sqrt{3}$ seconds is :

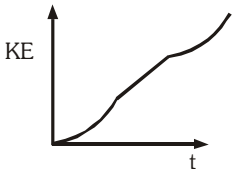


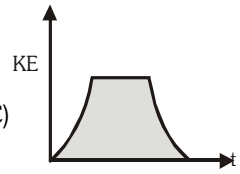
(A) 30J (B) 60 J (C) 150 J (D) 100 $\sqrt{3}$ J

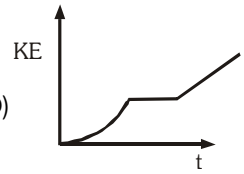
30. Acceleration versus time graph of a particle moving in a straight line is as shown in adjoining figure. If initially particle was at rest then corresponding kinetic energy versus time graph will be:



(A) 

(B) 

(C) 

(D) 

31. A body is moved along a straight line by a machine delivering constant power. The distance moved by the body in time t is proportional to ***[IIT-JEE 1984]***

(A) $t^{1/2}$ (B) $t^{3/4}$ (C) $t^{3/2}$ (D) t^2

32. A uniform chain of length L and mass M is lying on a smooth table and one-third of its length is hanging vertically down over the edge of the table. If g is acceleration due to gravity, the work required to pull the hanging part on to the table is : ***[IIT-JEE 1985]***

(A) MgL (B) $\frac{MgL}{3}$ (C) $\frac{MgL}{9}$ (D) $\frac{MgL}{18}$

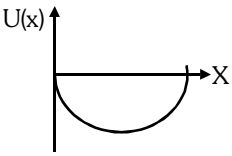
33. A force $\vec{F} = -K(y\hat{i} + x\hat{j})$ (where K is a positive constant) acts on a particle moving in the x-y plane. Starting from the origin, the particle is taken along the positive x-axis to the point (a, 0) and then to the point (a, a). The total work done by the force $\vec{F}$ on the particle is ***[IIT-JEE 1998]***

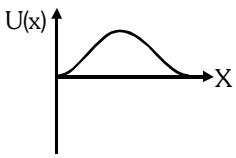
(A) $-2Ka^2$ (B) $2Ka^2$ (C) $-Ka^2$ (D) Ka^2

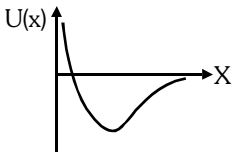
34. A wind–powered generator converts wind energy into electric energy. Assume that the generator converts a fixed fraction of the wind energy intercepted by its blades into electrical energy. For wind speed v, the electrical power output will be proportional to :– ***[IIT-JEE 2000]***

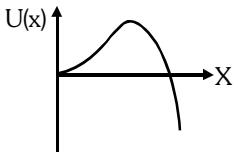
(A) v (B) v^2 (C) v^3 (D) v^4

35. A particle, which is constrained to move along x–axis, is subjected to a force in the same direction which varies with the distance x of the particle from the origin as $F(x) = -kx + ax^3$. Here, k and a are positive constant. For $x \geq 0$, the functional form of the potential energy U(x) of the particle is :– ***[IIT-JEE 2002]***

(A) 

(B) 

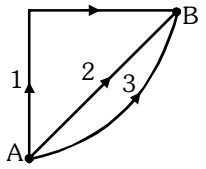
(C) 

(D) 

36. An ideal spring with spring–constant k is hung from the ceiling and a block of mass M is attached to its lower end. The mass is released with the spring initially unstretched. Then the maximum extension in the spring is :– ***[IIT-JEE 2002]***

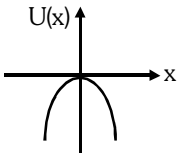
(A) $\frac{4Mg}{k}$ (B) $\frac{2Mg}{k}$ (C) $\frac{Mg}{k}$ (D) $\frac{Mg}{2k}$

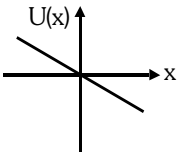
37. If W_1, W_2 and W_3 represent the work done in moving a particle from A to B along three different paths 1, 2 and 3 respectively (as shown) in the gravitational field of a point mass m. Find the correct relation between W_1, W_2 and W_3 :–

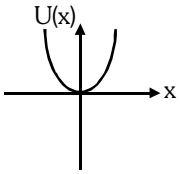


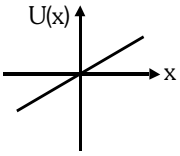
(A) $W_1 > W_2 > W_3$ (B) $W_1 = W_2 = W_3$
(C) $W_1 < W_2 < W_3$ (D) $W_2 > W_1 > W_3$ ***[IIT-JEE 2003]***

38. A particle is placed at the origin and a force F = kx is acting on it (where k is positive constant). If U(0) = 0, the graph of U(x) versus x will be (where U is the potential energy function) :– ***[IIT-JEE 2004]***

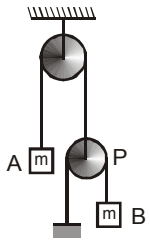
(A) 

(B) 

(C) 

(D) 

39. In the figure shown, the system is released from rest. Find the velocity of block A when block B has fallen a distance 'ℓ'. Assume all pulleys to be massless and frictionless.



(A) $\sqrt{\frac{g\ell}{5}}$ (B) $\sqrt{g\ell}$
(C) $\sqrt{5g\ell}$ (D) None of these

40. The potential energy of a particle of mass m free to move along x–axis is given by U = ½ kx^2 for x < 0 and U = 0 for x ≥ 0 (x denotes the x–coordinate of the particle and k is a positive constant). If the total mechanical energy of the particle is E, then its speed at $x = -\sqrt{\frac{2E}{k}}$ is :

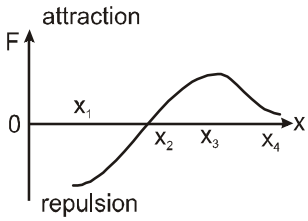
(A) zero (B) $\sqrt{\frac{2E}{m}}$ (C) $\sqrt{\frac{E}{m}}$ (D) $\sqrt{\frac{E}{2m}}$

Multiple Choice Correct

41. If one of the forces acting on a particle is conservative then :
(A) Its work is zero when the particle moves exactly once around any closed path.
(B) Its work equals the change in the kinetic energy of the particle.
(C) It obeys Newton's second law.
(D) Its work depends on the end points of the motion, not on the path between.

42. A particle is acted upon by a force of constant magnitude which is always perpendicular to the velocity of the particle. The motion of the particle takes place in a plane. If follows that
(A) its velocity is constant (B) its acceleration is constant
(C) its kinetic energy is constant (D) acceleration is constant in magnitude

43. The diagram given shows how the net interaction force (conservative) between two particles A and B is related to the distance between them varies from x_1 to x_4. Then:



(A) potential energy of the system increases from x_1 to x_2.
(B) potential energy of the system increases from x_2 to x_3.
(C) potential energy of the system increases from x_3 to x_4.
(D) kinetic energy increases from x_1 to x_2 and decreases from x_2 to x_3.

44*. The potential energy of a particle of mass 1 kg in a conservative field is given as $U = (3x^2y^2 + 6x)$ J, where x and y are measured in meter. Initially particle is at (1,1) & at rest then :

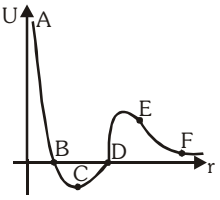
(A) Initial acceleration of particle is $6\sqrt{5}$ ms^2

(B) Work done to slowly bring the particle to origin is 9 J

(C) Work done to slowly bring the particle to origin is – 9 J

(D) If particle is left free it moves in straight line

45. The given plot shows the variation, the potential energy (U) of interaction between two particles with the separating distance (r) between them. Which of the above statements are correct ?



(1) B and D are equilibrium points

(2) C is a point of stable equilibrium points

(3) The force of interaction between the two particles is attractive between points C and D and repulsive between points D and E on the curve.

(4) The force of interaction between the particles is repulsive between points E and F on the curve.

(A) 1 and 3 (B) 1 and 4 (C) 2 and 4 (D) 2 and 3

46*. The potential energy (in joules) of a particle of mass 1kg moving in a plane is given by V = 3x + 4y, the position coordinates of the point being x and y, measured in metres. If the particle is at rest at (6, 4) ; then

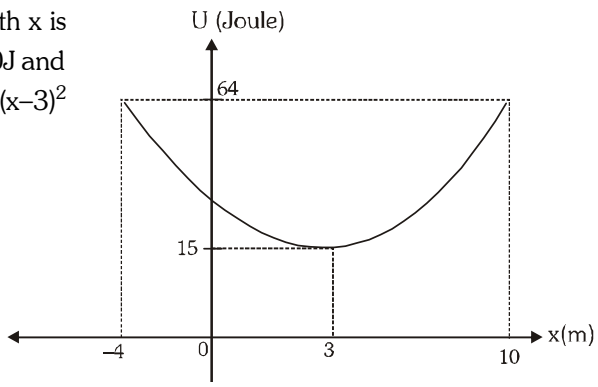
(A) its acceleration is of magnitude $5 m/s^2$

(B) its speed when it crosses the y–axis is 10m/s

(C) it crosses the y-axis (x = 0) at y = –4

(D) it moves in a striaght line passing through the origin (0, 0)

47*. A single conservative force F(x) acts on a particle that moves along the x-axis. The graph of the potential energy with x is given. At x = 5m, the particle has a kinetic energy of 50J and its potential energy is related to position 'x' as $U = 15+(x-3)^2$ Joule, where x is in meter. Then :



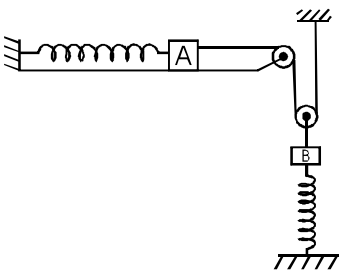
(A) The mechanical energy of system is 69 J.

(B) The mechanical energy of system is 19J.

(C) At x = 3, the kinetic energy of particle is minimum

(D) The maximum value of kinetic energy is 54 J.

48. The system is released from rest with both the springs in unstretched position. Mass of each block is 1 kg and force constant of each spring is 10 N/m. Assume pulleys and strings are massless and all contacts are smooth. ($g = 10 m/s^2$)



(A) Extension of horizontal spring in equilibrium is 2/5 m

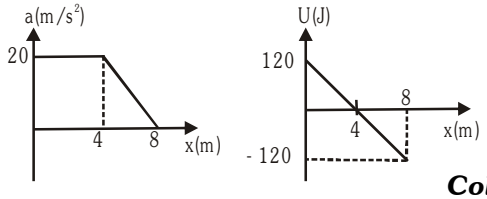
(B) Compression of vertical spring in equilibrium is 1/5 m

(C) Maximum speed of the block A is $\sqrt{28}$ m/s

(D) Maximum speed of the block A is $\sqrt{14}$ m/s

Match the Column

49. Acceleration 'a' versus x and potential energy 'U' versus x graph of a particle moving along x–axis is as shown in figure. Mass of the particle is 1kg and velocity at x = 0 is 4 m/s.



Column I	Column II
(A) Kinetic energy at x = 8 m	(p) 120J
(B) Work done by conservative forces from x = 0 to x = 8 m	(q) 240 J
(C) Total work done from x = 0 to x = 8 m	(r) 128 J
(D) Work done by non-conservative forces from x = 0 to x = 8 m	(s) 112 J
	(t) –120 J

Comprehension

Comprehension 1.

In a conservative force field we can find the radial component of force from the potential energy function by using $F = -\frac{dU}{dr}$. Here, a positive force means repulsion and a negative force means attraction. From the given potential energy function U(r) we can find the equilibrium position where force is zero. We can also find the ionisation energy which is the work done to move the particle from a certain position to infinity.

Let us consider a case in which a particle is bound to a certain point at a distance r from the centre of the force. The potential energy of the particle is : $U(r) = \frac{A}{r^2} - \frac{B}{r}$ where r is the distance from the centre of the force and A and B are positive constants.

50. The equilibrium distance is given by :

(A) $\frac{A}{B}$ (B) $\frac{2A}{B}$ (C) $\frac{3A}{B}$ (D) $\frac{B}{2A}$

51. The equilibrium is :

(A) Stable (B) Unstable (C) Neutral (D) Cannot be predicted

52. The work required to move the particle from equilibrium distance to infinity is :

(A) $\frac{B}{4A}$ (B) $\frac{4B}{A}$ (C) $\frac{B^2}{4A}$ (D) $\frac{4B^2}{A}$

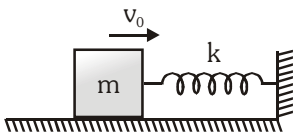
53*. If the total energy of the particle is $E = -\frac{3B^2}{16A}$, and it is known that the motion is radial only then the velocity is zero at : (here, r_0 = equilibrium distance)

(A) $\frac{r_0}{3}$ (B) $\frac{2r_0}{3}$ (C) r_0 (D) $\frac{2r_0}{5}$

Comprehension 2.

A block of mass m moving with a velocity v_0 on a smooth horizontal surface strikes and compresses a spring of stiffness k till mass comes to rest as shown in the figure. This phenomenon is observed by two observers :

A : Standing on the horizontal surface; ***B :*** Standing on the block



54. To an observer A, the work done by spring force is

(A) negative but nothing can be said about its magnitude

(B) $-\frac{1}{2}mv_0^2$

(C) positive but nothing can be said about its magnitude

(D) $+\frac{1}{2}mv_0^2$

55. To an observing A, the net work done on the block is

(A) $-mv_0^2$ (B) $+mv_0^2$ (C) $-\frac{1}{2}mv_0^2$ (D) zero

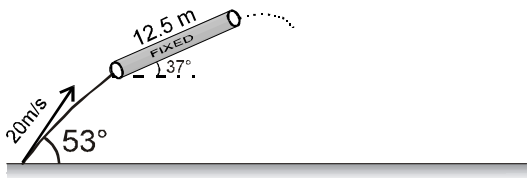
56*. According to the observer A
(A) the kinetic energy of the block is converted into the potential energy of the spring
(B) the mechanical energy of the spring–mass system is conserved
(C) the block loses its kinetic energy because of the negative work done by the conservative force of spring
(D) all the above

57. To an observer B, when the block is compressing the spring
(A) velocity of the block is decreasing (B) retardation of the block is increasing
(C) kinetic energy of the block is zero (D) all the above

58. According to observer B, the potential energy of the spring increases
(A) due to the positive work done by pseudo force (B) due to the negative work done by pseudo force
(C) due to the decrease in the kinetic energy of the block
(D) all the above

Comprehension-3.

A particle of mass 0.1 kg is launched at an angle of 53° with the horizontal. The particle enters a fixed rough hollow tube whose length is slightly less than 12.5 m and which is inclined at an angle of 37° with the horizontal as shown in figure. It is known that the velocity of ball when it enters the tube is parallel to the axis of the tube. The coefficient of friction between the particle and tube inside the tube is $\mu = \frac{3}{8}$.[Take g = 10 m/s^2]



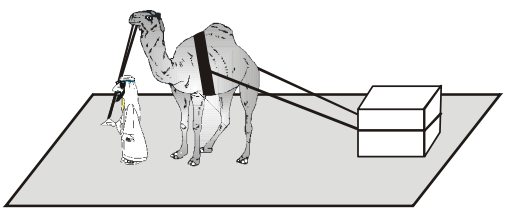
59. The velocity of the particle as it enters the tube is :
(A) 12 m/s (B) 16m/s (C) 9 m/s (D) 15 m/s

60. The kinetic energy of the particle when it comes out of the tube is approximately equal to :
(A) Zero (B) 4 J (C) 7.2 J (D) 11.2 J

61. The distance from the point of projection where the particle will land on the horizontal plane after coming out from the tube is approximately equal to :
(A) 8.4 m (B) 10 m (C) 18.4 m (D) 36.8 m

Comprehension 4.

Ram and Shyam are two fast friends since childhood. Shyam neglected studies and now has no means to earn money other than a camel whereas Ram becomes an engineer. Now both are working in the same factory. Shyam uses camel to transport the load within the factory.



Due to low salary & degradation in health of camel, Shyam becomes worried and meet his friend Ram and discusses his problem. Ram collected some data & with some assumptions concluded the following:

- The load used in each trip is 1000 kg and has friction coefficient $\mu_k = 0.1$ and $\mu_s = 0.2$.
- Mass of camel is 500 kg.
- Load is accelerated for first 50 m with constant acceleration, then it is pulled at a constant speed of 5m/s for 2 km and at last stopped with constant retardation in 50 m.
- From biological data, the rate of consumption of energy of camel can be expressed as $P = 18 \times 10^3 v + 10^4$ J/s where P is the power and v is the velocity of the camel. After calculations on different issues Ram suggested proper food, speed of camel etc. to his friend. For the welfare of Shyam, Ram wrote a letter to the management to increase his salary.

(Assuming that the camel exerts a horizontal force on the load) :

62. Sign of work done by the camel on the load during parts of motion : accelerated motion, uniform motion and retarted motion respectively are :
(A) +ve, +ve, +ve (B) +ve, +ve, –ve (C) +ve, zero, –ve (D) +ve, zero, +ve

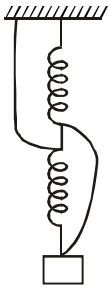
63. The ratio of magnitude of work done by camel on the load during accelerated motion to retarded motion is–
(A) 3 : 5 (B) 2.2 : 1 (C) 1 : 1 (D) 5 : 3

64. Maximum power transmitted by the camel to load is–
(A) 6250 J/s (B) 5000 J/s (C) 10^5 J/s (D) 1250 J/s

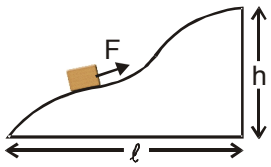
65*. The ratio of the energy consumed of the camel during uniform motion for the two cases when it moves with speed 5 m/s to the case when it moves with 10 m/s.
(A) $\frac{19}{20}$ (B) $\frac{19}{10}$ (C) $\frac{10}{19}$ (D) $\frac{20}{19}$

66*. The total energy consumed of the camel during the trip of 2100 m is–
(A) 2.1×10^6 J (B) 4.22×10^7 J (C) 2.22×10^4 J (D) 4.22×10^6 J

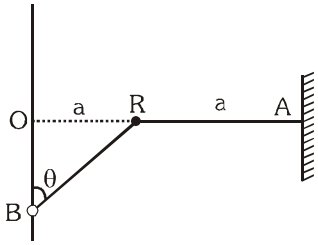
Subjetive Questions



67*. In figure two identical springs, each with a relaxed length of 50 cm and a spring constant of 500 N/m, are connected by a short cord of length 10 cm. The upper string is attached to the ceiling, a box that weighs 100N hangs from the lower spring. Two additional cords, each 85 cm long, are also tied to the assembly; they are limp (i.e. slack).
(i) If the short cord is cut, so that the box then hangs from the springs and the two longer cords, does the box move up or down?
(ii) How far does the box move before coming to rest again?



68. A body of mass m was slowly hauled up the hill (Fig.) by a force F which at each point was directed along a tangent to the trajectory. Find the work performed by this force, if the height of the hill is h, the length of its base ℓ, and the coefficient of friction μ.



69*. A small bead of mass m is free to slide on a fixed smooth vertical wire, as indicated in the diagram. One end of a light elastic string, of unstretched length a and force constant 2mg/a is attached to B. The string passes through a smooth fixed ring R and the other end of the string is attached to the fixed point A, AR being horizontal. The point O on the wire is at same horizontal level as R, and AR = RO = a.
(i) In the equilibrium position, find OB.
(ii) The bead B is raised to a point C of the wire above O, where OC = a, and is released from rest. Find the speed of the bead as it passes O, and find the greatest depth below O of the bead in the subsequent motion.

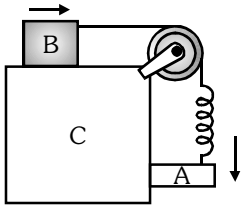
70. A small body of mass m is located on a horizontal plane at the point O. The body acquires a horizontal velocity v_0. Find :
(a) the mean power developed by the friction force during the whole time of motion, if the friction coefficient k = 0.27, m = 1.0 kg, and v_0 = 1.5 m/s;
(b) the maximum instantaneous power developed by the friction force, if the friction coefficient varies as $k = \alpha x$, where α is a constant, and x is the distance from the point O.

71. A system consists of two springs connected in series and having the stiffness coefficients k_1 and k_2. Find the minimum work to be performed in order to stretch this system by $\Delta\ell$.

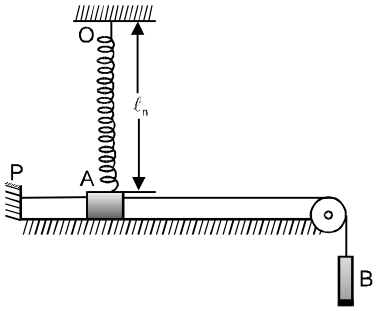
72. A body of mass m is hauled from the Earth's surface by applying a force F varying with the height of ascent y as F = –2 (ay – 1) mg, where a is a positive constant. Find the work performed by this force and the increment of the body's potential energy in the gravitational field of the Earth over the first half of the ascent.

73. There are two stationary fields of force F = ayi and F = axi + byj where i and j are the unit vectors of the x and y axes, and a and b are constants. Find out whether these fields are potential.

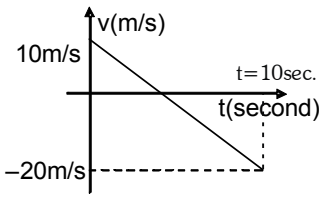
74. Two blocks A and B are connected to each other by a string and a spring; the string pass overs a frictionless pulley as shown in the figure. Block B slides over the horizontal top surface of a stationary block C and the block A slides along the vertical side of C, both with the same uniform speed. The coefficient of friction between the surface and the block is 0.2. Force constant of the spring is 1960 N/m. If mass of block A is 2 kg, calculate the mass of block B and the energy stored in the spring.



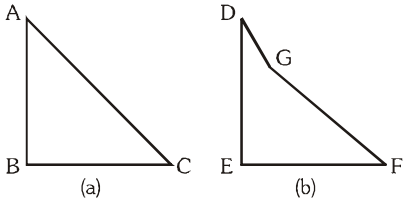
75. A small bar A resting on a smooth horizontal plane is attached by threads to a point P (Fig.) and by means of a weightless pulley, to a weight B possessing the same mass as the bar itself. Besides, the bar is also attached to a point O by means of a light non deformed spring of length $\ell_0 = 50$ cm and stiffness $x = 5\ mg/\ell_0$, where m is the mass of the bar. The thread PA having been burned, the bar starts moving. Find its velocity at the moment when it is breaking off the plane.



76. Velocity time graph of a particle moving in a straight line is shown. Mass of the particle is 2 kg. Work done by all the forces acting on the particle in time interval t = 0 to t = 10 s



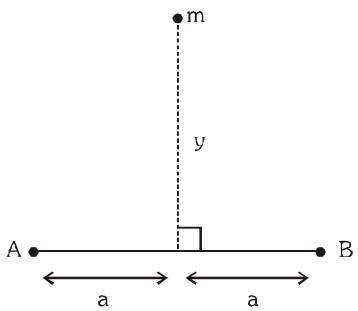
77. In the figure (A) and (B) AC, DG and GF are fixed inclined planes, BC = EF = x and AB = DE = y. A small block of mass M is released from the point A. It slides down AC and reaches C with a speed v_C. The same block is released from rest from the point D. It slides down DGF and reaches the point F with speed v_F. The coefficients of kinetic friction between the block and both the surfaces AC and DGF are μ. Calculate v_C and v_F.



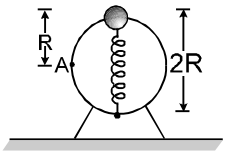
78. A body of mass 2 kg is being dragged with a uniform velocity of 2 m/s on a rough horizontal plane. The coefficient of friction between the body and the surface is 0.20, J = 4.2 J/cal and $g = 9.8\ m/s^2$. Calculate the amount of heat generated in 5 s.

79*. Two blocks of masses m_1 and m_2 are connected by a spring of stiffness k. The coefficient of friction between the blocks and the surface is μ. Find the minimum constant force F to be applied to m_1 in order to slide the mass m_2.

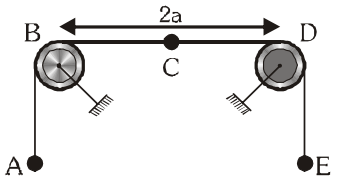
80*. Potential energy of a particle of mass m, depends on distance y from line AB according to given relation $U = \dfrac{K}{\sqrt{y^2 + a^2}}$, where K is a positive constant. A particle of mass m is projected from $y = \sqrt{3}\,a$ towards line AB (perpendicular to it) then minimum velocity so that it cannot return to its initial point is $\sqrt{\dfrac{K}{aNm}}$. Calculate N.



81*. A bead of mass m slides without friction on a vertical hoop of radius R. The bead moves under the combined influence of gravity and a spring of spring constant k attached to the bottom of the hoop. The bead is released at the top of the hoop with negligible speed as shown. Find the velocity of the bead at point A. (Natural length is R)



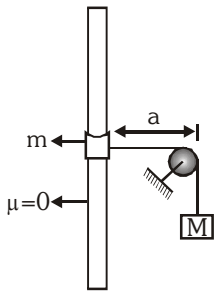
82. A light string ABCDE whose mid point i s C passes through smooth rings B and D, which are fixed in a horizontal plane distance 2a apart. To each of the points A, C and E is attached a mass m. Initially C is held at rest at O (mid point BD) and is then set free. What is the distance OC when C comes to instantaneous rest?



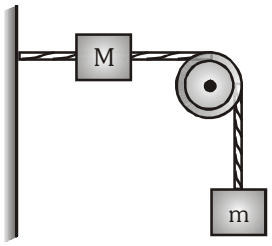
83*. A particle of mass m is hanging in equilibrium with the help of an elastic string of unstretched length a and force constant $\frac{mg}{a}$. The other end is fixed to a peg on vertical wall. String is given an additional extension of 2a in vertical downward direction by pulling the mass and released from rest. Find the maximum height reached by it during its subsequent motion above point of release. (Neglect interaction with peg if any)

84. A chain of mass m = 0.80 kg and length ℓ = 1.5 m rests on a rough-surfaced table so that one of its ends hangs over the edge. The chain starts sliding off the table all by itself provided the over-hanging part equals $\eta = 1/3$ of the chain length. What will be the total work performed by the friction forces acting on the chain by the moment it slides completely off the table?

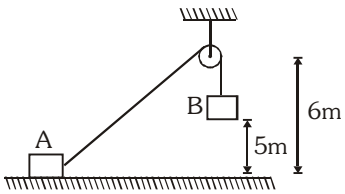
85. A ring of mass m slides on a smooth vertical rod. A light string is attached to the ring and is passing over a smooth peg distant a from the rod, and at the other end of the string is a mass M (M>m). The ring is held on a level with the peg and released. Show that it first comes to rest after falling a distance $\frac{2mMa}{M^2 - m^2}$



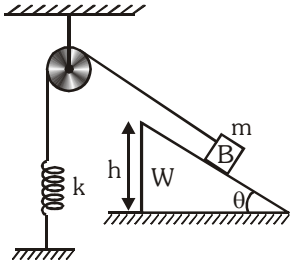
86*. A string, with one end fixed on a rigid wall, passing over a fixed frictionless pulley at a distance of 2m from the wall, has a point mass M = 2kg attached to it at a distance of 1m from the wall. A mass m = 0.5 kg attached at the free end is held at rest so that the string is horizontal between the wall and the pulley and vertical beyond the pulley. What will be the speed with which the mass M will hit the wall when the mass m is released?



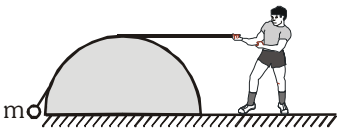
87. 'A' block of mass m is held at rest on a smooth horizontal floor. A light frictionless, small pulley is fixed at a height of 6 m from the floor. A light inextensible string of length 16m, connected with A passes over the pulley and another identical block B is hung from the string. Initial height of B is 5m from the floor as shown in figure. When the system is released from rest, B starts to move vertically downwards and A slides on the floor towards right. (i) If at an instant string makes an angle θ with horizontal, calculate relation between velocity u of A and v of B (ii) Calculate v when B strikes the floor.



88. In the figure shown the pulley is smooth. The spring and the string are light. The block 'B' slides down from the along the fixed rough wedge of inclination θ. Assuming that the block reaches the end of the wedge. Find the speed of the block at the end. Take the coefficient of friction between the block and the wedge to be μ and the spring was relaxed when the blockwas released from the top of the wedge.



89. As shown in the figure a person is pulling a mass 'm' from ground on a fixed rough hemispherical surface upto the top of the hemisphere with the help of a light inextensible string. Find the work done by tension in the string if radius of hemisphere is R and friction co–efficient is μ. Assume that the block is pulled with negligible velocity.



90. A particle of mass m approaches a region of force starting from $r = +\infty$. The potential energy function in terms of distance r from the origin is given by,

$$U(r) = \frac{K}{2a^3}(3a^2 - r^2) \quad \text{for}, \ 0 \le r \le a$$

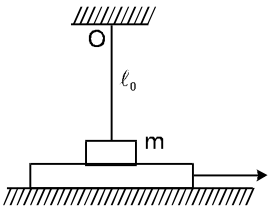
$$= K/r \quad \text{for}, \ r \ge a$$

(a) Derive the force F (r) and determine whether it is repulsive or attractive.

(b) With what velocity should the particle start at $r = \infty$ to cross over to other side of the origin.

(c) If the velocity of the particle at $r = \infty$ is $\sqrt{\frac{2K}{am}}$, towards the origin describe the motion.

91. A horizontal plane supports a plank with a bar of mass m = 1.0 kg placed on it and attached by a light elastic non-deformed cord of length ℓ_0 = 40 cm to a point O (Fig.). The coefficient of friction between the bar and the plank equals k = 0.20. The plank is slowly shifted to the right until the bar starts sliding over it. It occurs at the moment when the cord deviates from the vertical by an angle $\theta = 30°$. Find the work that has been performed by that moment by the friction force acting on the bar in the reference frame fixed to the plane.



ANSWERS

- ***True and False***

1.	False	**2.**	False	**3.**	False	**4.**	True

- ***Fill in the Blanks***

5.	zero	**6.**	$\frac{-3}{4}$ Mgh	**7.**	$\frac{mg(h+s)}{s}$	**8.**	9.8

- ***Assertion–Reason***

9.	A	**10.**	D	**11.**	D	**12.**	A	**13.**	B
14.	A	**15.**	A	**16.**	C				

- ***Single Choice Correct***

17.	C	**18.**	B	**19.**	A	**20.**	B	**21.**	A
22.	A	**23.**	A	**24.**	C	**25.**	D	**26.**	A
27.	C	**28.**	A	**29.**	C	**30.**	A	**31.**	C
32.	D	**33.**	C	**34.**	C	**35.**	D	**36.**	B
37.	B	**38.**	A	**39.**	A	**40.**	A		

- ***Multiple Choice Correct***

41.	ACD	**42.**	CD	**43.**	BCD	**44.**	AC	**45.**	C
46.	ABC	**47.**	AD	**48.**	AB				

- ***Match the Column***

49. (A) r; (B) q; (C) p; (D) t

- ***Comprehension***

Comprehension 1 :	**50.**	B	**51.**	A	**52.**	C	**53.**	B		
Comprehension 2 :	**54.**	B	**55.**	C	**56.**	D	**57.**	C	**58.**	B
Comprehension 3 :	**59.**	D	**60.**	A	**61.**	C				
Comprehension 4 :	**62.**	A	**63.**	D	**64.**	A	**65.**	D	**66.**	B

- ***Subjective Questions***

67. up, 10 cm **68.** A = mg (h + $\mu\ell$)] **69.** (i) $\frac{a}{2}$ (ii) $2\sqrt{ga}$, 2a

70. (a) <P> =–kmgv_0/2 = –2W ; (b) P_{max} = –1/2m$v_0^2\sqrt{\alpha g}$]

71. A_{min} = 1/2 k($\Delta\ell$)^2, where k =k_1k_2 / (k_1 + k_2)] **72.** A = 3mg/4a , ΔU = mg/2a]

73. The latter field is potential.

74. 10 kg, 0.098 J

75. $v = \sqrt{19 g \ell_0/32} = 1.7$ m/s]

76. 300 J

77. $v_C = v_F = \sqrt{2(gy - \mu gx)}$

78. 9.33 cal

79. $\mu m_1 g + \frac{\mu m_2 g}{2}$

80. 1

81. $V = \sqrt{\frac{2(\sqrt{2}-1)kR^2}{m} + 2gR}$

82. $\frac{4a}{3}$

83. $\frac{9a}{2}$

84. $A = -(1-\eta)\eta mg\ell/2 = -1.33$ J]

86. 3.71 ms^{-1}

87. $u = v \sec\theta$, $v = \frac{40}{\sqrt{41}} ms^{-1}$

88. $v = \sqrt{\frac{2}{m}\left[mgh - \frac{1}{2}k\left(\frac{h}{\sin\theta}\right)^2 - \mu mgh\cot\theta\right]}$

89. $mgR(1+\mu)$

90. (a) repulsive (b) $\sqrt{\frac{3k}{am}}$

91. $A = \frac{kmg\ell_0}{2}\frac{1-\cos\theta}{(\sin\theta + k\cos\theta)\cos\theta} = 0.09$ J]

CIRCULAR MOTION

True or False

1. A particle is moving in a circle with variable speed the cross product of angular velocity and tangential acceleration will be zero.

2. In case of circular motion the direction of angular velocity & angular acceleration must be same.

3. In case of uniform circular motion acceleration of particle in constant.

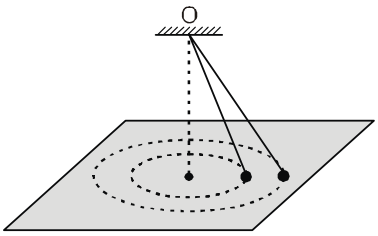
4. A simple pendulum with a bob of mass m swings with an angular amplitude of 40°. When its angular displacement is 20°, the tension in the string is greater than mg cos20°.

5. Two identical trains are moving on rails along the equator on the earth in opposite directions with the same speed. They will exert the same pressure on the rails.

Assertion & Reason

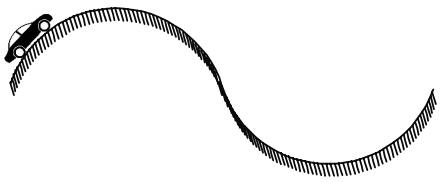
These questions contains, Statement I (assertion) and Statement II (reason).
(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.
(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1.
(C) Statement-1 is True, Statement-2 is False.
(D) Statement-1 is False, Statement-2 is True.

6*. ***STATEMENT-1*** : Two small spheres are suspended from same point O on roof with string of different lengths. Both spheres move along horizontal circles as shown. Then both spheres may move along circles in same horizontal plane.



STATEMENT-2 : For both spheres in statement-1 to move in circular paths in same horizontal plane, their angular speeds must be same.

7. ***STATEMENT-1:*** A car moves along a road with uniform speed. The path of car lies in vertical plane and is shown in figure. The radius of curvature(R) of the path is same everywhere. If the car does not loose contact with road at the highest point, it can travel the shown path without loosing contact with road anywhere else.



STATEMENT-2: For car to loose contact with road, the normal reaction between car and road should be zero.

8. ***STATEMENT-1:*** A ball tied by thread is undergoing circular motion (of radius R) in a vertical plane. (Thread always remains in vertical plane). The difference of maximum and minimum tension in thread is independent of speed (u) of ball at the lowest position ($u > \sqrt{5gr}$).

STATEMENT-2: For a ball of mass m tied by thread undergoing vertical circular motion (of radius R), difference in maximum and minimum magnitude of centripetal acceleration of the ball is independent of speed (u) of ball at the lowest position ($u > \sqrt{5gr}$).

Single Choice Correct

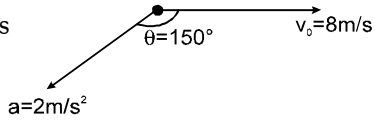
9. A particle of mass m is moving in a circular path of constant radius r such that its centripetal acceleration a_C is varying with time t as $a_C = k^2rt^2$, where k is a constant. The power delivered to the particle by the force acting on it is :

(A) $2\pi mk^2r^2$ (B) mk^2r^2t (C) $\frac{(mk^4r^2t^5)}{3}$ (D) zero

10. A particle of mass m starts undergoing a circular motion of radius R. The speed of particle is increasing as V = Kt (K is a constant), (t is time in seconds). The magnitude of net acceleration after 1 second is

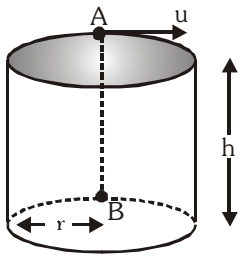
(A) K (B) $\frac{K^2}{R}$ (C) $K\sqrt{1+\frac{K^2}{R^2}}$ (D) $2K\sqrt{1+\frac{K^2}{R^2}}$

11*. The figure shows the velocity and acceleration of a point like body at the initial moment of its motion. The acceleration vector of the body remains constant. The minimum radius of curvature of trajectory of the body is



(A) 2 meter (B) 4 meter
(C) 8 meter (D) 16 meter.

12*. A hollow vertical cylinder of radius r and height h has a smooth internal surface. A small particle is placed in contact with the inner side of the upper rim, at point A, and given a horizontal speed u, tangential to the rim. It leaves the lower rim at point B, vertically below A. If n is an integer then



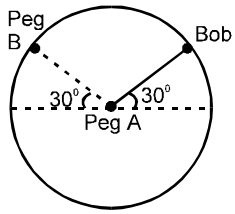
(A) $\frac{u}{2\pi r}\sqrt{\frac{2h}{g}} = n$ (B) $\frac{h}{2\pi r} = n$

(C) $\frac{2\pi r}{h} = n$ (D) $\frac{u}{\sqrt{2gh}} = n$

13*. Three point particles P, Q, R move in a circle of radius ' r ' with different but constant speeds. They start moving at t = 0 from their initial positions as shown in the figure. The angular velocities (in rad/sec) of P, Q and R are 5π, 2π & 3π respectively, in the same sense. The time interval after which they all meet is:

(A) 2/3 sec (B) 1/6 sec (C) 1/2 sec (D) 3/2 sec

14*. A bob is attached to one end of a string other end of which is fixed at peg A. The bob is taken to a position where string makes an angle of 30^0 with the horizontal. On the circular path of the bob in vertical plane there is a peg 'B' at a symmetrical position with respect to the position of release as shown in the figure. If V_c and V_a be the minimum speeds in clockwise and anticlockwise directions respectively, given to the bob in order to hit the peg 'B' then ratio $V_c : V_a$ is equal to :

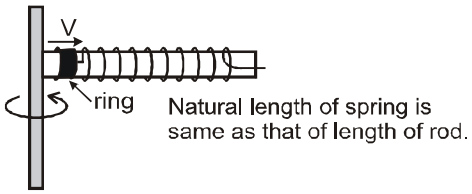


(A) 1 : 1 (B) 1 : $\sqrt{2}$
(C) 1 : 2 (D) 1 : 4

15. An automobile enters a turn of radius R. If the road is banked at an angle of 45^0 and the coefficient of friction is 1, the minimum and maximum speed with which the automobile can negotiate the turn without skidding is:

(A) $\sqrt{\frac{rg}{2}}$ and $\sqrt{rg}$ (B) $\frac{\sqrt{rg}}{2}$ and $\sqrt{rg}$ (C) $\frac{\sqrt{rg}}{2}$ and $2\sqrt{rg}$ (D) 0 and infinite

16. A ring attached with a spring is fitted in a smooth rod. The spring is fixed at the outer end of the rod. The mass of the ring is 3kg & spring constant of spring is 300 N/m. The ring is given a velocity 'V' towards the outer end of the rod. And the rod is set to be rotating with an angular velocity ω. Then ring will move with constant speed with respect to the rod if :

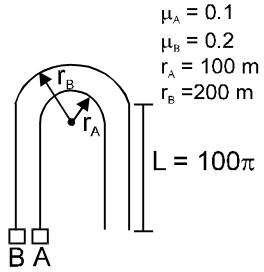


(A) angular velocity of rod is increased continuously
(B) ω = 10 rad/s
(C) angular velocity of rod is decreased continuously.
(D) constant velocity of ring is not possible

17. A car is travelling at 57.6 km/hr on an unbanked (horizontal) circular road of radius $\frac{160}{3}$ m. If the coefficient of friction between the road and the car is 0.8, then the maximum tangential deceleration that driver of car can achieve by applying the brakes at this moment is : ($g = 10\ m/s^2$)

(A) $8\ m/s^2$ (B) $4.8\ m/s^2$ (C) $6.4\ m/s^2$ (D) $16\ m/s^2$

18. Two cars A and B start racing at the same time on a flat race track which consists of two straight sections each of length 100π and one circular section as in fig. The rule of the race is that each car must travel at constant speed at all times without ever skidding :



(A) car A completes its journey before car B
(B) both cars complete their journey in same time
(C) velocity of car A is greater than that of car B
(D) car B completes its journey before car A.

19. A particle begins to move with a tangential acceleration of constant magnitude $0.6\ m/s^2$ in a circular path. If it slips when its total acceleration becomes $1\ m/s^2$, then the angle through which it would have turned before it starts to slip is :

(A) 1/3 rad (B) 2/3 rad (C) 4/3 rad (D) 2 rad

20. Two masses of 1 g and 4 g are moving with equal kinetic energies. The ratio of the magnitudes of their momenta is : ***[IIT-JEE 1980]***

(A) 4 : 1 (B) $\sqrt{2}$: 1 (C) 1 : 2 (D) 1 : 16

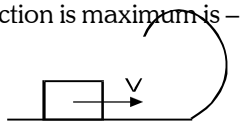
21. A stone tied to a string of length L is whirled in a vertical circle with the other end of the string at the centre. At a certain instant of time, the stone is at its lowest position, and has a speed u. The magnitude of the change in its velocity as it reaches a position where the string is horizontal is : ***[IIT-JEE 1998]***

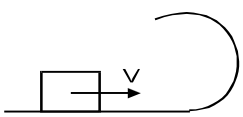
(A) $\sqrt{u^2 - 2gL}$ (B) $\sqrt{2gL}$ (C) $\sqrt{u^2 - gL}$ (D) $\sqrt{2(u^2 - gL)}$

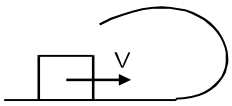
22. A long horizontal rod has a bead which can slide along its length and is initially placed at a distance L from one end A of the rod. The rod is set in angular motion about A with a constant angular acceleration, α. If the coefficient of friction between the rod and bead is μ, and gravity is neglected, then the time after which the bead starts slipping is : ***[IIT-JEE 2000]***

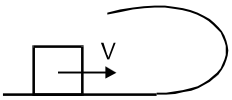
(A) $\sqrt{\frac{\mu}{\alpha}}$ (B) $\frac{\mu}{\sqrt{\alpha}}$ (C) $\frac{1}{\sqrt{\mu\alpha}}$ (D) infinitesimal

23. A small block is shot into each of the four tracks as shown below. Each of the tracks rises to the same height. The speed with which the block enters the track is the same in all cases. At the highest point of the track, the normal reaction is maximum is – ***[JEE (Scr) 2001]***

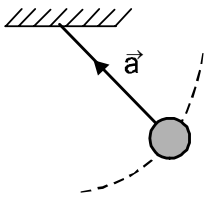
(A)


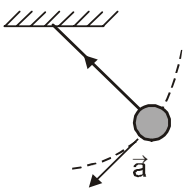
(B)


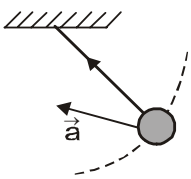
(C)


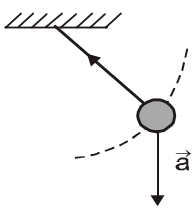
(D)


24. A simple pendulum is oscillating without damping. When the displacements of the bob is less than maximum, its acceleration vector $\vec{a}$ is correctly shown in ***[JEE 2002 (Scr)]***

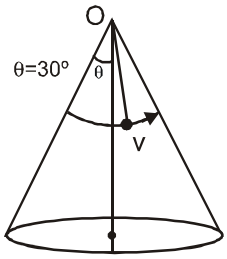
(A)


(B)


(C)


(D)


25*. A bob of mass 2 kg is suspended from point O of a cone with an inextensible string of length $\sqrt{3}$ m. It is moving in horizontal circle over the surface of cone as shown in the figure. Then : ($g = 10\ m/s^2$)



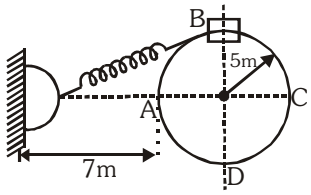
(A) bob looses contact with cone if $v > \sqrt{5}$ m/s

(B) normal force on bob is 19 N when v = 2 m/s

(C) normal force on bob is $\frac{17}{\sqrt{3}}$ N when v = 2m/s

(D) None of these

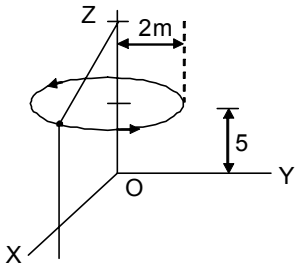
26. A collar 'B' of mass 2 kg is constrained to move along a horizontal smooth and fixed circular track of radius 5m. The spring lying in the plane of the circular track and having spring constant 200 N/m is undeformed when the collar is at 'A'. If the collar starts from rest at B' the normal reaction exerted by the track on the collar when it passes through 'A' is (neglect gravity):



(A) 360 N (B) 720 N (C) 1440 N (D) 2880 N

Multiple Choice Correct

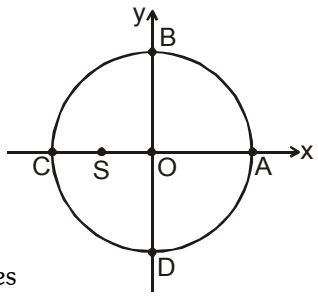
27*. The upper end of the string of a conical pendulum is fixed to a vertical z-axis, and set in motion such that the bob moves along a horizontal circular path of radius 2 m, parallel to the x-y plane, 5 m above the origin. The bob has a speed of 3 m/s. The string breaks when the bob is vertically above the x-axis, and the bob lands on the xy plane at a point (x, y)



(A) x = 2m (B) x > 2m

(C) y = 3m (D) y = 5m

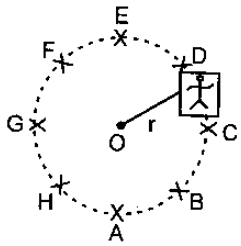
28. A particle is describing circular motion in a horizontal plane in contact with the smooth inside surface of a fixed right circular cone with its axis vertical and vertex down. The height of the plane of motion above the vertex in h and the semivertical angle of the cone in α. The period of revolution of the particle :



(A) increases at h increases (B) decreases as h increases

(C) increases as α in creases (D) decreases as α increases

29*. A machine, in an amusement park, consists of a cage at the end of one arm, hinged at O. The cage revolves along a vertical circle of radius r (ABCDEFGH) about its hinge O, at constant linear speed



$v = \sqrt{gr}$. The cage is so attached that the man of weight 'w' standing on a weighing machine, inside the cage, is always vertical.

Then which of the following is correct

(A) the weight reading at A is greater than the weight reading at E by 2 w.

(B) the weight reading at G = w

(C) the ratio of the weight reading at E to that at A = 0

(D) the ratio of the weight reading at A to that at C = 2.

30*. On a circular table, A and B are moving on the circumference. Man A runs behind man B to catch him. A runs with constant angular speed ω_1 with respect to table and B runs at constant tangential speed v_2 with respect to ground. If it is found that the table rotates 30° in the opposite direction in every one second and the initial angular seperation between A and B is 30°, then A catches B after : (Radius of table is 3 m)

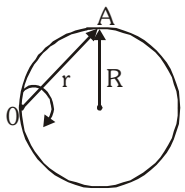
(A) 0.5 sec, if $\omega_1 = \frac{5\pi}{6}$ rad/s and $v_2 = 3.14$ m/s

(B) 0.5 sec, if $\omega_1 = \frac{4\pi}{3}$ rad/s and $v_2 = 3.14$ m/s

(C) 0.5 sec, if $\omega_1 = \frac{4\pi}{3}$ rad/s and $v_2 = 6.26$ m/s

(D) A can not catch B within 0.2 s, if $\omega_1 = \frac{\pi}{6}$ rad/s and $v_2 = 6.28$ m/s

31*. A particle A moves along a circle of radius R=50 cm so that its radius vector r relative to the point O (figure) rotates with the constant angular velocity ω=0.40 rad/s. Then modulus of the velocity of the particle, and the modulus of its total acceleration will be

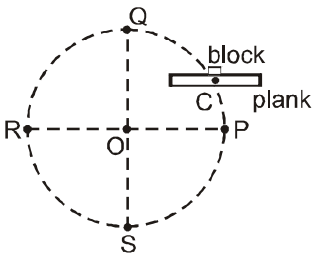


(A) v= 0.4 m/s, a = 0.4 m/s^2 (B) v = 0.32 m/s, a = 0.32 m/s^2

(C) v = 0.32 m/s, a = 0.4 m/s^2 (D) v = 0.4 m/s, a = 0.32 m/s^2

Match the Column

32. A small block lies on a rough horizontal platform above its centre C as shown figure. The plank is moved in vertical plane such that it always remains horizontal and its centre C moves in a vertical circle of centre O with constant angular velocity ω. There is no relative motion between block and the plank and the block does not loose contact with the plank anywhere. P, Q, R and S are four points on circular trajectory of centre C of platform. P and R lie on same horizontal level as O. Q is the highest point on the circle and S is the lowest point on the shown circle. Match the statements in column-I with points in column-II.

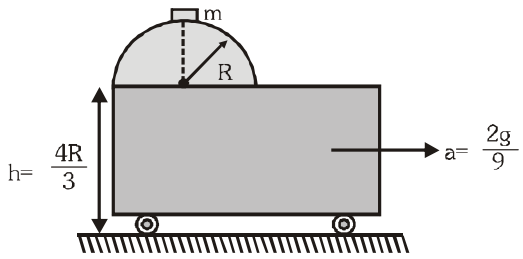


Column-I	***Column-II***
(A) Magnitude of frictional force on block is maximum	(P) when block is at position P
(B) Magnitude of normal reaction on block is equal to mg	(Q) when block is at position Q
(C) Magnitude of frictional force is zero	(R) when block is at position R
(D) Net contact force on the block is directed toward centre	(S) when block is at position S
	(T) None of these

Comprehension

Comprehension 1

A vertical frictionless semicircular track of radius R is fixed on the edge of movable trolley. Initially the system is at rest and a mass m is kept at the top of the track. The trolley starts moving to the right with a uniform horizontal acceleration a $= \frac{2g}{9}$. The mass slides down the track, eventually losing contact with it and dropping to the floor h below the trolley.



33. The angle θ with vertical, at which it losses contact with the trolley is

(A) 37° (B) 53° (C) $\cos^{-1}\left(\frac{2}{3}\right)$ (D) $\frac{\pi}{2} - \cos^{-1}\left(\frac{2}{3}\right)$

34. The height at which mass m losing contact is

(A) $\frac{4}{5}R$ (B) $\frac{17}{15}R$ (C) R (D) $\frac{32}{15}R$

35*. The time taken by the mass to drop on the floor, after losing contact is

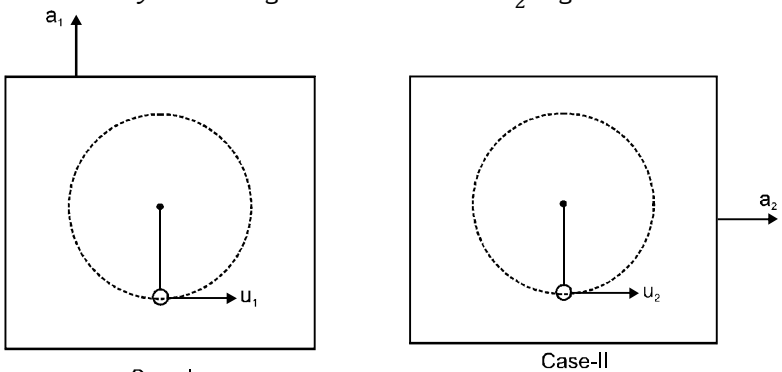
(A) $\sqrt{\frac{2R}{3g}}$ (B) $\sqrt{\frac{2R}{g}}$ (C) $2\sqrt{\frac{2R}{3g}}$ (D) Can't be determined

Comprehension 2

A man inside the lift swings a stone tied to a string of length L in a vertical plane. The string remains taut throughout the time of rotation of the stone.

Case-I: The lift accelerates vertically upwards with acceleration $a_1 = \frac{g}{2}$

Case-II: The lift accelerates horizontally towards right with acceleration $a_2 = g$



Case-I Case-II

36. For case I, find the minimum velocity 'u_1' of the stone (relative to the lift) required at the lowest point of its path for successful completion of the loop.

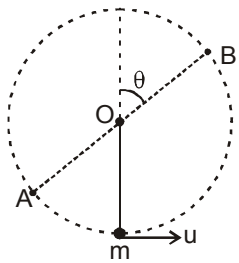
(A) $\sqrt{\frac{7}{2}gL}$ (B) $\sqrt{4gL}$ (C) $\sqrt{5gL}$ (D) $\sqrt{\frac{15}{2}gL}$

37. For case II, what is the minimum velocity 'u_2' of the stone (relative to the lift) required at the lowest point of its path for successful completion of loop.

(A) $\sqrt{(1+\sqrt{2})gL}$ (B) $\sqrt{(3+\sqrt{2})gL}$ (C) $\sqrt{(2+3\sqrt{2})gL}$ (D) $\sqrt{(\sqrt{2}+1)gL}$

Comprehension 3

A ball is hanging vertically by a light inextensible string of length L from fixed point O. The ball of mass m is given a speed u at the lowest position such that it completes a vertical circle with centre at O as shown. Let AB be a diameter of circular path of ball making an angle θ with vertical as shown. (g is acceleration due to gravity)



38. Let T_A and T_B be tension in string when ball is at A and B respectively, then $T_A - T_B$ is equal to

(A) 6 mg cosθ (B) 6 mg (C) 12 mg cosθ (D) None of these

39. Let $\vec{a}_A$ and $\vec{a}_B$ be acceleration of ball when it is at A and B respectively, then $|\vec{a}_A + \vec{a}_B|$ is equal to

(A) 2 g sinθ (B) $g\sqrt{12\cos^2\theta + 4}$ (C) 4 g cosθ (D) None of these

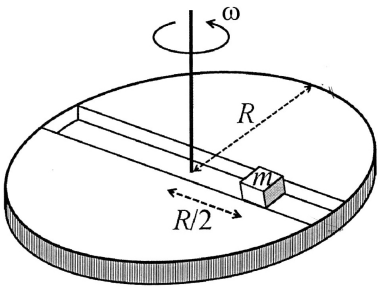
Comprehension 4

A frame of reference that is accelerated with respect to an inertial frame of reference is called a non-inertial frame of reference. A coordinate system fixed on a circular disc rotating about a fixed axis with a constant angular velocity ω is an example of a non-inertial frame of reference. The relationship between the force $\vec{F}_{rot}$ experienced by a particle of mass m moving on the rotating disc and the force $\vec{F}_{in}$ experienced by the particle in an inertial frame of reference is

$$\vec{F}_{rot} = \vec{F}_{in} + 2m(\vec{v}_{rot} \times \vec{\omega}) + m(\vec{\omega} \times \vec{r}) \times \vec{\omega}$$

where $\vec{v}_{rot}$ is the velocity of the particle in the rotating frame of reference and $\vec{r}$ is the position vector of the particle with respect to the centre of the disc.

Now consider a smooth slot along a diameter of a disc of radius R rotating counter-clockwise with a constant angular speed ω about its vertical axis through its center. We assign a coordinate system with the origin at the center of the disc, thex-axis along the slot, the y-axis perpendicular to the slot and the z-axis along the rotation axis $(\vec{\omega} = \omega\hat{k})$. A small block of mass m is gently placed in the slot at $\vec{r} = (R/2)\hat{i}$ at t = 0 and is constrained to move only along the slot.



40. The distance r of the block at time t is **[JEE(Adv.) - 2016]**

(A) $\frac{R}{4}(e^{2\omega t} + e^{-2\omega t})$ (B) $\frac{R}{2}\cos 2\omega t$ (C) $\frac{R}{2}\cos \omega t$ (D) $\frac{R}{4}(e^{\omega t} + e^{-\omega t})$

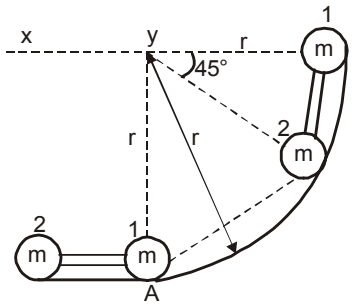
41. The net reaction of the disc on the block is **[JEE(Adv.) - 2016]**

(A) $-m\omega^2 R\cos\omega t\,\hat{j} - mg\,\hat{k}$ (B) $m\omega^2 R\sin\omega t\,\hat{j} - mg\,\hat{k}$

(C) $\frac{1}{2}m\omega^2 R(e^{\omega t} - e^{-\omega t})\hat{j} + mg\,\hat{k}$ (D) $\frac{1}{2}m\omega^2 R(e^{2\omega t} - e^{-2\omega t})\hat{j} + mg\,\hat{k}$

Comprehension-5

Two small spheres, each of mass m are rigidly connected by a rod of negligible mass and are released from rest in the position shown and slide down a smooth circular guide in the vertical plane.



42. Their common velocity as they reach the horizontal dashed position will be :

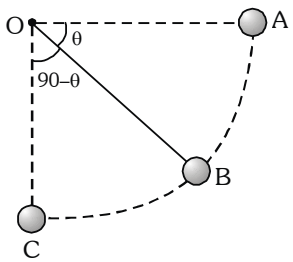
(A) $\sqrt{2gr - \frac{1}{\sqrt{2}}gr}$ (B) $10\sqrt{2gr - \frac{1}{\sqrt{2}}gr}$ (C) $\sqrt{gr}$ (D) $\sqrt{gr}/2$

43. The force R between sphere 1 and the supporting surface at an instant just before the sphere reaches the bottom position A will be :

(A) 22.9 mg (B) 2.29 mg (C) mg (D) mg/2

Comprehension 6

One end of a light string of length L is connected to a ball and the other end is connected to a fixed point O. The ball is released from rest at t = 0 with string horizontal and just taut. The ball then moves in vertical circular path as shown. The time taken by ball to go from position A to B is t_1 and from B to lowest position C is t_2. Let the velocity of ball at B is $\vec{v}_B$ and at C is $\vec{v}_C$ respectively.



44. If $|\vec{v}_C| = 2|\vec{v}_B|$ then the value of θ as shown is

(A) $\cos^{-1}\frac{1}{4}$ (B) $\sin^{-1}\frac{1}{4}$ (C) $\cos^{-1}\frac{1}{2}$ (D) $\sin^{-1}\frac{1}{2}$

45*. If $|\vec{v}_C| = 2|\vec{v}_B|$ then :

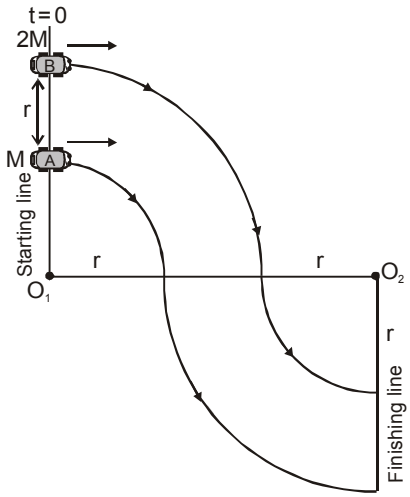
(A) $t_1 > t_2$ (B) $t_1 < t_2$ (C) $t_1 = t_2$ (D) Information insufficient

46*. If $|\vec{v}_C - \vec{v}_B| = |\vec{v}_B|$, then the value of θ as shown is :

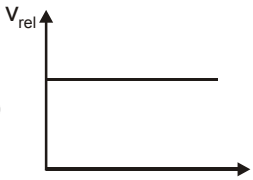
(A) $\cos^{-1}\left(\frac{1}{4}\right)^{1/3}$ (B) $\sin^{-1}\left(\frac{1}{4}\right)^{1/3}$ (C) $\cos^{-1}\left(\frac{1}{2}\right)^{1/3}$ (D) $\sin^{-1}\left(\frac{1}{2}\right)^{1/3}$

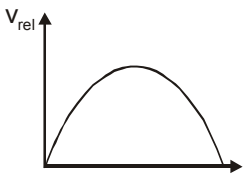
Comprehension 7

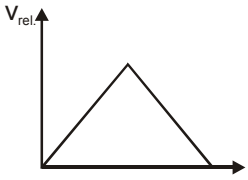
Two racing cars 'A' and 'B' having masses 'M' and '2M' respectively start running from the starting line on a horizontal plane. Both cars 'A' and 'B' have same speed 'V' which is constant through out the journey. The track of the two car are the arcs of concentric circles having centres O_1 and O_2 as shown in figure with data. The friction coefficient of the two car with the road is same. There is a finishing line at the end of the arc. Using these informations solve the following questions.

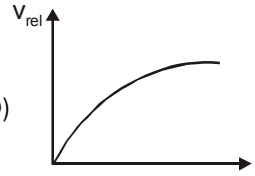


47. Graph between the magnitude of relative velocity of the two cars and time is :

(A) 

(B) 

(C) 

(D) 

48*. The magnitude of relative acceleration of two cars when car 'A' just reaches the end of circular arc of radius 'r'.

(A) 0 (B) $(\sqrt{5-2\sqrt{2}})\frac{V^2}{2r}$ (C) $\sqrt{2}\frac{V^2}{r}$ (D) $\frac{V^2}{r}$

49. The time interval during which the two cars have same angular speed :

(A) Always along the motion (B) Never

(C) $\frac{\pi r}{2V}$ (D) $\frac{\pi r}{4V}$

50. Which of the following statements is ***incorrect***.

(A) Both car reaches the finishing line at same time.

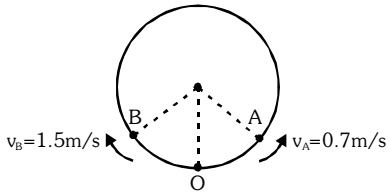
(B) Frictional force acting on the cars is directed towards centre whenever it acts

(C) Frictional force have same magnitude for two car 'A' and 'B' during the trip.

(D) None of these

Subjetive Questions

51. Two particles A and B start at O and travel in opposite directions along the circular path at constant speed $v_A = 0.7$ m/s and $v_B = 1.5$ m/s respectively. Determine the time when they collide and the magnitude of the acceleration of B just before this happening. (radius = 5m)



52. A particle moves along an arc of a circle of radius R according to law $\ell = a\sin\omega t$, where ℓ is the displacement from the initial position measured along the arc and a and ω are constants. Assuming R = 1.00 m, a = 0.80 m and ω = 2.00 rad/s. Find :

(a) the magnitude of the total acceleration of the particle at the points $\ell = 0$ and $\ell = \pm a$;

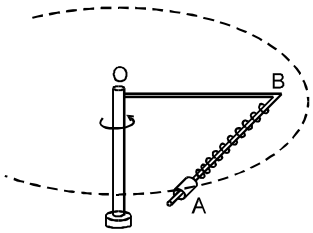
(b) the minimum value of the total acceleration w_{min} and the corresponding displacement ℓ_m .

53. A particle of mass m moves along a circle of radius R. Find the modulus of the average vector of the force acting on the particle over the distance equal to a quarter of the circle, if the particle moves

(a) uniformly with velocity v;

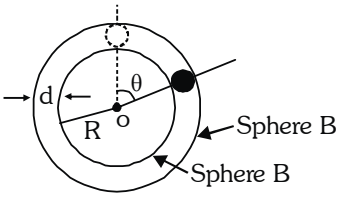
(b) with constant tangential acceleration w_τ, the initial velocity being equal to zero.

54. A device (Fig.) consists of a smooth L-shaped rod located in a horizontal plane and a sleeve A of mass m attached by a weightless spring to a point B. The spring stiffness is equal to x. The whole system rotates with a constant angular velocity ω about a vertical axis passing through the point O. Find the elongation of the spring. How is the result affected by the rotation direction?



55. A cyclist rides along the circumference of a circular horizontal plane of radius R, the friction coefficient being dependent only on distance r from the centre O of the plane as $k = k_0(1—r/R)$, where k_0 is a constant. Find the radius of the circle with the centre at the point along which the cyclist can ride with the maximum velocity. What is this velocity?

56. A spherical ball of mass m is kept at the highest point in the space between two fixed, concentric spheres A and B (see figure). The smaller sphere A has a radius R and the space between the two spheres has a width d. The ball has a diameter very slightly less then d. All surfaces are frictionless. The ball is given a gentle push (towards the right in the figure). The angle made by the radius vector of the ball with the upward vertical is denoted by θ.



(a) Express the total normal reaction force exerted by the spheres on the ball as a function of angle θ.

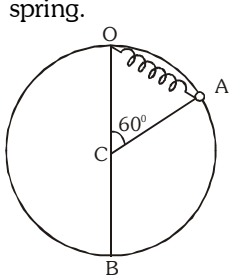
(b) Let N_A and N_B denote the magnitudes of the normal reaction forces on the ball exerted by the spheres A and B, respectively. Sketch the variations of N_A and N_B as function of $\cos\theta$ in the range $0 \le \theta \le \pi$ by drawing two separate graphs in your answer book, taking $\cos\theta$ on the horizontal axis. ***[IIT-JEE 2002]***

57. A park has a radius of 10m. If a vehicle goes round it at an average speed of 18 km/hr , what should be the proper angle of banking?

58. A person stands on a spring balance at the equator. By what fraction is the balance reading less than his true weight ?

59. A body of mass 2 kg is moving under the influence of a central force whose potential energy is given by $U(r) = 2r^3$ J. If the body is moving in a circular orbit of radius 5m, then find its energy.

60. A particle of mass 5 kg is free to slide on a smooth ring of radius r=20 cm fixed in a vertical plane. The particle is attached to one end of a spring whose other end is fixed to the top point O of the ring. Initially the particle is at rest at a point A of the ring such that $\angle OCA = 60^0$, C being the centre of the ring. The natural length of the spring is also equal to r = 20 cm. After the particle is released, it slides down the ring, the contact force between the particle & the ring becomes zero when it reaches the lowest position B. Determine the force constant of the spring.



61. A particle of mass m moves along a circle of radius R with a normal acceleration varying with time as $a_n = bt^2$, where b is a constant. Find the time dependence of the power developed by all the forces acting on the particle, and the mean value of this power averaged over the first t seconds after the beginning of motion.

62. Two particles A and B move anticlockwise with the same speed v in a circle of radius R and are diametrically opposite to each other. At t=0, A is given a constant acceleration (tangential) $a_t = \frac{72v^2}{25\pi R}$. Calculate the time in which A collides with B, the angle traced by A, its angular velocity and radial acceleration at the time of collision.

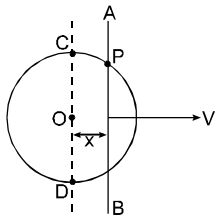
63*. Two blocks of mass m_1 = 10 Kg and m_2 = 5 Kg connected to each other by a massless inextensible string of length 0.3 m are placed along a diameter of turn table. The coefficient of friction between the table and m_1 is 0.5 while there is no friction between m_2 and the table. The table is rotating with an angular velocity of 10 rad/s about a vertical axis passing through its centre O. The masses are placed along the diameter of the table on either side of the centre O such that the mass m_1 is at a distance of 0.124 m from O. The masses are observed to be at rest with respect to an observer on the turn table.

(i) Calculate the frictional force on m_1.

(ii) What should be the minimum angular speed of the turn table so that the masses will slip from this position?

(iii) How should the masses be placed with the string remaining taut so that there is no frictional force acting on the mass m_1 ? (Assuming ω = 10 rad. /s)

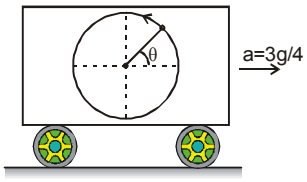
64*. A rod AB is moving on a fixed circle of radius R with constant velocity 'v' as shown in figure. P is the point of intersection of the rod and the circle. At an instant the rod is at a distance $x = \frac{3R}{5}$ from centre of the circle. The velocity of the rod is perpendicular to the rod and the rod is always parallel to the diameter CD.



(a) Find the speed of point of intersection P.

(b) Find the angular speed of point of intersection P with respect to centre of the circle.

65*. A bus is moving with a constant acceleration a = 3g/4 towards right. In the bus, a ball is tied with a rope of length ℓ and is rotated in vertical circle in the train as shown.

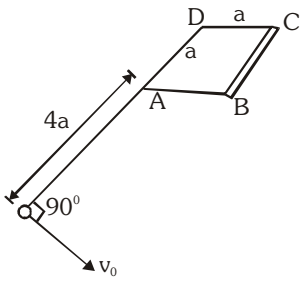


(a) Find at what value of angle θ, tension in the rope will be minimum

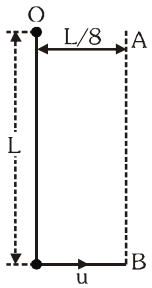
(b) At above mentioned position, find the minimum possible speed V_{min} during whole path to just complete the circular motion :

(c) For above value of V_{min} find maximum tension in the string during circular motion.

66. A square plate is firmly attached to a frictionless horizontal plane. One end of a taut cord is attached to point A of the plate and the other end is attached to a sphere of mass m. In the process, the cord gets wrapped around the plate. The sphere is given an initial velocity v_0 on the horizontal plane perpendicular to the cord which causes it to make a complete circle of the plate and return to point A. Find the velocity of the sphere when it hits point A again after moving in a circle on the horizontal plane. Also find the time taken by the sphere to complete the circle.



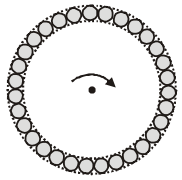
67. A particle is suspended vertically from a point O by an inextensible massless string of length L. A vertical line AB is at a distance $\frac{L}{8}$ from O as shown in figure. The object is given a horizontal velocity u. At some point, its motion ceases to be circular and eventually the object passes through the line AB. At the instant of crossing AB, its velocity is horizontal. Find u.



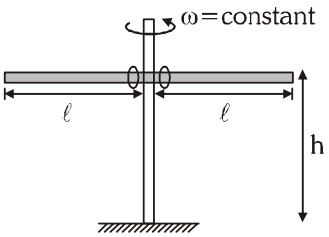
68. Starting from rest, a particle rotates in a circle of radius $R = \sqrt{2}$ m with an angular acceleration $\alpha = \frac{\pi}{4}$ rad/sec^2. Calculate the magnitude of average velocity of the particle over the time it rotates quarter circle.

69. A stone weighing 0.5 kg tied to a rope of length 0.5m revolves along a circular path in a vertical plane. The tension of the rope at the bottom point of the circle is 45 newtons. To what height will the stone rise if the rope breaks at moment the velocity is directed upwards? ($g = 10$ m/s^2)

70. A uniform metallic chain in a form of circular loop of mass m with a length ℓ rotates at the rate of n revolutions per second. Find the tension T in the chain.



71*. Two identical rings which can slide along the rod are kept near the mid point of a smooth rod of length 2ℓ. the rod is rotated with constant angular velocity ω about vertical axis passing through its centre. The rod is at height 'h' from the ground. Find the distance between the points on the ground where the rings will fall after leaving the rods.



72. A particle of mass m is suspended by string of length ℓ from a fixed rigid support. A horizontal velocity $v_0 = \sqrt{3g\ell}$ is imparted to it suddenly. Calculate the angle made by the string with the vertical when the acceleration of the particle is inclined to the string by 45°.

73. A particle moves along the plane trajectory y(x) with velocity v whose modulus is constant. Find the acceleration of the particle at the point x = 0 and the curvature radius of the trajectory at point x = 0, if the trajectory has the form
(a) of a parabola $y = ax^2$. (b) of an ellipse $(x/a)^2 + (y/b)^2 = 1$; a and b are constants here.

74. A point moves in the plane so that its tangential acceleration $\omega_\tau = a$, and its normal acceleration $\omega_n = bt^4$, where a and b are positive constants , and t is time. At the moment t = 0, the point was at rest. Find how the curvature radius R of the point's trajectory and the total acceleration ω depend on the distance covered s.

ANSWERS

- ***True and False***

1. False **2.** False **3.** False **4.** True **5.** False

- ***Assertion–Reason***

6. (A) **7.** (D) **8.** (A)

- ***Single Choice Correct***

9.	(B)	**10.**	(C)	**11.**	(C)	**12.**	(A)	**13.**	(D)
14.	(C)	**15.**	(D)	**16.**	(B)	**17.**	(C)	**18.**	(D)
19.	(B)	**20.**	(C)	**21.**	(D)	**22.**	(A)	**23.**	(A)
24.	(C)	**25.**	(A)	**26.**	(C)				

- ***Multiple Choice Correct***

27. (AC) **28.** (AC) **29.** (ABCD) **30.** (AD) **31.** (D)

- ***Match the Column***

32. (A) P,R (B) P,R (C) Q,S (D) S

- ***Comprehension***

Comprehension 1 :	**33.**	A	**34.**	D	**35.**	C		
Comprehension 2 :	**36.**	D	**37.**	C				
Comprehension 3 :	**38.**	A	**39.**	B				
Comprehension 4 :	**40.**	D	**41.**	C				
Comprehension 5 :	**42.**	A	**43.**	B				
Comprehension 6 :	**44.**	B	**45.**	B	**46.**	B		
Comprehension 7 :	**47.**	B	**48.**	B	**49.**	C	**50.**	C

- ***Subjective Questions***

51. 14.3s,0.45 ms^{-2}

52. (a) $w_0 = a^2\omega^2 / R = 2.6\ m/s^2$, $w_a = a\omega^2 = 3.2\ m/s^2$;

(b) $w_{min} = a\omega^2 \sqrt{1-(R/2a)^2} = 2.5\ m/s^2$, $l_m = \pm a \sqrt{1-(R^2/2a^2)} = \pm 0.37$ m.]

53. (a) $|<F>| = 2\sqrt{2}\ mv^2/\pi R$; (b) $|<F>| = mw_\tau$]

54. $\varepsilon = 1/(x/m\omega^2 - 1)$. Is independent of the rotation direction

55. $r = R/2$, $v_{max} = 1/2\sqrt{kgR}$

56. (a) $N = mg(3\cos\theta - 2)$,

(b) For $\theta \le \cos^{-1}\left(\frac{2}{3}\right)$, $N_B = 0$, $N_A = mg(3\cos\theta - 2)$ and for

$\theta \ge \cos^{-1}\left(\frac{2}{3}\right)$, $N_A = 0$, $N_B = mg(2 - 3\cos\theta)$

57. $\tan^{-1}(1/4)$] **58.** 3.5×10^{-3} **59.** 625 J

60. 500 N/m **61.** mRbt, $\frac{mRbt}{2}$ **62.** $\frac{5\pi R}{6v}, \frac{11\pi}{6}, \frac{17v}{5R}, \frac{289v^2}{25R}$

63. (i) 36 N (ii) 11.67 rad/s (iii) $r_1 = 0.1$ m and $r_2 = 0.2$ m

64. (a) $\frac{5}{4}$ V; (b) $\frac{5V}{4R}$

65. (a) $\theta = 53°$ (b) $\frac{\sqrt{5g\ell}}{2}$ (c) $\frac{15}{2}mg$

66. $v=v_0$, $t = \frac{5\pi a}{v_0}$

67. $u = \sqrt{gL\left(2+\frac{3\sqrt{3}}{2}\right)}$

68. 1 ms^{-1}

69. 1.5 m

70. $T = m\ell n^2$

71. $2\sqrt{y^2+(x+\ell)^2}$, where $x = y = \omega\ell\sqrt{\frac{2h}{g}}$

72. $\alpha = 90°$.

73. (a) acceleration $= 2av^2$, $R = \frac{1}{2a}$ (b) acceleration $= bv^2/a^2$, $R = a^2/b$

74. $R = a^3/2bs$, $\omega = a\sqrt{1+(4bs^2/a^3)^2}$]

True / False

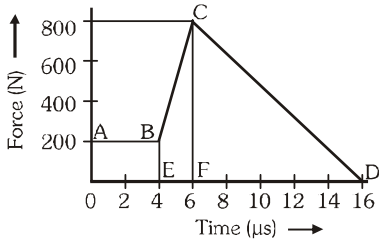
1. In an elastic collision of two bodies, the momentum and energy of each body is conserved.

2. Two particles of mass 1 kg and 3 kg move towards each other under their mutual force of attraction. No other force acts on them. When the relative velocity of approach of the two particles is 2 m/s, their centre of mass has a velocity of 0.5 m/s. When the relative velocity of approach becomes 3 m/s, the velocity of the centre of mass is 0.75 m/s.

Fill in the blanks

3. A particle of mass 4m which is at rest explodes into three fragments. Two of the fragments each of mass m are found to move with a speed v each in mutually perpendicular directions. The total energy released in the process of explosion is .....

4. The magnitude of the force (in newtons) acting on a body varies with time t (in microseconds) as shown in the figure AB, BC and CD are straight line segments. The magnitude of the total impulse of the force on the body from t = 4 μs to t = 16 μs is ..... N–s.



5. A ball of mass 1 g is released down an inclined plane, just describes a circle of radius 10 cm in the vertical plane, on reaching the bottom, the minimum height of the inclined plane is .....cm.

6. Two spheres of masses 3 kg and 2 kg collide directly. Their relative velocity before collision is 15 m/s and after collision is 5 m/s. The total loss of K.E. in joules due to collision is _____.

7. A ball is dropped from height h to the ground. If the coefficient of restitution is 0.8, the height to which ball goes up after it rebounds third time is .....

8. The rate of change of total momentum of a many–particle system is proportional to the ..... on the system.

9. In an inelastic collision of two bodies, the quantities which do not change after the collision are the ..... of the system of two bodies.

Assertion - Reason

These questions contains, Statement 1 (assertion) and Statement 2 (reason).
(A) Statement–1 is True, Statement–2 is True ; Statement–2 is a correct explanation for Statement–1
(B) Statement–1 is True, Statement–2 is True ; Statement–2 is not a correct explanation for Statement–1
(C) Statement–1 is True, Statement–2 is False.
(D) Statement–1 is False, Statement–2 is True.

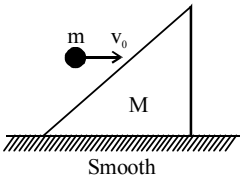
10. ***Statement–1 :*** In case of bullet fired from gun, the ratio of kinetic energy of gun and bullet is equal to ratio of mass of bullet and gun.
and
Statement–2 : In firing, momentum is conserved.

11. ***Statement–1 :*** When a girl jumps from a boat, the boat slightly moves away from the shore.
and
Statement–2 : The total linear momentum of an isolated system remain conserved.

12. ***Statement–1 :*** In a two body collision, the momenta of the particles are equal and opposite to one another, before as well as after the collision when measured in the center of mass frame.
and
Statement–2 : The momentum of the system is zero from the centre of mass frame.

13. ***Statement–1 :*** The centre of mass and centre of gravity of a body are two different positions in general.
and
Statement–2 : The centre of mass and centre of gravity of a body coincide if gravitational field is uniform.

14. ***Statement–1 :*** A particle of mass m strikes a smooth wedge of mass M as shown in the figure. Linear momentum of particle along the inclined surface of wedge is conserved during collision.
and
Statement–2 : Wedge exerts a force on particle perpendicular to inclined face of wedge during collision.



15. ***Statement–1 :*** The coefficient of restitution is less than one for all collisions studied under Newton's laws of restitution.
and
Statement–2 : For a perfectly elastic collision, coefficient of restitution is equal to one.

16. ***Statement–1 :*** No external force acts on system of two spheres which undergo a perfectly elastic head on collision. The minimum kinetic energy of this system is zero if the net momentum of this system is zero.
and
Statement–2 : In any two body system undergoing perfectly elastic head on collision, at the instant of maximum deformation, the complete kinetic energy of the system is converted to deformation potential energy of the system.

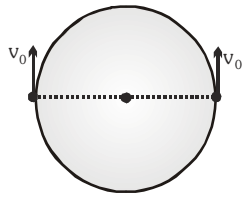
17. ***Statement–1 :*** A sphere of mass m moving with speed u undergoes a perfectly elastic head on collision with another sphere of heavier mass M at rest (M>>>m), then direction of velocity of sphere of mass m is reversed due to collision [no external force acts on system of two spheres]
and
Statement–2 : During a collision of spheres of unequal masses, the heavier exerts more force on lighter mass in comparison to the force which lighter mass exerts on heavier mass.

18. ***Statement–1 :*** If a ball projected up obliquely from the ground breaks up into several fragments in its path, the centre of mass of the system of all fragments move in same parabolic path compared to initial one till all fragments are in air.
and
Statement–2 : In the situation of statement–1, at the instant of breaking, the fragments may be thrown in different directions with different speeds.

Single Choice Correct

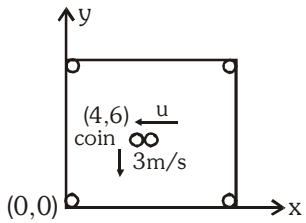
19*. A particle of mass 2m is connected by an inextensible string of length 1.2 m to a ring of mass m which is free to slide on a horizontal smooth rod. Initially the ring and the particle are at the same level with the string taut. Both are then released simultaneously. The distance in meters moved by the ring when the string becomes vertical is
(A) 0 (B) 0.4 (C) 0.8 (D) 1.2

20*. Two particles of mass m, constrained to move along the circumference of a smooth circular hoop of equal mass m, are initially located at opposite ends of a diameter and given equal velocities v_0 shown in the figure. The entire arrangement is located in gravity free space. Their velocity just before collision is



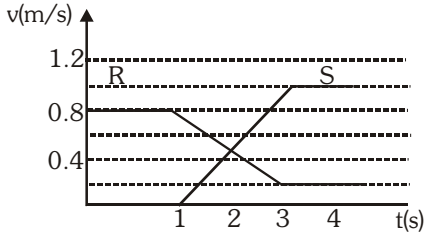
(A) $\frac{1}{\sqrt{3}}v_0$ (B) $\frac{\sqrt{3}}{2}v_0$
(C) $\frac{2}{\sqrt{3}}v_0$ (D) $\frac{\sqrt{7}}{3}v_0$

21*. On a smooth carom board, a coin moving in negative y–direction with a speed of 3 m/s is being hit at the point (4, 6) by a striker moving along negative x–axis. The line joining centres of the coin and the striker just before the collision is parallel to x–axis. After collision the coin goes into the hole located at the origin. Masses of the striker and the coin are equal. Considering the collision to be elastic, the initial and final speeds of the striker in m/s will be–



(A) (1.2, 0) (B) (2, 0)
(C) (3, 0) (D) None of these

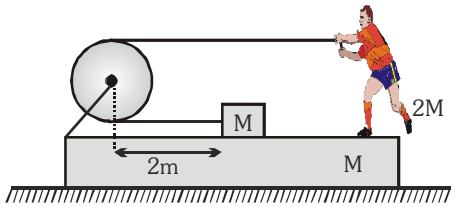
22*. The diagram shows the velocity–time graph for two masses R and S that collided elastically. Which of the following statements is true ?



I. R and S moved in the same direction after the collision
II. The velocities of R and S were equal at the mid time of the collision.
III. The mass of R was greater than mass of S.

(A) I only (B) II only (C) I and II only (D) I, II and III

23*. A block of mass M is tied to one end of a massless rope. The other end of the rope is in the hands of a man of mass 2M as shown in the figure. The block and the man are resting on a rough wedge of mass M as shown in the figure. The whole system is resting on a smooth horizontal surface. The man pulls the rope. Pulley is massless and frictionless. What is the displacement of the wedge when the block meets the pulley. (Man does not leave his position during the pull)

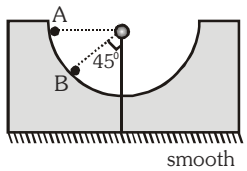


(A) 0.5m (B) 1m (C) Zero (D) 2/3 m

24*. Three particles start from origin at the same time with a velocity $2ms^{-1}$ along positive x–axis, the second with a velocity $6ms^{-1}$ along negative y–axis. Find the velocity of the third particle along x = y line so that the three particles may always lie in a straight line

(A) $-3\sqrt{3}$ (B) $3\sqrt{2}$ (C) $-3\sqrt{2}$ (D) $2\sqrt{2}$

25*. A ball of mass m is released from A inside a smooth wedge of mass m as shown in the figure. What is the speed of the wedge when the ball reaches point B ?



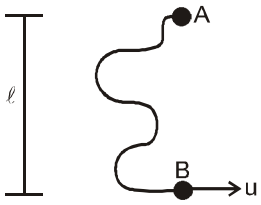
(A) $\left(\frac{gR}{3\sqrt{2}}\right)^{1/2}$ (B) $\sqrt{2gR}$

(C) $\left(\frac{5gR}{2\sqrt{3}}\right)^{1/2}$ (D) $\sqrt{\frac{3}{2}gR}$

26. A stationary body explodes into four identical fragments such that three of them fly off mutually perpendicular to each other, each with same K.E. E_0, energy of explosion will be:

(A) $6E_0$ (B) $\frac{4E_0}{3}$ (C) $4E_0$ (D) $8E_0$

27. Two particles A and B each of mass m are attached by a light inextensible string of length 2ℓ. The whole system lies on a smooth horizontal table with B initially at a distance ℓ from A. The particle at end B is projected across the table with speed u perpendicular to AB. Velocity of ball A just after the jerk is



(A) $\frac{u\sqrt{3}}{4}$ (B) $u\sqrt{3}$

(C) $\frac{u\sqrt{3}}{2}$ (D) $\frac{u}{2}$

28. Two particles A and B initially at rest, move towards each other under the mutual force of attraction. At the instant when the speed of A is v and the speed of B is 2v, the speed of the centre of mass of the system is:–

(A) 3v (B) v (C) 1.5v (D) zero

29. A ball of mass 1 kg drops vertically on to the floor with a speed of 25 m/s. It rebounds with an initial velocity of 10 m/s. What impulse acts on the ball during contact?

(A) 35kg m/s downwards (B) 35 kg m/s upwards
(C) 30 kg m/s downwards (D) 30kg m/s upwards

30. A cannon of mass 5m (including a shell of mass m) is at rest on a smooth horizontal ground, fires the shell with its barrel at an angle θ with the horizontal at a velocity u relative to cannon. Find the horizontal distance of the point where shell strikes the ground from the initial position of the cannon:

(A) $\frac{4u^2 \sin 2\theta}{5g}$ (B) $\frac{u^2 \sin 2\theta}{5g}$ (C) $\frac{3u^2 \sin 2\theta}{5g}$ (D) $\frac{8u^2 \sin 2\theta}{5g}$

31. A body of mass 1 kg strikes elastically with another body at rest and continues to move in the same direction with one fourth of the initial velocity. The mass of the other body is –

(A) 0.6 kg (B) 2.4 kg (C) 3 kg (D) 4 kg

32. A small bucket of mass M kg is attached to a long inextensible cord of length L m . The bucket is released from rest when the cord is in a horizontal position. At its lowest position, the bucket scoops up m kg of water and swings up to a height h. The height h in meters is

(A) $\left(\frac{M}{M+m}\right)^2 L$ (B) $\left(\frac{M}{M+m}\right) L$ (C) $\left(\frac{M+m}{M}\right)^2 L$ (D) $\left(\frac{M+m}{M}\right) L$

33. A ball of mass 2m impinges directly on a ball of mass m, which is at rest. If the velocity with which the larger ball impinges be equal to the velocity of the smaller mass after impact then the coefficient of restitution

(A) $\frac{1}{3}$ (B) $\frac{3}{4}$ (C) $\frac{1}{2}$ (D) $\frac{2}{5}$

34. A body of mass 2kg is projected upward from the surface of the ground at t = 0 with a velocity of 20m/s. One second later a body B, also of mass 2kg, is dropped from a height of 20m. If they collide elastically, then velocities just after collision are

(A) v_A = 5 m/s downward, v_B = 5 m/s upward (B) v_A = 10 m/s downward, v_B= 5 m/s upward
(C) v_A = 10 m/s upward, v_B = 10 m/s downward (D) both move downward with velocity 5 m/s

35. Two objects move in the same direction in a straight line. One moves with a constant velocity v_1 . The other starts at rest and has constant acceleration a. They collide when the second object has velocity $2v_1$. The distance between the two objects when the second one starts moving is

(A) zero (B) $\frac{v_1^2}{2a}$ (C) $\frac{v_1^2}{a}$ (D) $\frac{2v_1^2}{a}$

36. A piece of paper (shown in figure1) is in form of a square. Two corners of this square are folded to make it appear like figure.2 . Both corners are put together at centre of square 'O'. If O is taken to be (0,0), the centre of mass of new system will be at

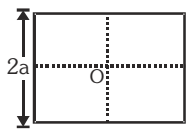


Fig.1

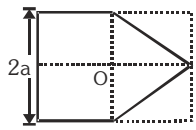


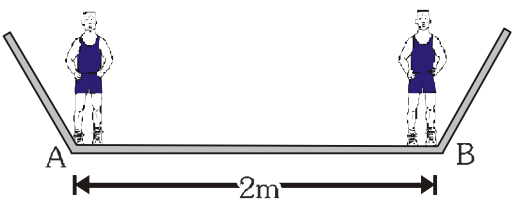
Fig.2

(A) $\left(-\frac{a}{8}, 0\right)$ (B) $\left(-\frac{a}{6}, 0\right)$ (C) $\left(\frac{a}{12}, 0\right)$ (D) $\left(-\frac{a}{12}, 0\right)$

37. A body of mass M moves in outer space with velocity v. It is desired to break the body into two parts so that the mass of one part is one–tenth of the total mass. After the explosion, the heavier part comes to rest while the lighter part continues to move in the original direction of motion. The velocity of the small part will be

(A) v (B) $\left(\frac{v}{2}\right)$ (C) $\left(\frac{v}{10}\right)$ (D) 10 v

38. Two persons A and B of weight 80 kg and 50 kg respectively are standing at opposite ends of a boat of mass 70 kg and length 2m at rest. When they interchange their positions then displacement of the centre of mass of the boat will be:

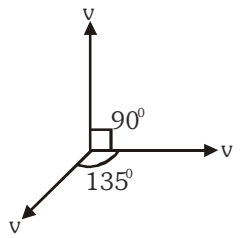


(A) 60 cm towards left (B) 30 cm towards right
(C) 30 cm towards left (D) stationary

39. Two balls of same mass are dropped from the same height onto the floor. The first ball bounces upwards from the floor elastically. The second ball sticks to the floor. The first applies an impulse to the floor of I_1 and the second applies an impulse I_2 . The impulses obey

(A) $I_2 = 2I_1$ (B) $I_2 = \frac{I_1}{2}$ (C) $I_2 = 4I_1$ (D) $I_2 = \frac{I_1}{4}$

40. A particle of mass 4m which is at rest explodes into four equal fragments. All 4 fragments scattered in the same horizontal plane. Three fragments are found to move with velocity v each as shown in the fig. The total energy released in the process of explosion is



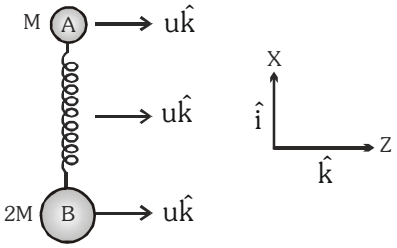
(A) $mv^2 (3-\sqrt{2})$ (B) $mv^2 (3-\sqrt{2})/2$

(C) $2mv^2$ (D $mv^2 (1+\sqrt{2})/2$

41. After scaling a wall of 3 m height a man of weight W drops himself to the ground. If his body comes to a complete stop in 0.15 s. After his feet touch the ground, calculate the average impulsive force in the vertical direction exerted by ground on his feet.

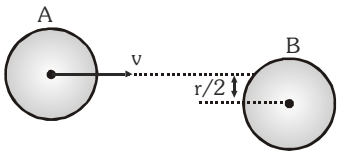
(A) 5W (B) 5.21W (C) 3W (D) 6W

42. Two masses A and B of mass M and 2M respectively are connected by a compressed ideal spring. The system is placed on a horizontal frictionless table and given a velocity $u\hat{k}$ in the z–direction as shown in the figure. The spring is then released. In the subsequent motion the line from B to A always points along the $\hat{i}$ unit vector. At some instant of time mass B has a x–component of velocity as $v_x\hat{i}$. The velocity $\vec{v}_A$ of mass A at that instant is



(A) $v_x\hat{i} + u\hat{k}$ (B) $-v_x\hat{i} + u\hat{k}$ (C) $-2v_x\hat{i} + u\hat{k}$ (D) $2v_x\hat{i} + u\hat{k}$

43. A disk A of radius r moving on perfectly smooth surface at a speed v undergoes an elastic collision with an identical stationary disk B. Find the velocity of the disk B after collision if the impact parameter is r/2 as shown in the figure



(A) $\frac{\sqrt{15}}{4}v$ (B) $\frac{v}{4}$ (C) $\frac{v}{2}$ (D) $\frac{\sqrt{3}v}{2}$

44. Two particles of masses m_1 and m_2 in projectile motion have velocities $\vec{v}_1$ and $\vec{v}_2$ respectively at time t = 0. They collide at time t_0. Their velocities become $\vec{v}'_1$ and $\vec{v}'_2$ at time $2t_0$ while still moving in air. The value of: $[(m_1\vec{v}'_1 + m_2\vec{v}'_2) - (m_1\vec{v}_1 + m_2\vec{v}_2)]$ is :– ***[IIT-JEE 2001]***

(A) zero (B) $(m_1 + m_1)gt_0$ (C) $2(m_1 + m_2)gt_0$ (D) $\frac{1}{2}(m_1 + m_2)gt_0$

45. Two blocks of masses 10 kg and 4 kg are connected by a spring of negligible mass and placed on a frictionless horizontal surface. An impulse gives a velocity of 14 m/s to the heavier block in the direction of the lighter block. The velocity of the centre of mass is :– ***[IIT-JEE 2002]***

(A) 30 m/s (B) 20 m/s (C) 10 m/s (D) 5 m/s

46*. For a two-body system in absence of external forces, the kinetic energy as measured from ground frame is K_o and from center of mass frame is K_{cm}. Pick up the wrong statement
(A) The kinetic energy as measured from center of mass frame is least
(B) Only the portion of energy K_{cm} can be transformed from one form to another due to internal changes in the system.
(C) The system always retains at least $K_o - K_{cm}$ amount of kinetic energy as measured from ground frame irrespective of any kind of internal changes in the system.
(D) The system always retains at least K_{cm} amount of kinetic energy as measured from ground frame irrespective of any kind of internal changes in the system

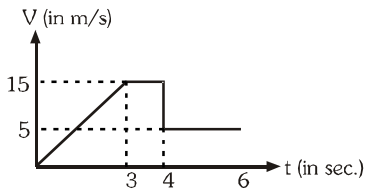
Multiple Choice Correct

47. A ball hits the floor and rebounds after an inelastic collision. In this case : ***[IIT-JEE 1986]***
(A) the momentum of the ball just after the collision is the same as that just before the collision
(B) the mechanical energy of the ball remains the same in the collision
(C) the total momentum of the ball and the earth is conserved
(D) the total energy of the ball and the earth is conserved

48*. The Fig. shows a string of equally placed beads of mass m, separated by distance d. The beads are free to slide without friction on a thin wire. A constant force F acts on the first bead initially at rest till it makes collision with the second bead. The second bead then collides with the third and so on. Suppose that all collisions are elastic,

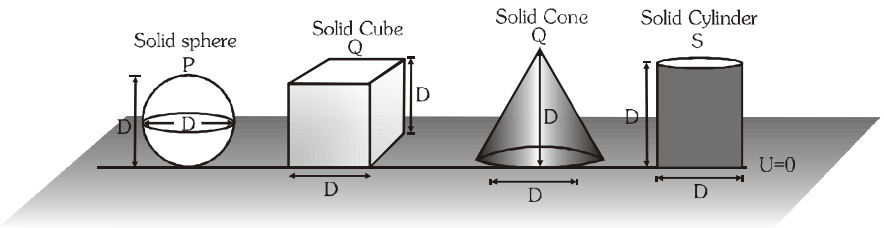
(A) Speed of the first bead immediately before and immediately after its collision with the second bead is $\sqrt{\frac{2Fd}{m}}$ and zero respectively.
(B) Speed of the first bead immediately before and immediately after its collision with the secondbead is $\sqrt{\frac{2Fd}{m}}$ and $\frac{1}{2}\sqrt{\frac{2Fd}{m}}$ respectively.
(C) Speed of the second bead immediately after its collision with third bead is zero.
(D) The average speed of the first bead during it's motion is $\frac{1}{2}\sqrt{\frac{2Fd}{m}}$.

49. The fig. shows the velocity as a function of the time for an object with mass 10 kg being pushed along a frictionless surface by external force. At t= 3s, the force stops pushing and the object moves freely. It then collides head on and sticks to another object of mass 25 kg.



(A) External force acting on the system is 50 N
(B) Velocity of the 2nd particle just before the collision is 1 m/s
(C) Before collision both bodies are moving in the same direction
(D) Before collision, bodies are moving in opposite direction with respect to each other

50. Assuming potential energy 'U' at ground level to be zero.



All objects are made up of same material.
U_P = Potential energy of solid sphere
U_Q = Potential energy of solid cube
U_R = Potential energy of solid cone
U_S = Potential energy of solid cylinder
(A) $U_S > U_P$ (B) $U_Q > U_S$ (C) $U_P > U_Q$ (D) $U_S > U_R$

51. A bag of mass M hangs by a long thread and a bullet (mass m) comes horizontally with velocity v and gets caught in the bag. Then for the combined system (bag + bullet) :
(A) Momentum is mMv/(M + m)
(B) kinetic energy is $(1/2)\,Mv^2$
(C) Momentum is mv
(D) kinetic energy is $m^2v^2/2(M + m)$

52. A body has its centre of mass at the origin. The x-coordinates of the particles
(A) may be all positive
(B) may be all negative
(C) may be all non-negative
(D) may be positive for some cases and negative in other cases

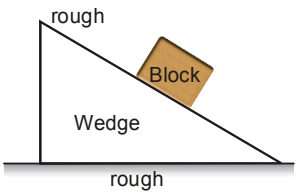
53. In which of the following cases the centre of mass of a rod is certainly not at its centre ?
(A) the density continuously increases from left to right
(B) the density continuously decreases from left to right
(C) the density decreases from left to right upto the centre and then increases
(D) the density increases from left to right upto the centre and then decreases

54. If a ball is thrown upwards from the surface of earth:
(A) The earth remains stationary while the ball moves upwards
(B) The ball remains stationary while the earth moves downwards
(C) The ball and earth both moves towards each other
(D) The ball and earth both move away from each other

55. If the external forces acting on a system have zero resultant, the centre of mass
(A) must not move
(B) must not accelerate
(C) may move
(D) may accelerate

56. A body moving towards a finite body at rest collides with it. It is possible that
(A) both the bodies come to rest
(B) both the bodies move after collision
(C) the moving body comes to rest and the stationary body starts moving
(D) the stationary body remains stationary, the moving body changes its velocity.

57*. When a block is placed on a wedge as shown in figure, the block starts sliding down and the wedge also start sliding on ground. All surfaces are rough. The centre of mass of (wedge + block) system will move
(A) leftward and downward.
(B) right ward and downward.
(C) leftward and upwards.
(D) only downward.



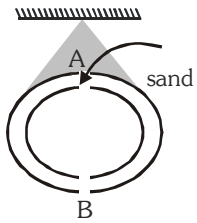
58*. A ball is projected from a point in one of the two smooth parallel vertical walls against the other in a plane perpendicular to both after being reflected at each wall impinge again on the second at a point in the same horizontal plane as is started. The distance between two walls is a,b is the free range on a horizontal plane and e be the coefficient of restitution
(A) The total time taken in moving from O to C is $\frac{a}{e^2u}(e^2 + e + 1)$
(B) The free range on the horizontal plane $b = \frac{2uv}{g}$
(C) $be^2 = a(e^2 + e + 1)$
(D) All above options are correct

59. A ball hits the floor and rebounds after an inelastic collision. In this case :–
(A) the momentum of the ball just after the collision is the same as that just before the collision
(B) the mechanical energy of the ball remains the same in the collision
(C) the total momentum of the ball and the earth is conserved
(D) the total energy of the ball and the earth is conserved

60. Two particles A and B start moving due to their mutual interaction only. If at any time 't', $\vec{a}_A$ and $\vec{a}_B$ are their respective accelerations, $\vec{v}_A$ and $\vec{v}_B$ are their respective velocities, and upto that time W_A and W_B are the work done on A and B respectively by the mutual force, m_A and m_B are their masses respectively, then which of the following is always correct.

(A) $\vec{v}_A + \vec{v}_B = 0$ (B) $m_A\vec{v}_A + m_B\vec{v}_B = 0$ (C) $W_A + W_B = 0$ (D) $\vec{a}_A + \vec{a}_B = 0$

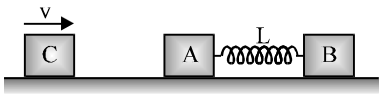
61. A uniform metallic spherical shell is suspended from ceiling. It has two holes A and B at top and bottom respectively. Which of the following is/are true:



(A) If B is closed and sand is poured from A, centre of mass first rises and then falls
(B) If shell is completely filled with sand and B is opened then centre of mass falls initially
(C) If shell is slightly filled with sand and B is opened, then centre of mass falls.
(D) None of these

62. In head on elastic collision of two bodies of equal masses
(A) the velocities are interchanged
(B) the speeds are interchanged
(C) the momenta are interchanged
(D) the faster body slows down and the slower body speeds up.

63. Two blocks A and B each of mass m, are connected by a massless spring of natural length L and spring constant k. The blocks are initially resting on a smooth horizontal floor with the spring at its natural length, as shown in figure. A third identical block C, also of mass m, moves on the floor with a speed v along the line joining A and B, and collides elastically with A. Then : ***[IIT-JEE 1993]***



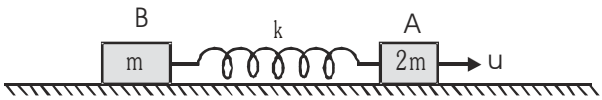
(A) the kinetic energy of the A-B system, at maximum compression of the spring, is zero
(B) the kinetic energy of the A-B system, at maximum compression of the spring, is $mv^2/4$
(C) the maximum compression of the spring is $v\sqrt{m/K}$
(D) the maximum compression of the spring is $v\sqrt{\frac{m}{2K}}$

Match the Column

64.

	Column I		***Column II***
(A)	Elastic collision	(p)	KE is conserved
(B)	Inelastic collision	(q)	KE after collision = KE before collision
(C)	Perfectly inelastic collision	(r)	KE after collision ≠ KE before collision
		(s)	Particles stick after collision
		(t)	Linear momentum is conserved
		(u)	Relative velocity of separation after is zero

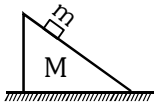
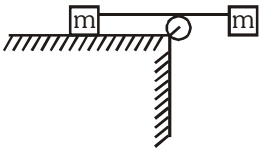
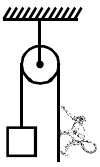
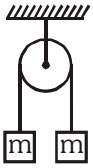
65*. Two blocks A and B of mass 2m and m respectively are connected by a massless spring of spring constant k. This system lies over a smooth horizontal surface. At t = 0 the block A has velocity u towards right as shown while the speed of block B is zero, and the length of spring is equal to its natural length at that instant. In each situation of column–I, certain statements are given and corresponding results are given in column II.



smooth horizontal surface

	Column I		***Column II***
(A)	The velocity of block A	(p)	Can never be zero
(B)	The velocity of block B	(q)	May be zero at certain instants of time
(C)	The kinetic energy of system of two blocks	(r)	is minimum at maximum compression of spring
(D)	The potential energy of spring	(s)	Is maximum at maximum extension of spring

66*. In each situation of column–I, a system involving two bodies is given. All strings and pulleys are light and friction is absent everywhere. Initially each body of every system is at rest. Consider the system in all situation of column I from rest till any collision occurs. Then match the statements in column – I with the corresponding results in column–II

	Column I			***Column II***
(A)	The block plus wedge system is placed over smooth horizontal surface. After the system is released from rest, the centre of mass of system		(p)	Shifts towards right
(B)	The string connecting both the blocks of mass m is horizontal. Left block is placed over smooth horizontal table as shown. After the two block system is released from rest, the centre of mass of system		(q)	Shifts downwards
(C)	The block and monkey have same mass. The monkey starts climbing up the rope. After the monkey starts climbing up, the centre of mass of monkey + block system		(r)	Shifts upwards
(D)	Both block of mass m are initially at rest. The left block is given initial velocity u downwards. Then, the centre of mass of two block system afterwards		(s)	Does not shift

67. Two balls of mass m and 2m each have momentum 2p and p in the direction shown in figure. During collision they exert an impulse of magnitude p on each other.

	Column I		***Column II***
(A)	After collision momentum of m	(p)	2p
(B)	After collision momentum of 2m	(q)	p
(C)	Coefficient of restitution between them	(r)	1
		(s)	None

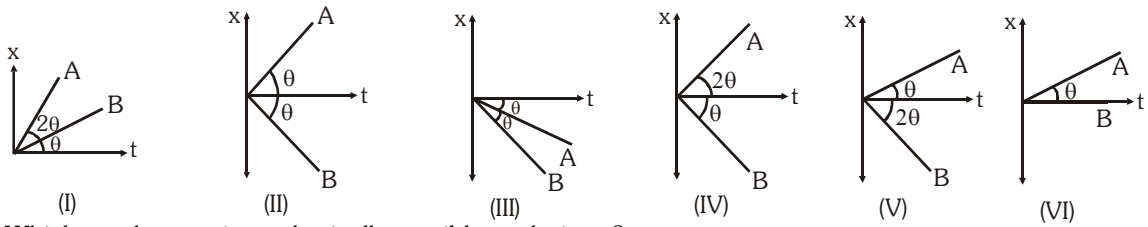
68. If net force on a system of particles is zero, then

	Column I		***Column II***
(A)	Acceleration of centre of mass	(p)	Constant
(B)	Velocity of centre of mass	(q)	Zero
(C)	Momentum of centre of mass	(r)	May be zero
(D)	Velocity of an individual particle of the system	(s)	May be constant

Comprehension

Comprehension-1

An initially stationary box on a frictionless floor explodes into two pieces, piece A with mass m_A and piece B with mass m_B. Two pieces then move across the floor along x–axis. Graph of position versus time for the two pieces are given.



69. Which graphs pertain to physically possible explosions ?
(A) II, V (B) VI (C) I, III (D) IV

70. Based on the above question, Match column A with the column B.

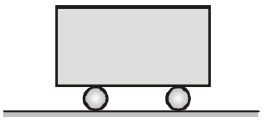
Column A	***Column B (Graph number)***
(P) $m_A = m_B$	I
(Q) $m_A > m_B$	II
(R) $m_A < m_B$	III
	IV
	V
	VI

(A) P – VI, Q – III, R – I (B) P – II, Q – V, R – IV
(C) P – II, Q – IV, R – V (D) P – VI, Q – II, R – IV

71. If all the graphs are possible then, in which of the following cases external force must be acting on the box :-
(A) II (B) V (C) VI (D) I

Comprehension-2*.

When the mass of a system is variable, a thrust force has to be applied on it in addition to all other forces acting on it. This thrust force is given by : $\vec{F} = \vec{v}_r\left(\pm\frac{dm}{dt}\right)$



Here $\vec{v}_r$ is the relative velocity with which the mass dm either enters or leaves the system. A car has total mass 50 kg. Gases are ejected from this backwards with relative velocity 20 m/s. The rate of ejection of gas is 2 kg/s. Total mass of gas is 20 kg. Coefficient of friction between the car and road is $\mu = 0.1$.

72. Car will start moving after time t = ... second :
(A) 4 (B) 10 (C) 5 (D) 8

73. Maximum speed of car will be v = ... m/s : (Take $\ell n\,\frac{4}{3} = 0.28$)
(A) 0.6 (B) 0.8 (C) 1.0 (D) 1.2

74. Car will stop after (from starting) t = ... seconds :
(A) 12.2 (B) 6.4 (C) 10.6 (D) 5.8

Comprehension-3

One particle of mass 1 kg is moving along positive x–axis with velocity 3 m/s. Another particle of mass 2 kg is moving along y–axis with 6 m/s. At time t = 0, 1 kg mass is at (3m, 0) and 2 kg at (0, 9m), x–y plane is the horizontal plane. (Surface is smooth for question 1 and rough for question 2 and 3)

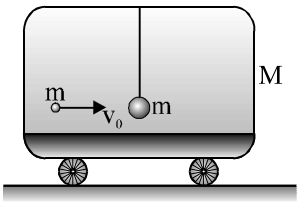
75. The centre of mass of the two particles is moving in a straight line which equation is :
(A) y = x + 2 (B) y = 4x + 2
(C) y = 2x – 4 (D) y = 2x + 4

76. If both the particles have the same value of coefficient of friction $\mu = 0.2$. The centre of mass will stop at time t = ...s :
(A) 1.5 (B) 4.5 (C) 3.0 (D) 2.0

77. Co–ordinates of centre of mass where it will stop finally are :–
(A) (2.0 m, 14.25 m) (B) (2.25 m, 10 m)
(C) (3.75 m, 9 m) (D) (1.75 m, 12 m)

Comprehension-4*.

A ball of mass m = 1 kg is hung vertically by a thread of length $\ell = 1.50$ metre. Upper end of the thread is attached to the ceiling of a trolley of mass M = 4 kg. Initially, trolley is stationary and it is free to move along horizontal rails without friction. A shell of mass m = 1 kg, moving horizontally with velocity $v_0 = 6$ m/s, collides with the ball and gets stuck with it. As a result, thread starts to deflect towards right. ($g = 10$ m/s^2)



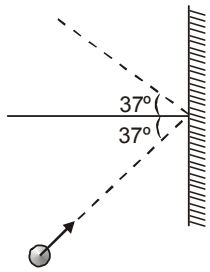
78. Velocity of combined mass 2m just after collision is :
(A) 3 m/sec (B) 6 m/sec (C) 1 m/sec (D) 1.5 m/sec

79. Velocity of the trolley, at the time of maximum deflection of the ball is :
(A) 3 m/sec (B) 6 m/sec (C) 1 m/sec (D) 1.5 m/sec

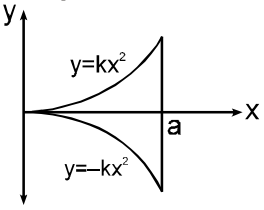
80. Maximum inclination of thread with the vertical is :
(A) 30° (B) 37° (C) 45° (D) 53°

Subjetive Questions

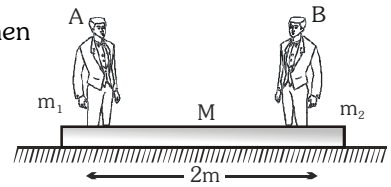
81*. A particle moving on a smooth horizontal surface strikes a stationary wall. The angle of strike is equal to the angle of rebound & is equal to 37° and the coefficient of restitution with wall is $e = \frac{1}{5}$. Find the friction coefficient between wall and the particle in the form $\frac{X}{10}$ and fill value of X.:



82*. A thin sheet of metal of uniform thickness is cut into the shape bounded by the line x = a and $y = \pm kx^2$, as shown. Find the coordinates of the centre of mass.

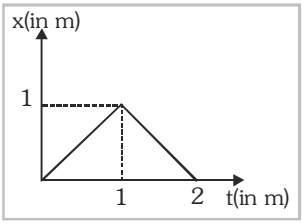


83. In the figure shown, when the persons A and B exchange their positions, then
(i) the distance moved by the centre of mass of the system is _____.
(ii) the plank moves toward _____.
(iii) the distance moved by the plank is ____.
(iv) the distance moved by A with respect to ground is _____.
(v) the distance moved by B with respect to ground is __.



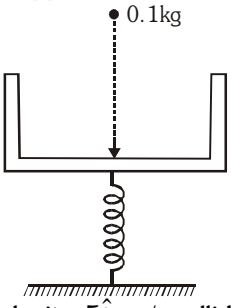
$m_1 = 50$kg; $m_2 = 70$kg; M = 80kg

84. 2 bodies m_1 & m_2 of mass 1 and 2 kg respectively are moving along x–axis under the influence of mutual force only. The velocity of their centre of mass at a given instant is 2 m/s. The x–coordinate of m_1 is plotted against time. Then plot the x–coordinate of m_2 against time (Both are located at origin).



85. A ball of mass 100 g is projected vertically upwards from the ground with a velocity of 49m/s. At the same time another identical ball is dropped from a height of 98 m to fall freely along the same path as that followed by the first ball. After some time the two balls collide and stick together and finally fall to the ground. Find the time of flight of the masses.

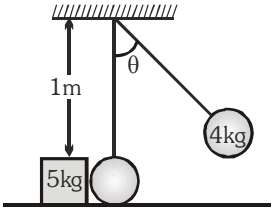
86. A massless platform is kept on a light elastic spring, shown in Fig. When a sand particle of 0.1 kg mass is dropped on the pan from a height 0.24 m, the particle strikes the pan, and the spring compresses by 0.01 m. From what height should the particle be dropped to cause a compression of 0.04 m ?



87. A particle of mass 2 kg moving with a velocity $5\hat{i}$ m/s collides head–on with another particle of mass 3 kg moving with a velocity $-2\hat{i}$ m/s. After the collision the first particle has speed of 1.6 m/s in negative x direction. Find :
(i) Velocity of the centre of mass after the collision
(ii) Velocity of the second particle after the collision
(iii) Coefficient of restitution.

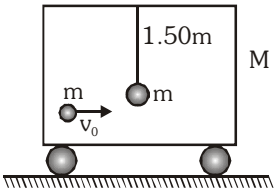
88. A bullet of mass M is fired with a velocity 50 m/s at an angle θ with the horizontal. At the highest point of its trajectory, it collides head–on with a bob of mass 3M suspended by a massless string of length $\frac{10}{3}$ metres and gets embedded in the bob, after the collision the string moves through an angle of 120°. Find :
(i) the angle θ,
(ii) the vertical and horizontal coordinates of the initial position of the bob with respect to the point of firing of the bullet. (Take g = 10 m/s^2).

89. The 4 kg sphere from rest when θ =60° strikes a block mass of 5 kg placed on a rough horizontal plane and comes to rest after collision. The 5 kg block comes to rest after moving a distance of 0.8m. Find μ of ground & block & coefficient of restitution e.

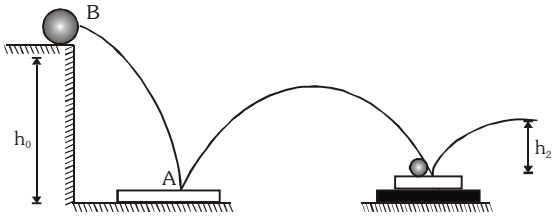


90. After a completely inelastic collision two objects of the same mass and same initial speed are found to move away together at half their initial speed. Find the angle between the initial velocities of the objects.

91. A ball of mass m=1 kg is hung vertically by a thread ℓ=1.50 m. Upper end of the thread is attached to the ceiling of a trolley of mass M = 4 kg. Initially, trolley is stationary and it free to move along horizontal rails without friction. A shell of mass m = 1 kg moving horizontally with velocity v_0=6 ms^{-1} collides with the ball and gets stuck with it. As a result, thread starts to deflected towards right. Calculate its maximum deflection with the vertical. (g = 10 ms^{-2})

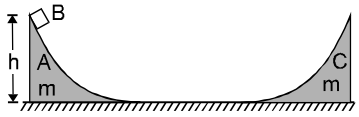


92. A 70 g ball B dropped from a height h_0 = 9 m reaches a height h_2 = 0.25 m after bouncing twice from identical 210 g plates. Plate A rests directly on hard ground, while plate C rests on a foam –rubber mat. Determine.

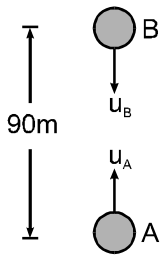


(i) the coefficient of restitution between the ball and the plates,
(ii) the height h_1 of the ball's first bounce.

93. In the figure shown a small block B of mass m is released from the top of a smooth movable wedge A of the same mass m. The height of wedge A shown in figure is h = 100 cm. B ascends another movable smooth wedge C of the same mass. Neglecting friction any where the maximum height (in cm) attained by block B on wedge C is 20 + h . Find h :

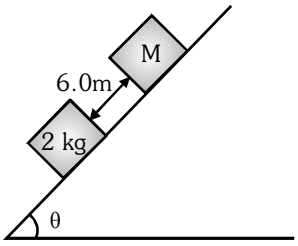


94. Two particles A and B of masses 1 kg and 2 kg respectively are projected in the same vertical line as shown in figure with speeds $u_A = 200$ m/s and $u_B = 85$ m/s respectively. Initially they were 90 m apart. Find the maximum height attained by the centre of mass of the system of particles A and B, from the initial position of centre of mass of the system. Assume that none of these particles collides with the ground in that duration Take g = 10 m/s^2.

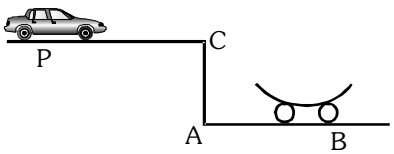


95. Two blocks of mass 2 kg and M are at rest on an inclined plane and are separated by a distance of 6.0 m as shown. The coefficient of friction between each block and the inclined plane is 0.25. The 2 kg block is given a velocity of 10.0 m/s up the inclined plane. It collides with M, comes back and has a velocity of 1.0 m/s when it reaches its initial position. The other block M after the collision moves 0.5 m up and comes to rest. Calculate the coefficient of restitution between the blocks and the mass of the block M. (Take $\sin\theta \approx \tan\theta = 0.05$ and g = 10 m/s^2)

[IIT-JEE 1999]



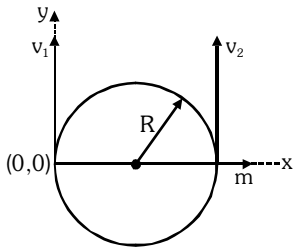
96*. A car P is moving with a uniform speed of $5\sqrt{3}$ m/s towards a carriage of mass 9 kg at rest kept on the rails at a point B as shown in figure. The height AC is 120 m. Cannon balls of 1 kg are fired from the car with an initial velocity 100 m/s at an angle 30° with the horizontal. The first cannon balls hits the stationary carriage after a time t_0 and sticks to it. Determine t_0.



At t_0, the second cannon ball is fired. Assume that the resistive force between the rails and the carriage is constant and ignore the vertical motion of the carriage throughout. If the second ball also hits and sticks of the carriage, what will be the horizontal velocity of the carriage just after the second impact? ***[IIT-JEE 2001]***

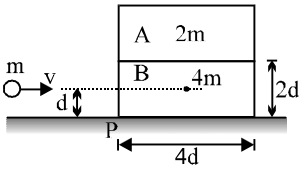
97*. A particle of mass m, moving in a circular path of radius R with a constant speed v_2 is located at point (2R, 0) at time t = 0 and a man starts moving with a velocity v_1 along the positive y–axis from origin at time t = 0. Calculate the linear momentum of the particle w.r.t. man as a function of time.

[IIT-JEE 2003]



98*. Two point masses m_1 and m_2 are connected by a spring of natural length ℓ_0. The spring is compressed such that the two point masses touch each other and then they are fastened by a string. Then the system is moved with a velocity v_0 along positive x–axis. When the system reaches the origin the string breaks (t = 0). The position of the point mass m_1 is given by $x_1 = v_0t - A(1-\cos\omega t)$ where A and ω are constants. Find the position of the second block as a function of time. Also find the relation between A and ℓ_0. ***[IIT-JEE 2003]***

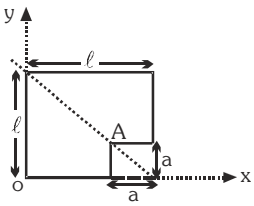
99. A block A of mass 2m is placed on another block B of mass 4m which in turn is placed on a fixed table. The two blocks have a same length 4d and they are placed as shown in figure. The coefficient of friction (both static and kinetic) between the block B and table is μ. There is no friction between the two blocks. A small object of mass m moving horizontally along a line passing through the centre of mass (CM) of the block B and perpendicular to its face with a speed v collides elastically with the block B at a height above the table.



(a) What is the mimimum value of v (call it v_0) required to make the block A topple?
(b) If $v = 2v_0$, find the distance (from the point P in the figure) at which the mass m falls on the table after collision. (Ignore the role of friction during the collision). ***[IIT-JEE 1991]***

100. A particle of mass 2 kg moving with a velocity $5\hat{i}$ m/s collides head - on with another particle of mass 3 kg moving with a velocity $-2\hat{i}$ m/s. After the collision the first particle has a speed of $-1.6\hat{i}$ m/s. Find
(a) velocity of the centre of mass after the collision.
(b) velocity of the second particle after the collision.
(c) coefficient of restitution.

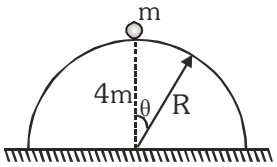
101. The figure shows a square metal plate of side ℓ from which a square plate of side a has been cut as shown in the figure. Find the ratio (a/ℓ) so that the centre of mass of the remaining L–shaped plate coincides with the point A .



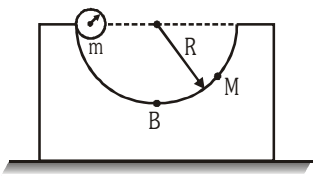
102*. A man whose mass is m kg jumps vertically into air from a sitting position in which his centre of mass is at a height h_1 from the ground. When his feet are just about to leave the ground his centre of mass is h_2 from the ground and finally rises to h_3 when he is at the top of the jump. What is the average upward force exerted by the ground on him?

103. A uniform thin rod of mass M and length L is standing vertically along the y–axis on a smooth horizontal surface, with its lower end at the origin (0, 0). A slight disturbance at t = 0 causes the lower end to slip on the smooth surface the positive x–axis, and the rod starts falling.
(i) What is the path followed by the centre of mass of the rod during its fall ?
(ii) Find the equation of the trajectory of a point on the rod located at a distance r from the lower end. What is the shape of the path of this point ?

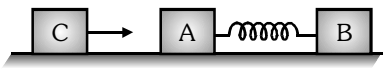
104*. A hemisphere of radius R and of mass 4m is free to slide with its base on a smooth horizontal table. A particle of mass m is placed on the top of the hemisphere. Find the angular velocity of the particle relative to hemisphere an angular displacement θ when velocity of hemisphere has become v.



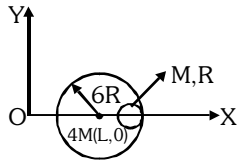
105*. A block of mass M with a semicircular track of radius R, rests on a horizontal frictionless surface. A uniform cylinder of radius r and mass m is released from rest at the top point A (see Fig). The cylinder slips on the semicircular frictionless track. How far has the block moved when the cylinder reaches the bottom (point B) of the track ? How fast is the block moving when the cylinder reaches the bottom of the track ?



106. Two bodies A and B of masses m and 2m respectively are placed on a smooth floor. They are connected by a spring. A third body C of mass m moves with velocity v_0 along the line joining A and B and collides elastically with A as shown in fig. At a certain instant of time t_0 after collision, it is found that the instantaneous velocities of A and B are the same. Further at this instant the compression of the spring is found to be x_0. Determine –
(i) the common velocity of A and B at time t_0 and
(ii) the spring constant.

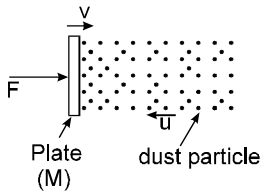


107. A small sphere of radius R is held against the inner surface of a larger sphere of radius 6R. The masses of large and small spheres are 4M and M respectively. This arrangement is placed on a horizontal table. There is no friction between any surfaces of contact. The small sphere is now released. Find the co–ordinates of the centre of the larger sphere when the smaller sphere reaches the other extreme position.



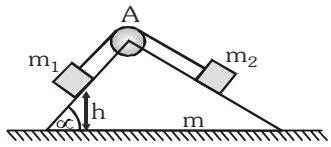
108. A body 'A' moving in a straight line with velocity v makes a collision with a body 'B' initially at rest. After collision, B acquires a velocity of 1.6 v. Assuming the bodies to be perfectly elastic, what is the ratio of the mass of A to that of B? What percentage of A's energy is transferred to B as a result of collision.

109. A plate of mass M is moved with constant velocity v against dust particles moving with velocity u in opposite direction as shown. The density of the dust is ρ and plate area is A. Find the force F required to keep the plate moving uniformly. (ρ in kg /m^3)



110. An object of mass 5 kg is projected with a velocity of 20 m/s at an angle of 60° to the horizontal. At the highest point of its path the projectile explodes and breaks up into two fragments of masses 1 kg and 4 kg. The fragments separate horizontally after the explosion. The explosion releases internal energy such that the kinetic energy of the system at the highest point is doubled. Calculate the separation between the two fragments when they reach the ground.

111*. Two blocks of masses m_1 and m_2 are connected by a massless pulley A, slides along the smooth sides of a rectangular wedge of mass m, which rests on a smooth horizontal plane. Find the distance covered by the wedge on the horizontal plane till the mass m_1 is lowered by the vertical distance h.



112*. Two particles A and B of mass 2m and m respectively are attached to the ends of a light inextensible string of length 4a which passes over a small smooth peg at a height 3a from an inelastic table. The system is released from rest with each particle at a height a from the table. Find–

(i) The speed of B when A strikes the table.

(ii) The time that elapses before A first hits the table.

(iii) The time for which A is resting on the table after the first collision & before it is first jerked off.

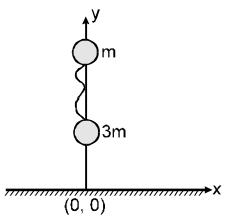
113*. Two particles, each of mass m, are connected by a light inextensible string of length 2ℓ. Initially they lie on a smooth horizontal table at points A and B distant ℓ apart. The particle at A is projected across the table with velocity u. Find the speed with which the second particle begins to move if the direction of u is :-

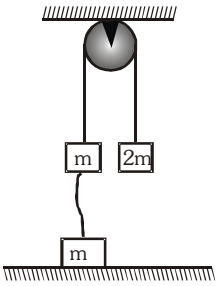
(i) along BA, (ii) at an angle of 120° with AB

(iii) perpendicular to AB. In each case calculate (in terms of m and u) the impulsive tension in the string.

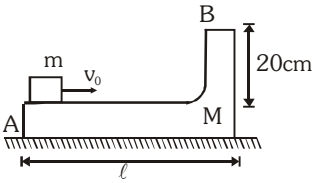
114*. A cylindrical solid of mass 10^{-2} kg and cross–sectional area 10^{-4} m^2 is moving parallel to its axis (the x–axis) with a uniform speed of 10^3 m/s in the positive direction. At t = 0, its front face passes the plane x = 0. The region to the right of this plane is filled with the dust particle of uniform density 10^{-3} kg/m^3. When a dust particles collides with the face of the cylinder, it sticks to its surface. Assuming that the dimensions of the cylinder remain practically unchanged and that the dust sticks only to the front face of the cylinder find the x–coordinate of the front of the cylinder at t = 150 s.

115. A coordinate axis system taking x-axis as horizontal smooth floor is shown in figure. Two small balls of masses m and 3m attached with a string are released from some heights on y-axis as shown in figure. The balls may collide head on or obliquely. After a certain time mass m is at (9 cm, 20 cm) while mass 3m is 25 cm above the x axis and the strings is taut. The balls always remain in x-y plane. Find the length of string.

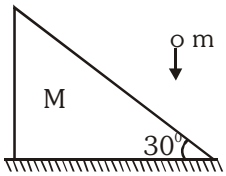




116*. The Atwood machine in figure has a third mass attached to it by a limp string. After being released, the 2m mass falls a distance x before the limp string becomes taut. Thereafter both the mass on the left rise at the same speed. What is the final speed? Assume that pulley is ideal.



117*. A wedge of mass M=2m rests on a smooth horizontal plane. A small block of mass m rests over it at left end A as shown in figure. A sharp impulse is applied on the block, due to which it starts moving to the right with velocity $v_0 = 6\ ms^{-1}$. At highest point of its trajectory, the block collides with a particle of same mass m moving vertically downwards with velocity $v = 2\ ms^{-1}$ and gets stuck with it. If the combined body lands at the end point A of body of mass M, calculate length ℓ. Neglect friction ($g = 10\ ms^{-2}$)



118*. A ball of mass m = 1 kg falling vertically with a velocity v_0 = 2 m/s strikes a wedge of mass M = 2 kg kept on a smooth, horizontal surface as shown in figure. The coefficient of resitution between the ball and the wedge is e = 1/2. Find the velocity of the wedge and the ball immediately after collision.

ANSWERS

- ***True and False***

1. False **2.** False

- ***Fill in the Blanks***

3. $\frac{3mv^2}{2}$ **4.** 5×10^{-3} **5.** 25 **6.** 120 **7.** $(0.8)^6$h

8. External force **9.** Linear momentum

- ***Assertion–Reason***

10.	A	**11.**	A	**12.**	A	**13.**	B	**14.**	A
15.	B	**16.**	C	**17.**	C	**18.**	B		

- ***Single Choice Correct***

19.	C	**20.**	D	**21.**	B	**22.**	D	**23.**	A
24.	B	**25.**	A	**26.**	A	**27.**	A	**28.**	D
29.	B	**30.**	A	**31.**	A	**32.**	A	**33.**	C
34.	A	**35.**	A	**36.**	D	**37.**	D	**38.**	C
39.	B	**40.**	A	**41.**	B	**42.**	C	**43.**	A
44.	C	**45.**	C	**46.**	D				

- ***Multiple Choice Correct***

47.	CD	**48.**	ACD	**49.**	ABC	**50.**	ABD	**51.**	CD
52.	CD	**53.**	AB	**54.**	D	**55.**	BC	**56.**	BC
57.	B	**58.**	ABCD	**59.**	C	**60.**	B	**61.**	B
62.	ABCD	**63.**	BD						

- ***Match the Column***

64. A–q,t, B–r,t, C–r,s,t,u **65*.** A–p, B–q, C–p, D–q,s

66*. A–q, B–p, q, C–r, D–s **67.** A–q, B–p, C–s

68. A–q, B–p,r, C–p,r, D–r,s

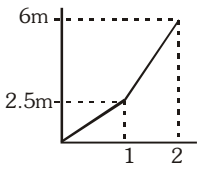
- ***Comprehension***

Comprehension-1 :	**69.**	(AD)	**70.**	(B)	**71.**	(CD)
Comprehension-2 :	**72.**	(C)	**73.**	(A)	**74.**	(C)
Comprehension-3 :	**75.**	(B)	**76.**	(C)	**77.**	(D)
Comprehension-4 :	**78.**	(A)	**79.**	(C)	**80.**	(B)

- ***Subjective Questions***

81. 5 **82.** $\frac{3}{4}a$ **83.** (i) zero (ii) right (iii) 0.2 m (iv) 2.2 m (v) 1.8 m

84.



85. 4.53 s **86.** 3.96 m

87. (i) $0.8\hat{i}$ ms^{-1} (ii) $2.4\hat{i}$ ms^{-1}(iii) 4/7 **88.** (i) 37^0 (ii) (120, 45)

89. $e=0.8$, $\mu=0.4$ **90.** 120^0 **91.** 37^0

92. (i) 0.66 (ii) 4 m **93.** 5 **94.** 5 m **95.** $e = 0.84$, M = 15.21 kg

96. 12 s, 15.75 ms^{-1} **97.** $-mv_2 \sin\frac{v_2}{R}t\,\hat{i} + m\left(v_2\cos\frac{v_2}{R}t - v_1\right)\hat{j}$

98. $x_2 = v_0t + \frac{m_1}{m_2}A\left(1-\cos\omega t\right)$, $\ell_0 = \left(\frac{m_1}{m_2}+1\right)A$

99. (a) $5\sqrt{\frac{3}{2}\mu gd}$ (b) $6d\sqrt{3\mu}$ **100.** (a) $0.8\,\hat{i}$ m/s, (b) $2.4\,\hat{i}$ m/s (c) 4/7

101. $\left(\frac{\sqrt{5}-1}{2}\right)$ **102*.** $\frac{mg(h_3-h_1)}{(h_2-h_1)}$ **103.** (i) straight line (ii) $\frac{x^2}{\left(\frac{L}{2}-r\right)^2}+\frac{y^2}{r^2}=1$ **104*.** $\frac{5v}{R\cos\theta}$

105. $\frac{m(R-r)}{M+m}$, $m\sqrt{\frac{2g(R-r)}{M(M+m)}}$ **106.** (i) $\frac{v_0}{3}$ (ii) $\frac{2mv_0^2}{3x_0^2}$

107. (L + 2R, 0) **108.** 64% **109.** $\rho A(u+v)^2$ **110.** 44.25 m

111. $\frac{(m_2+m_1\cot\alpha)h}{m+m_1+m_2}$ **112.** (i) $\sqrt{\frac{2ag}{3}}$ (ii) $\frac{3v}{g}$ (iii) $\frac{2v}{g}$

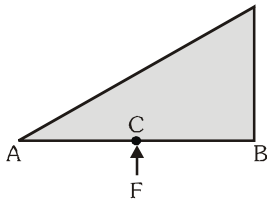
113. (i) $\frac{u}{2}, \frac{mu}{2}$ (ii) $\frac{u\sqrt{3}}{8}, \frac{mu\sqrt{3}}{8}$ (iii) $\frac{u\sqrt{3}}{4}, \frac{mu\sqrt{3}}{4}$ **114.** 10^5 m

115. 13 cm **116.** $\sqrt{\frac{3gx}{8}}$ **117.** 40 cm

118. $v_1 = \frac{1}{\sqrt{3}}ms^{-1}$, $v_2 = \frac{2}{\sqrt{3}}ms^{-1}$

True / False

1. A triangular plate of uniform thickness and density is made to rotate about an axis perpendicular to the plane of the paper and (a) passing through A, (b) passing through B, by the application of the same force, F at C (mid-point of AB) as shown in the figure. The angular acceleration in both the cases will be the same.



2. A thin uniform circular disc of mass M and radius R is rotating in a horizontal plane about an axis passing through its centre and perpendicular to its plane with an angular velocity ω. Another disc of the same dimensions but of mass $\frac{M}{4}$ is placed gently on the first disc coaxially. The final angular velocity of system will be $\frac{2\omega}{\sqrt{5}}$.

3. A ring of mass 0.3 kg and radius 0.1 m and a solid cylinder of mass 0.4 kg and of the same radius are given the same kinetic energy and released simultaneously on a flat horizontal surface such that they begin to roll as soon as released towards a wall which is at the same distance from the ring and the cylinder. The rolling friction in both cases is negligible the cylinder will reach the wall first.

4. If more mass is concentrated near the axis of rotation, the moment of inertia will be less and the angular acceleration produced by a given torque will be more than if the masses were uniformly distributed.

5. A wheel is revolving about a fixed axis through its centre and perpendicular to the plane of wheel. Consider a point on the rim. When the wheel rotates with constant angular velocity, the point has only a radial acceleration and zero tangential acceleration.

6. If the torque is not zero, rotational equilibrium will not be there.

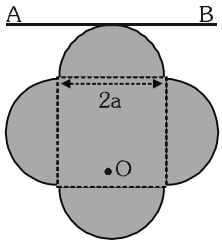
Fill in the blanks

7. A stone of mass m, tied to the end of a string, is whirled around in a horizontal circle. (Neglect the force due to gravity). The length of the string is reduced gradually keeping the angular momentum of the stone about the centre of the circle constant. Then, the tension in the string is given by $T = Ar^n$ where A is a constant, r is the instantaneous radius of the circle and n = ...

8. A uniform disc of mass m and radius R is rolling up a rough inclined plane which makes an angle of 30° with the horizontal. If the coefficient of static and kinetic friction are each equal to μ and the only forces acting are gravitational and frictional, then the magnitude of the frictional force acting on the disc is ..... and its direction is ..... (up or down) the inclined plane.

9. A rod of weight w is supported by two parallel knife edges A and B and is in equilibrium in a horizontal position. The knifes are at a distance d from each other. The centre of mass of the rod is at distance x from A. The normal reaction on A is ..... and on B is .....

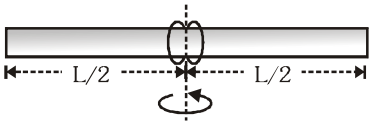
10. A symmetric lamina of mass M consists of a square shape with a semicircular section over of the edge of the square as shown in figure. The side of the square is 2a. The moment of inertia of the lamina about an axis through its centre of mass and perpendicular to the plane is $1.6\ Ma^2$. The moment of inertia of the lamina about the tangent AB in the plane of the lamina is.....



11. A cylinder of mass M and radius R is resting on a horizontal platform (which is parallel to the x-y plane) with it axis fixed along the y-axis and free to rotate about its axis. The platform is given a motion in the x-direction given by $x = A\cos(\omega t)$. There is no slipping between the cylinder and platform. The maximum torque acting on the cylinder during its motion is .....

12. The translational kinetic energy is the ..... percent of total energy for a rolling hollow sphere.

13. A smooth uniform rod of length L and mass M has two identical beads of negligible size, each of mass m, which can slide freely along the rod. Initially the two beads are at the centre of the rod and the system is rotating with an angular velocity ω_0 about an axis perpendicular to the rod and passing through the mid-point of the rod (see fig). There are no external forces. When the beads reach the ends of the rod, the angular velocity of the system is .....



Assertion-Reason

In each of the following questions, a Statement of Assertion (A) is given followed by a corresponding Statement of Reason (R) just below it . Of the Statements mark the correct answer as

(A) Statement–1 is True, Statement–2 is True ; Statement–2 is a correct explanation for Statement–1

(B) Statement–1 is True, Statement–2 is True ; Statement–2 is not a correct explanation for Statement–1

(C) Statement–1 is True, Statement–2 is False.

(D) Statement–1 is False, Statement–2 is True.

14. ***Statement –1 :*** A rigid disc rolls without slipping on a fixed rough horizontal surface with uniform angular velocity. Then the acceleration of lowest point on the disc is zero.

and

Statement –2 : For a rigid disc rolling without slipping on a fixed rough horizontal surface, the velocity of the lowest point on the disc is always zero.

15. ***Statement –1 :*** A sphere rolling on a rough horizontal surface with constant velocity then it start going up on a smooth inclined plane. Rotational KE of sphere decreases continuously on horizontal and inclined surface.

and

Statement –2 : Rotational KE decreases if torque due to friction opposes angular velocity of sphere.

16. ***Statement –1 :*** A disc is rolling on an inclined plane without slipping. The velocity of centre of mass is v. These others points on the disc lies on a circular arc having same speed as centre of mass.

and

Statement –2 : When a disc is rolling on an inclined plane. The magnitude of velocities of all the point from the contact point is same, having distance equal to radius r.

17. ***Statement–1 :*** A sphere is performing pure rolling on a rough horizontal surface with constant angular velocity. Frictional force acting on the sphere is zero. [No other force acting on the sphere]

and

Statement–2 : Velocity of contact point is zero.

18. ***Statement –1 :*** In case of rolling friction force can in forward and backward direction both.

and

Statement –2 : The angular momentum of a system will be conserved only about that point about which external angular impulse is zero.

19. ***Statement –1 :*** For the purpose of calculation of moment of inertia, a body's mass can be thought to be concentrated at its centre of mass.

and

Statement –2 : Moment of inertia is a measure of how the mass is distributed about a certain axis.

20. ***Statement –1 :*** If a body (ball) is rolling on a surface without slipping, no frictional force acts on it.

and

Statement –2 : In the case of rolling without slipping point of contacts are relatively at rest.

21. ***Statement –1 :*** Torque $(\vec{\tau})$ acting on a rigid body is defined as $\vec{\tau} = \vec{A} \times \vec{L}, \vec{A}$ is a constant vector and $\vec{L}$ is the angular momentum of the body. The magnitude of the angular momentum of the body remains same.

and

Statement–2 : $\vec{\tau}$ is perpendicular to $\vec{L}$ and also perpendicular to $\vec{\omega}$, hence torque does not deliver any power to the body.

22. ***Statement –1 :*** The moment of inertia of a rigid body is not unique, about a given axis.

and

Statement –2 : The moment of inertia of a rigid body depends on axis about which it has to be calculated.

23. ***Statement –1 :*** A non-uniform sphere is placed such that its centre is origin of coordinate system. If I_x and I_y be moment of inertia about x axis and y axis respectively then moment of inertia about z axis is $I_x + I_y$.

and

Statement –2 : According to perpendicular axis theory $I_z = I_x + I_y$ when object is lying in x-y plane.

Single Choice

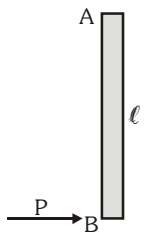
24*. A boy stands over the centre of a horizontal platform which is rotating freely with a speed of 2 revolutions/s about a vertical axis through the centre of the platform and straight up through the boy. He holds 2 kg masses in each of his hands close to his body. The combined moment of inertia of the system is 1 kg-m.^{2}. The boy now stretches his arms so as to hold the masses far from his body. In this situation the moment of inertia of the system increases to 2 kg-m.^{2}. The kinetic energy of the system in the latter case as compared with that in the previous case will-

(A) Remain unchanged (B) Decrease (C) Increase (D) Remain uncertain

25*. There is rod of length ℓ. The velocities of its two ends are v_1 and v_2 in opposite directions normal to the rod. The distance of the instantaneous axis of rotation from v_1 is :

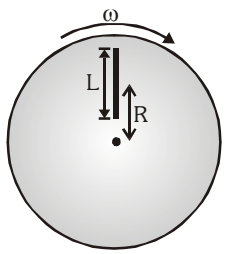
(A) Zero (B) $\frac{v_2}{v_1 + v_2}\ell$ (C) $\frac{v_1 \ell}{v_1 + v_2}$ (D) 2ℓ

26*. A uniform rod AB of mass m and length ℓ at rest on a smooth horizontal surface. An impulse P is applied to the end B. The time taken by the rod to turn through a right angle is :-



(A) $\frac{2\pi m\ell}{P}$ (B) $\frac{\pi m\ell}{3P}$ (C) $\frac{\pi m\ell}{12P}$ (D) $\frac{2\pi m\ell}{3P}$

27. A uniform rod of mass M and length L lies radially on a disc rotating with angular speed ω in a horizontal plane about its axis. The rod does not slip on the disc and the centre of the rod is at a distance R from the centre of the disc. Then the kinetic energy of the rod is-



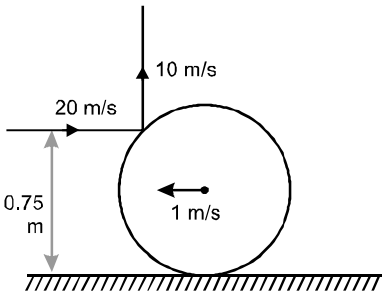
(A) $\frac{1}{2}m\omega^2\left(R^2 + \frac{L^2}{12}\right)$ (B) $\frac{1}{2}m\omega^2R^2$

(C) $\frac{1}{24}m\omega^2L^2$ (D) None of these

28*. A cord is wound over a cylinder of radius r and moment of inertia I. A mass m is attached to the free end of the cord. The cylinder is free to rotate about its own horizontal axis. If mass m is released from rest, then the velocity of the mass after it had fallen through a distance h will be-

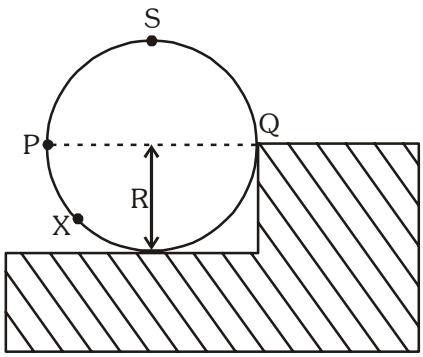
(A) $(2gh)^{1/2}$ (B) $\left(\frac{2mghr^2}{I}\right)^{1/2}$ (C) $\left(\frac{2mghr^2}{I+mr^2}\right)^{1/2}$ (D) $\left(\frac{mghr^2}{I+2mr^2}\right)^{1/2}$

29*. A thin ring of mass 2 kg and radius 0.5 m is rolling without slipping on a horizontal plane with velocity 1 m/s. A small ball of mass 0.1 kg, moving with velocity 20 m/s in the opposite direction, hits the ring at a height of 0.75 m and goes vertically up with velocity 10 m/s. Immediately after the collision : ***[IIT-JEE 2011]***



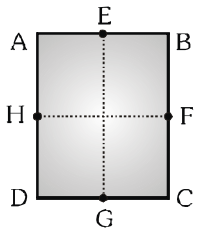
(A) the ring has pure rotation about its stationary CM.
(B) the ring comes to a complete stop.
(C) friction between the ring and the ground is to the left.
(D) there is no friction the ring and the ground.

30. A wheel of radius R and mass M is placed at the bottom of a fixed step of height R as shown in the figure. A constant force is continuously applied on the surface of the wheel so that it just climbs the step without slipping. Consider the torque τ about an axis normal to the plane of the paper passing through the point Q. Which of the following options is/are correct? ***[JEE (Adv.) 2017]***



(A) If the force is applied normal to the circumference at point X then τ is constant
(B) If the force is applied tangentially at point S then $\tau \neq 0$ but the wheel never climbs the step
(C) If the force is applied normal to the circumference at point P then τ is zero
(D) If the force is applied at point P tangentially then τ decreases continuously as the wheel climbs

31. We have a rectangular slab of same thickness. E, F, G, H are the middle point of AB, BC, CD and AD respectively then which of the following axis the moment of inertia will be minimum :–



(A) AD (B) EG
(C) BD (D) HF

32. Off two eggs which have identical sizes, shapes and weights, one is raw and the other is half-boiled. The ratio between the moment of inertia of the raw egg and that of the half-boiled egg about a central axis is :–

(A) one (B) greater than one (C) less than one (D) incomparable

33. The moment of inertia of a rod about an axis through its centre and perpendicular to it is $\frac{1}{12}ML^2$ (where M is the mass and L is the length of the rod). The rod is bent in the middle so that the two half make an angle of 60°. The moment of inertia of the bent rod about the same axis would be :–

(A) $\frac{1}{48}ML^2$ (B) $\frac{1}{12}ML^2$ (C) $\frac{1}{24}ML^2$ (D) $\frac{ML^3}{8\sqrt{3}}$

34. Four similar point masses (each of mass m) are placed on the circumference of a disc of mass M and radius R. The M.I. of the system about the normal axis through the centre O will be:-

(A) $MR^2 + 4mR^2$ (B) $\frac{1}{2}MR^2 + 4mR^2$

(C) $MR^2 + \frac{8}{5}mR^2$ (D) None of these

35. For the same total mass which of the following will have the largest moment of inertia about an axis passing through its centre of mass and perpendicular to the plane of the body

(A) a disc of radius a (B) a ring of radius a

(C) a square lamina of side 2a (D) four rods forming a square of side 2a

36. A rigid body of mass m rotates with angular velocity ω about an axis at a distance d from the centre of mass G. The radius of gyration about a parallel axis through G is k. The kinetic energy of rotation of the body is :–

(A) $\frac{1}{2}mk^2\omega^2$ (B) $\frac{1}{2}md^2\omega^2$ (C) $\frac{1}{2}m(d^2+k^2)\omega^2$ (D) $\frac{1}{2}m(d+k)^2\omega^2$

37. A weightless rod is acted on by upward parallel forces of 2N and 4N at ends A and B respectively. The total length of the rod is AB =3 m. To keep the rod in equilibrium a force of 6N should act in the following manner:–

(A) Downwards at any point between A and B (B) Downwards at mid point of AB

(C) Downwards at a point C such that AC =1m (D) Downwards at a point D such that BD =1m

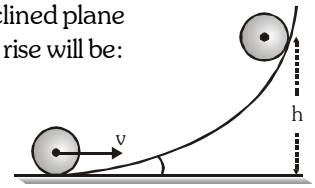
38. If a ring, a disc, a solid sphere and a cylinder of same radius rolls down on inclined plane, the first one to reach the bottom will be :

(A) disc (B) ring (C) solid sphere (D) cylinder

39. A body is rolling without slipping on a horizontal surface and its rotational kinetic energy is equal to the translational kinetic energy. The body is :–

(A) disc (B) sphere (C) cylinder (D) ring

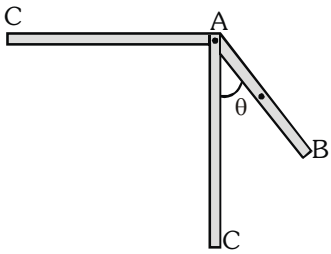
40. A disc of mass M and radius R rolls on a horizontal surface and then rolls up an inclined plane as shown in the figure. If the velocity of the disc is v, the height to which the disc will rise will be:



(A) $\frac{3v^2}{2g}$ (B) $\frac{3v^2}{4g}$

(C) $\frac{v^2}{4g}$ (D) $\frac{v^2}{2g}$.

41. A rod hinged at one end is released from the horizontal position as shown in the figure. When it becomes vertical its lower half separates without exerting any reaction at the breaking point. Then the maximum angle 'θ' made by the hinged upper half with the vertical is



(A) 30^0 (B) 45^0

(C) 60^0 (D) 90^0

42. A circular turn table has a block of ice placed at its centre. The system rotates with an angular speed ω about an axis passing through the centre of the table. If the ice melts on its own without any evaporation, the speed of rotation of the system :–

(A) becomes zero (B) remains constant at the same value of ω

(C) increases to value greater than ω (D) decreases to a value less than ω

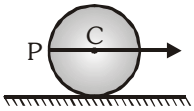
43. An ant is sitting at the edge of a rotating disc. If the ant reaches the other end, after moving along the diameter, the angular velocity of the disc will :-

(A) remain constant
(B) first decreases and then increases
(C) first increases, then decrease
(D) Increase continuously

44. Two rotating bodies have same angular momentum but their moments of inertia are I_1 and I_2 respectively ($I_1 > I_2$). Which body will have higher kinetic energy of rotation:–

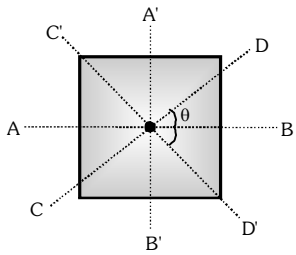
(A) First
(B) Second
(C) Both will have same kinetic energy
(D) Not possible to predict

45. A disc of radius R is rolling purely on a flat horizontal surface, with a constant angular velocity. The angle between the velocity and acceleration vectors of point P is



(A) Zero
(B) 45^0
(C) 135^0
(D) $\tan^{-1}(1/2)$

46. Let I be the moment of inertia of a uniform square plate about an axis AB that passes through its centre and is parallel to two of its sides. CD is a line in the plane of the plate that passes through the centre of the plate and makes an angle θ with AB. The moment of inertia of the plate about the axis CD is then equal to:- ***[IIT-JEE 1998]***

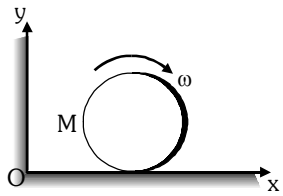


(A) I
(B) $I \sin^2\theta$
(C) $I \cos^2\theta$
(D) $I \cos^2\left(\frac{\theta}{2}\right)$

47. A smooth sphere A is moving on a frictionless horizontal plane with angular velocity ω and centre of mass velocity v. It collides elastically and head on with an identical sphere B at rest. Neglect friction everywhere. After the collision their angular speed are ω_A and ω_B respectively. Then :- ***[IIT-JEE 1999]***

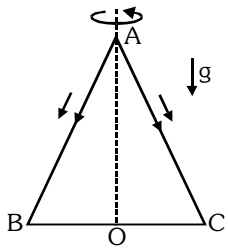
(A) $\omega_A < \omega_B$
(B) $\omega_A = \omega_B$
(C) $\omega_A = \omega$
(D) $\omega_B = \omega$

48. A disc of mass M and radius R is rolling with angular speed ω on a horizontal plane as shown. The magnitude of angular momentum of the disc about the origin O is :- ***[IIT-JEE 1999]***



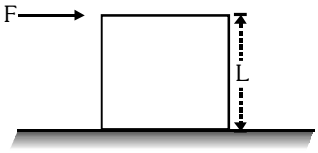
(A) $\left(\frac{1}{2}\right)MR^2\omega$
(B) $MR^2\omega$
(C) $\left(\frac{3}{2}\right)MR^2\omega$
(D) $2MR^2\omega$

49*. An equilateral triangle ABC formed from a uniform wire has two small identical beads initially located at A. The triangle is set rotating about the vertical axis AO. Then the beads are released from rest simultaneously and allowed to slide down, one along AB and other along AC as shown. Neglecting frictional effects, the quantities that are conserved as beads slides down are: ***[IIT-JEE 2000]***



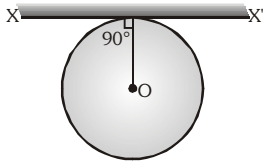
(A) angular velocity and total energy (kinetic and potential)
(B) total angular momentum and total energy
(C) angular velocity and moment of inertia about the axis of rotation
(D) total angular momentum and moment of inertia about the axis of rotation

50. A cubical block of side L rests on a rough horizontal surface with coefficient of friction μ. A horizontal force F is applied on the block as shown. If the coefficient of friction is sufficiently high, so that the block does not slide before toppling, the minimum force required to topple the block is :- ***[IIT-JEE 2000]***



(A) infinitesimal (B) $\frac{mg}{4}$ (C) $\frac{mg}{2}$ (D) mg $(1 - \mu)$

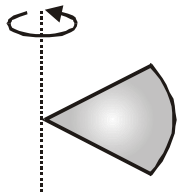
51. A thin wire of length L and uniform linear mass density ρ is bent into a circular loop with centre at O as shown. The moment of inertia of the loop about the axis XX' is :- ***[IIT-JEE 2000]***



(A) $\frac{\rho L^3}{8\pi^2}$ (B) $\frac{\rho L^3}{16\pi^2}$

(C) $\frac{5\rho L^3}{16\pi^2}$ (D) $\frac{3\rho L^3}{8\pi^2}$

52. One quarter section is cut from a uniform circular disc of radius R. This section has a mass M. It is made to rotate about a line perpendicular to its plane and passing through the centre of the original disc. Its moment of inertia about the axis of rotation is :- ***[IIT-JEE 2001***



(A) $\frac{1}{2}MR^2$ (B) $\frac{1}{4}MR^2$

(C) $\frac{1}{8}MR^2$ (D) $\sqrt{2}MR^2$

53. A cylinder rolls up an inclined plane and reaches some height and then rolls down (without slipping throughout these motions). The directions of the frictional force acting on the cylinder are : ***[IIT-JEE 2002]***

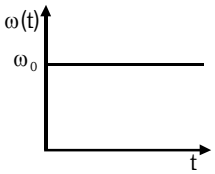
(A) up the incline while ascending and down the incline while descending

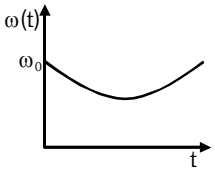
(B) up the incline while ascending as well as descending

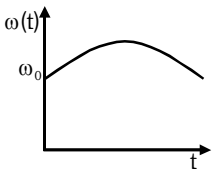
(C) down the incline while ascending and up the incline while descending

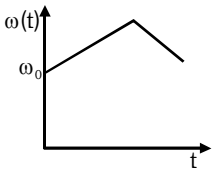
(D) down the incline while ascending as well as descending.

54. A circular platform is free to rotate in a horizontal plane about a vertical axis passing through its centre. A tortoise is sitting at the edge of the platform. Now the platform is given an angular velocity ω_0. When the tortoise move along a chord of the platform with a constant velocity (with respect to the platform). The angular velocity of the platform ω(t) will vary with time t as :- ***[IIT-JEE 2002]***

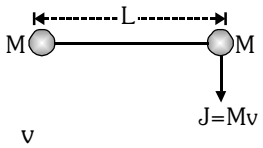
(A) 

(B) 

(C) 

(D) 

55*. Consider a body, shown in figure, consisting of two identical balls, each of mass M connected by a light rigid rod. If an impulse J = Mv is imparted to the body at one of its end, what would be its angular velocity: ***[IIT-JEE 2003]***

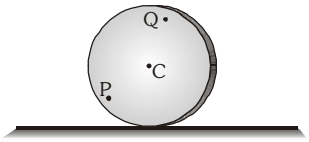


(A) $\frac{v}{L}$ (B) $\frac{2v}{L}$ (C) $\frac{v}{3L}$ (D) $\frac{v}{4L}$

56. A particle undergoes uniform circular motion. About which point on the plane of the circle, will the angular momentum of the particle remain conserved ? ***[IIT-JEE 2003]***

(A) Centre of circle
(B) On the circumference of the circle
(C) Inside the circle
(D) Outside the circle

57. A disc is rolling (with slipping) on a horizontal surface. C is its centre and Q and P are two points equidistant from C. Let v_P, v_Q and v_C be the magnitude of velocities of points P, Q and C respectively, then : ***[IIT-JEE 2004]***

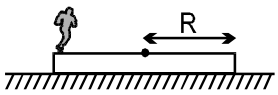


(A) $v_Q > v_C > v_P$
(B) $v_Q < v_C < v_P$
(C) $v_Q = v_P$, $v_C = \frac{1}{2}v_P$
(D) $v_Q < v_C > v_P$

58. A child is standing with folded hands at the centre of a platform rotating about its central axis. The kinetic energy of the system is K and moment of inertia is I. The child now stretches his arms so that the moment of inertia of the system doubles. The kinetic energy of the system now is :- ***[IIT-JEE 2004]***

(A) 2K
(B) K/2
(C) K/4
(D) 4K

59. A uniform disc of mass 'm' and radius R is placed on a smooth horizontal floor such that the plane surface of the disc is in contact with the floor. A man of mass m/2 stands on the disc at its periphery. The man starts walking along the periphery of the disc. The size of the man is negligible as compared to the size of the disc. Then the centre of disc.

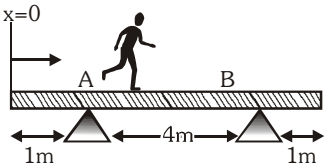


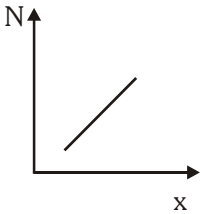
(A) moves along a circle of radius $\frac{R}{3}$
(B) moves along a circle of radius $\frac{2R}{3}$
(C) moves along a circle of radius $\frac{R}{2}$
(D) does not move along a circle

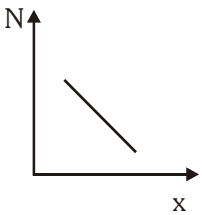
60*. A tube of length L is filled completely with an incompressible liquid of mass M and closed at both the ends. The tube is then rotated in a horizontal plane about one of its ends with a uniform angular velocity ω. The force exerted by the liquid at the other end is :-

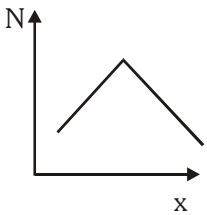
(A) $\frac{M\omega^2L}{2}$
(B) $M\omega^2L$
(C) $\frac{M\omega^2L}{4}$
(D) $\frac{M\omega^2L^2}{2}$

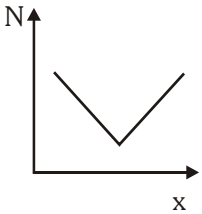
61*. A man can move on a horizontal plank supported symmetrically as shown. The variation of normal reaction on support A with distance x of the man from the end of the plank is best represented by



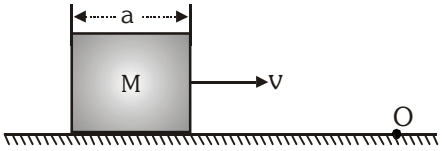
(A)


(B)


(C)


(D)


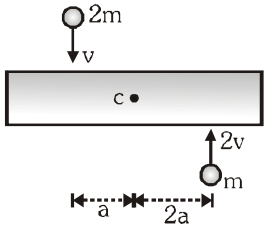
62*. A cubical block of side 'a' moving with velocity v on a horizontal smooth plane as shown. It hits a ridge at point O. The angular speed of the block after it hits O is :- ***[IIT-JEE 1999]***



(A) $\frac{3v}{4a}$
(B) $\frac{3v}{2a}$
(C) $\frac{\sqrt{3}}{\sqrt{2}a}$
(D) zero

Multiple Choice

63*. A uniform bar of length 6a and mass 8m lies on a smooth horizontal table. Two point masses m and 2m moving in the same horizontal plane with speed 2v and v respectively, strike the bar (as shown in the fig.) and stick to the bar after collision. Denoting angular velocity (about the centre of mass), total energy and centre of mass velocity by ω, E and v_C respectively, we have after collision :



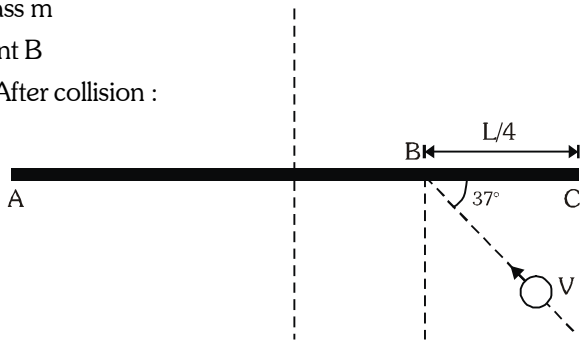
(A) $v_C = 0$

(B) $\omega = \dfrac{3v}{5a}$

(C) $\omega = \dfrac{v}{5a}$

(D) $E = 3\dfrac{mv^2}{5}$

64*. A rod AC of length L and mass m is kept on a horizontal smooth plane.It is free to rotate and move.A particle of same mass m moving on the plane with velocity v strikes the rod at point B making an angle 37° with the rod.The collision is elastic.After collision :



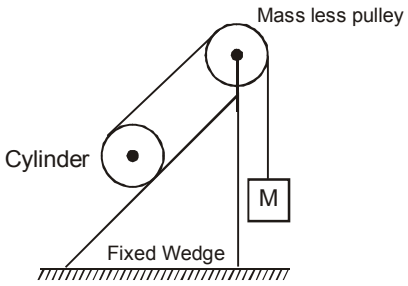
(A) Angular velocity of the rod will be $\dfrac{72v}{55L}$

(B) The centre of the rod will travel a distance $\dfrac{\pi L}{3}$ in the time in which it makes half rotation

(C) Impulse of the impact force is $\dfrac{24mV}{55}$

(D) None of these

65*. A cylinder and a variable mass M are arranged on a fixed wedge using a light string and a massless pulley. There is enough friction between cylinder and the wedge to prevent any slipping.



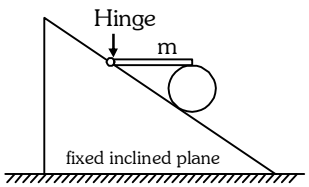
(A) Only one value of M is possible for which cylinder can remain in equilibrium.

(B) There is a range of value of M for which cylinder can remain in equilibrium.

(C) For a certain value of M, the cylinder starts to roll up the plane. In this situation, magnitude of friction force on the cylinder by the wedge will be greater than tension in the string

(D) For a certain value of M, the cylinder starts to roll down the plane. In this situation, magnitude of friction force on the cylinder by the wedge will be greater than tension in the string

66*. A horizontal uniform rod of mass 'm' has its left end hinged to the fixed incline plane, while its right end rests on the top of a uniform cylinder of mass 'm' which in turn is at rest on the fixed inclined plane as shown. The coefficient of friction between the cylinder and rod, and between the cylinder and inclined plane, is sufficient to keep the cylinder at rest.



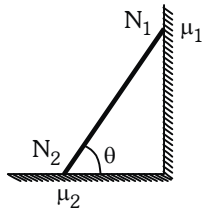
(A) The magnitude of normal reaction exerted by the rod on the cylinder is $\dfrac{mg}{2}$

(B) The ratio of magnitude of frictional force on the cylinder due to the rod and the magnitude of frictional force on the cylinder due to the inclined plane is 1 : 1

(C) The magnitude of normal reaction exerted by the inclined plane on the cylinder is $\dfrac{3mg}{2}$

(D) The magnitude of normal reaction exerted by the inclined plane on the cylinder is 2 mg

67*. In the figure, a ladder of mass m is shown leaning against a wall. It is in static equilibrium kaing an angle θ with the horizontal floor. The coefficient of friction between the wall and the ladder is μ_1 and that between the floor and the ladder is μ_2. The normal reaction of the wall on the ladder is N_1 and that of the floor is N_2. If the ladder is about to slip, then **[JEE(Adv.) 2014]**



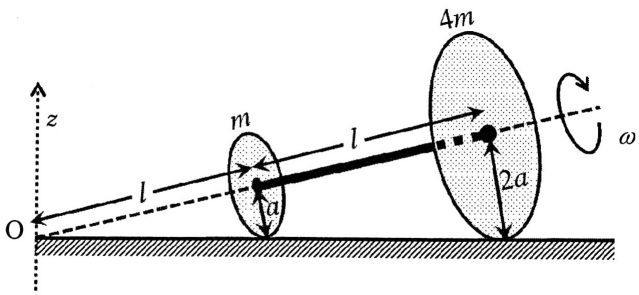
(A) $\mu_1 = 0$ $\mu_2 \neq 0$ and $N_2 \tan\theta = \frac{mg}{2}$

(B) $\mu_1 \neq 0$ $\mu_2 = 0$ and $N_1 \tan\theta = \frac{mg}{2}$

(C) $\mu_1 \neq 0$ $\mu_2 \neq 0$ and $N_2 = \frac{mg}{1+\mu_1\mu_2}$

(D) $\mu_1 = 0$ $\mu_2 \neq 0$ and $N_1 \tan\theta = \frac{mg}{2}$

68. Two thin circular discs of mass m and 4m, having radii of a and 2a, respectively, are rigidly fixed by a massless, rigid rod of length $\ell = \sqrt{24}a$ through their centers. This assembly is laid on a firm and flat surface, and set rolling without slipping on the surface so that the angular speed about the axis of the rod is ω. The angular momentum of the entire assembly about the point 'O' is $\vec{L}$ (see the figure). Which of the following statement(s) is (are) true ? **[JEE(Adv.) 2016]**



(A) The magnitude of angular momentum of the assembly about its center of mass is $ma^2\omega/2$

(B) The magnitude of the z-component of $\vec{L}$ is $55\ ma^2\omega$

(C) The magnitude of angular momentum of center of mass of the assembly about the point O is $81\ ma^2\omega$

(D) the center f mass of the assembly rotates about the z-axis with an angular speed of $\omega/5$

69*. The torque $\vec{\tau}$ on a body about a given point is found to be equal to $\vec{A} \times \vec{L}$, where $\vec{A}$ is a constant vector and $\vec{L}$ is the angular momentum of the body about that point. From this it follows that :-

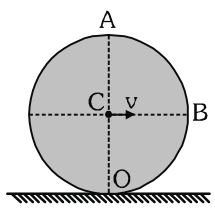
(A) $\frac{d\vec{L}}{dt}$ is perpendicular to $\vec{L}$ at all instants of time **[IIT-JEE 1998]**

(B) the component of $\vec{L}$ in the direction of $\vec{A}$ does not change with time

(C) the magnitude of $\vec{L}$ does not change with time

(D) $\vec{L}$ does not change with time

70*. A cylinder rolls without slipping over a horizontal plane with constant velocity. The radius of the cylinder is equal to r. The curvature radii of trajectories traced out by the points A and B in figure.



(A) $R_A = 4r$

(B) $R_B = 2\sqrt{2}r$

(C) $R_A = r$

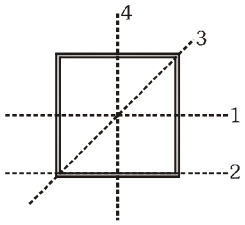
(D) $R_B = 4r$

Match the Column

71.

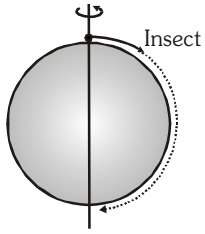
Column I	Column II
(A) In pure rolling work done by friction	(p) is always zero
	(q) may be zero
(B) In forward slipping work done by friction on one of the object	(r) is negative
	(s) is positive
(C) In backward slipping work done by friction on one of the object	(t) may be negative
	(u) may be positive

72. Four rods of equal length l and mass m each form a square as shown in figure. Moment of inertia about four axes 1, 2,3 and 4 are say I_1, I_2, I_3 and I_4.



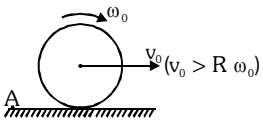
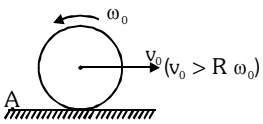
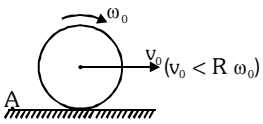
Column I	Column II
(A) I_1	(p) $\frac{4}{3}m\ell^2$
(B) I_2	(q) $\frac{2}{3}m\ell^2$
(C) I_3	(r) $\frac{1}{2}m\ell^2$
(D) I_4	(s) None

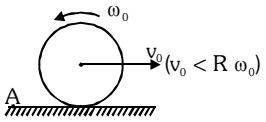
73. A solid sphere is rotating about an axis as shown in figure. An insect follows the dotted path on the circumference of sphere as shown.



Column I	Column II
(A) Moment of inertia of system about axis of rotation	(p) will remain constant
(B) Angular velocity	(q) will first increase then decrease
(C) Angular momentum of system about axis of rotation	(r) will first decrease then increase
(D) Rotational kinetic energy	(s) will continuously decrease
	(t) will continuously increase
	(u) data is insufficient

74. In each situation of column-I, a uniform disc of mass m and radius R rolls on a rough fixed horizontal surface as shown. At t = 0 (initially) the angular velocity of disc is ω_0 and velocity of centre of mass of disc is v_0 (in horizontal direction). The relation between v_0 and ω_0 for each situation and also initial sense of rotation is given for each situation in column-I. Then match the Statement in column-I with the corresponding results in column-II.

Column I	Column II
(A) 	(p) The angular momentum of disc about point A (as shown in figure) remains conserved
(B) 	(q) The kinetic energy of disc after it starts rolling without slipping is less than its initial kinetic energy
(C) 	(r) In the duration disc rolls with slipping, the friction acts on disc towards left.

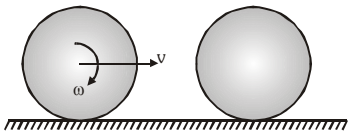
(D) 

(s) In the duration disc rolls with slipping, the friction acts on disc for some time to right and for some time to left.

Comprehension Type Question

Comprehension-1*.

A solid sphere is rolling without slipping on rough ground as shown in figure. It collides elastically with an identical another sphere at rest. There is no friction between the two spheres. Radius of each sphere is R and mass is m.



75. Linear velocity of first sphere after it again starts rolling without slipping is :

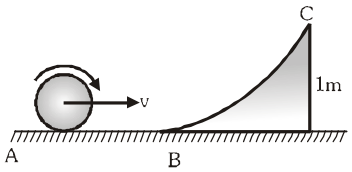
(A) $\frac{2}{5}\omega R$ (B) $\frac{2}{7}\omega R$ (C) $\frac{7}{10}\omega R$ (D) $\frac{7}{5}\omega R$

76. What is the net angular impulse imparted to second sphere by the external forces ?

(A) $\frac{2}{7}mRv$ (B) $\frac{5}{7}mRv$ (C) $\frac{2}{5}mRv$ (D) $\frac{7}{10}mRv$

Comprehension-2*.

A small sphere of mass 1 kg is rolling without slipping on a stationary base with linear speed $v = \sqrt{\frac{200}{7}}$ m/s. It leaves the inclined plane at point C at angle 30° with the horizontal. (Incline is fixed and sufficiently rough)



77. Find its linear speed at point C :

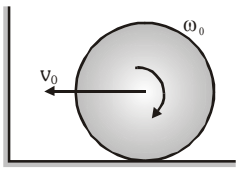
(A) $\sqrt{\frac{100}{7}}$ m/s (B) $\sqrt{\frac{50}{7}}$ m/s (C) $\sqrt{\frac{100}{35}}$ m/s (D) $\sqrt{\frac{200}{35}}$ m/s

78. Find ratio of rotational and translational kinetic energy of the sphere when it strikes the ground after leaving from point C :

(A) $\frac{2}{5}$ (B) $\frac{2}{3}$ (C) $\frac{1}{6}$ (D) $\frac{1}{2}$

Comprehension-3*.

A solid sphere has linear velocity $v_0 = 4$ m/s and angular velocity $\omega_0 = 9$ rad/s as shown. Ground on which it is moving, is smooth. It collides elastically with a rough wall of coefficient of friction μ. Radius of the sphere is 1 m and mass is 2 kg.



79. If the sphere after colliding with the wall roll without slipping in opposite direction, then coefficient of friction μ is :

(A) $\frac{1}{2}$ (B) $\frac{2}{3}$ (C) $\frac{1}{3}$ (D) $\frac{1}{4}$

80. What is net linear impulse imparted by the wall on the sphere during impact :-

(A) $\sqrt{32}$ N-s (B) $4\sqrt{17}$ N-s (C) $4\sqrt{5}$ N-s (D) $15\sqrt{2}$ N-s

Comprehension-4.

A rod of mass m and length ℓ is placed on a smooth table. An another particle of same mass m strikes the rod with velocity v_0 in a direction perpendicular to the rod at distance x $\left(< \frac{\ell}{2}\right)$ from its centre. Particle sticks to the rod. Let ω be the angular speed of system after collision, then :

81. As x is increased from 0 to $\frac{\ell}{2}$, the angular speed ω :-

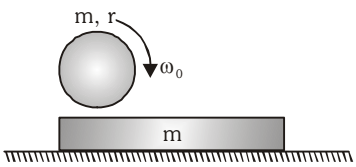
(A) will continuously increase
(B) will continuously decrease
(C) will first increase and then decrease
(D) will first decrease and then increase

82. Find maximum possible value of impulse (by varying x) that can be imparted to the particle during collision. Particle still sticks to the rod :

(A) $\frac{mv_0}{2}$
(B) $\frac{2mv_0}{3}$
(C) $\frac{3mv_0}{4}$
(D) $\frac{4mv_0}{5}$

Comprehension-5*.

In the figure shown a plank of mass m is lying at rest on a smooth horizontal surface. A disc of same mass m and radius r is rotated to an angular speed ω_0 and then gently placed on the plank. If we consider the plank and the disc as a system then frictional force between them is an internal force. Momentum of the system changes due to external force only. It is found that finally slipping cease, and 50% of total kinetic energy of the system is lost. Assume that plank is long enough. μ is coefficient of friction between disc and plank.



83. Final velocity of the plank is

(A) $\frac{r\omega_0}{4}$
(B) $\frac{r\omega_0}{\sqrt{10}}$
(C) $\frac{r\omega_0}{2}$
(D) $\frac{r\omega_0}{2\sqrt{10}}$

84. Time when slipping ceases

(A) $\frac{r\omega_0}{2\mu g}$
(B) $\frac{r\omega_0}{\sqrt{10}\mu g}$
(C) $\frac{r\omega_0}{4\mu g}$
(D) $\frac{r\omega_0}{2\sqrt{10}\mu g}$

85. Magnitude of the change in angular momentum of disc about centre of mass of disc

(A) $\frac{3}{4}mr^2\omega_0$
(B) $\frac{1}{4}mr^2\omega_0$
(C) zero
(D) $\frac{1}{2}mr^2\omega_0$

86. Distance moved by the plank from the placing of disc on the plank till the slipping ceases between disc and plank

(A) $\frac{r^2\omega_0^2}{16\mu g}$
(B) $\frac{r^2\omega_0^2}{8\mu g}$
(C) $\frac{r^2\omega_0^2}{32\mu g}$
(D) $\frac{r^2\omega_0^2}{200\mu g}$

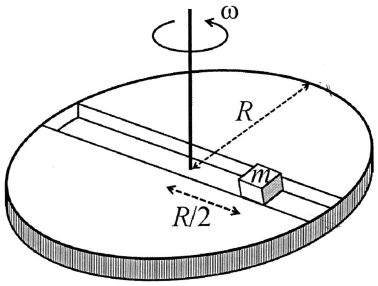
Comprehension-6.

A frame of reference that is accelerated with respect to an inertial frame of reference is called a non-inertial frame of reference. A coordinate system fixed on a circular disc rotating about a fixed axis with a constant angular velocity ω is an example of a non-inertial frame of reference. The relationship between the force $\vec{F}_{rot}$ experienced by a particle of mass m moving on the rotating disc and the force $\vec{F}_{in}$ experienced by the particle in an inertial frame of reference is

$$\vec{F}_{rot} = \vec{F}_{in} + 2m(\vec{v}_{rot} \times \vec{\omega}) + m(\vec{\omega} \times \vec{r}) \times \vec{\omega}$$

where $\vec{v}_{rot}$ is the velocity of the particle in the rotating frame of reference and $\vec{r}$ is the position vector of the particle with respect to the centre of the disc.

Now consider a smooth slot along a diameter of a disc of radius R rotating counter-clockwise with a constant angular speed ω about its vertical axis through its center. We assign a coordinate system with the origin at the center of the disc, thex-axis along the slot, the y-axis perpendicular to the slot and the z-axis along the rotation axis $(\vec{\omega} = \omega\hat{k})$.



A small block of mass m is gently placed in the slot at $\vec{r} = (R/2)\hat{i}$ at t = 0 and is constrained to move only along the slot.

[JEE(Adv.) 2016]

87. The distance r of the block at time t is

(A) $\frac{R}{4}(e^{2\omega t} + e^{-2\omega t})$ (B) $\frac{R}{2}\cos 2\omega t$ (C) $\frac{R}{2}\cos \omega t$ (D) $\frac{R}{4}(e^{\omega t} + e^{-\omega t})$

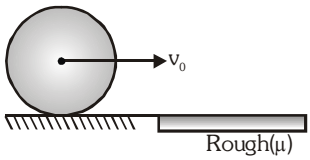
87. The net reaction of the disc on the block is

(A) $-m\omega^2 R\cos\omega t\,\hat{j} - mg\,\hat{k}$ (B) $m\omega^2 R\sin\omega t\,\hat{j} - mg\,\hat{k}$

(C) $\frac{1}{2}m\omega^2 R(e^{\omega t} - e^{-\omega t})\hat{j} + mg\,\hat{k}$ (D) $\frac{1}{2}m\omega^2 R(e^{2\omega t} - e^{-2\omega t})\hat{j} + mg\,\hat{k}$

Comprehension-7.

A ring of mass M and radius R sliding with a velocity v_0 suddenly enters into rough surface where the coefficient of friction is μ, as shown in figure.



88. Choose the correct statement(s)

(A) As the ring enters on the rough surface, the limiting friction force acts on it

(B) The direction of friction is opposite to the direction of motion

(C) The friction force accelerates the ring in the clockwise sense about its centre of mass

(D) As the ring enters on the rough surface it starts rolling

90. Choose the correct statement(s)

(A) The momentum of the ring is conserved

(B) The angular momentum of the ring is conserved about its centre of mass

(C) The angular momentum of the ring conserved about any point on the horizontal surface

(D) The mechanical energy of the ring is conserved

91. Choose the correct statement(s) :

(A) The ring starts its rolling motion when the centre of mass stationary

(B) The ring starts rolling motion when the point of contact becomes stationary

(C) The time after which the ring starts rolling is $\frac{v_0}{2\mu g}$

(D) The rolling velocity is $\frac{v_0}{2}$

92. Choose the correct alternative(s)

(A) The linear distance moved by the centre of mass before the ring starts rolling is $\frac{3v_0^2}{8\mu g}$

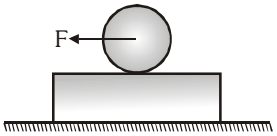
(B) The net work done by friction force is $-\frac{3}{8}mv_0^2$

(C) The loss in kinetic energy of the ring is $\frac{mv_0^2}{4}$

(D) The gain in rotational kinetic energy is $+\frac{mv_0^2}{8}$

Comprehension-8.

A disc of mass m and radius R is placed over a plank of same mass m. There is sufficient friction between disc and plank to prevent slipping. A force F is applied at the centre of the disc.



93. Acceleration of the plank is :-

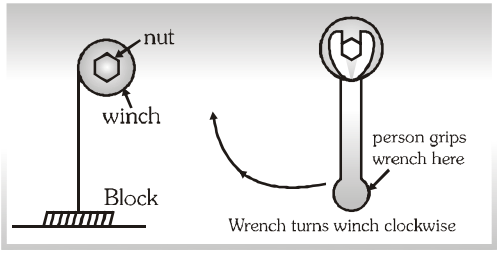
(A) $\frac{F}{2m}$ (B) $\frac{3F}{4m}$ (C) $\frac{F}{4m}$ (D) $\frac{3F}{2m}$

94. Force of friction between the disc and the plank is :-

(A) $\frac{F}{2}$ (B) $\frac{F}{4}$ (C) $\frac{F}{3}$ (D) $\frac{2F}{3}$

Comprehension-9*.

In figure, the winch is mounted on an axle, and the 6-sided nut is welded to the winch. By turning the nut with a wrench, a person can rotate the winch. For instance, turning the nut clockwise lifts the block off the ground, because more and more rope gets wrapped around the winch.



Three students agree that using a longer wrench makes it easier to turn the winch. But they disagree about why. All three students are talking about the case where the winch is used, over a 10 s time interval, to lift the block one metre off the ground.

Student 1 By using a longer wrench, the person decreases the average force he must exert on the wrench, in order to lift the block one metre in 10 s.

Student 2 : Using a longer wrench reduces the work done by the person as he uses the winch to lift the block 1m in 10s.

Student 3 : Using a longer wrench reduces the power that the person must exert to lift the block 1m in 10s.

95. Student 1 is :

(A) correct, because the torque that the wrench must exert to lift the block doesn't depend on the wrench's length

(B) correct, because using a longer wrench decreases the torque it must exert on the winch

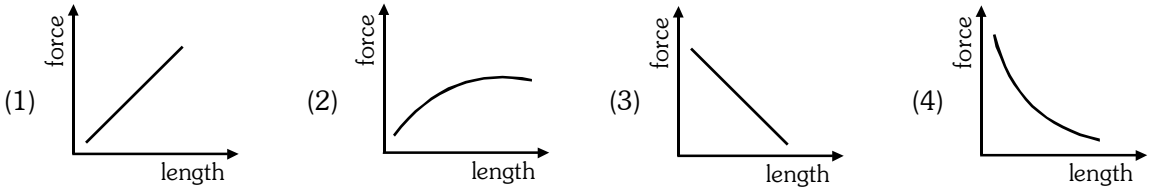
(C) incorrect, because the torque that the wrench must exert to lift the block doesn't depend on the wrench's length

(D) Incorrect, because using a longer wrench decreases the torque it must exert on the winch.

96. Which of the following is true about student 2 and 3 :-

(A) Student 2 and 3 are both correct
(B) Student 2 is correct, but student 3 is incorrect
(C) Student 3 is correct, but student 2 is incorrect
(D) Student 2 and 3 are both incorrect

97. If several wrenches all apply the same torque to a nut, which graph best expresses the relationship between the force the person must apply to the wrench, and the length of the wrench :-



(A) 1
(B) 2
(C) 3
(D) 4

Comprehension-10.

A cylinder and a ring of same mass M and radius R are placed on the top of a sufficient rough inclined plane of inclination θ . Both are released simultaneously from the same height h

98. Choose the correct statement(s) related to the motion of each body

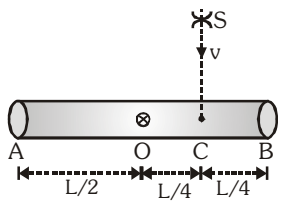
(A) The friction force acting on each body opposes the motion of its centre of mass
(B) The friction force provides the necessary torque to rotate the body about its centre of mass
(C) Without friction none of the two bodies can roll
(D) The friction force ensures that the point of contact must remain stationary

99. Identify the correct statement(s)

(A) The friction force acting on the cylinder is more than that acting on the ring
(B) The friction force acting on the ring is more than that acting on the cylinder
(C) The velocity of centre of mass of the ring is $\sqrt{gh}$ when it reaches at bottom
(D) The velocity of centre of mass of each body is $\sqrt{2gh}$ when it reaches at bottom

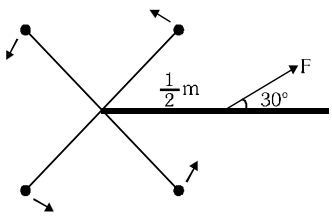
Subjetive Questions

100*. A homogeneous rod AB of length L = 1.8 m and mass M is pivoted at the centre O in such a way that it can rotate freely in the vertical plane (fig.). The rod is initially in the horizontal position. An insect S of the same mass M falls vertically with speed v on the point C, midway between the points O and B. Immediately after falling, the insect moves towards the end B such that the rod rotates with a constant angular velocity ω.

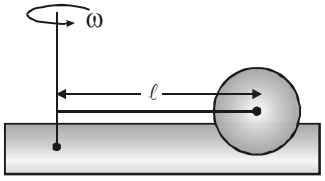


(i) Determine the angular velocity ω in terms of v and L.
(ii) If the insect reaches the end B when the rod has turned through an angle of 90°, determine v.

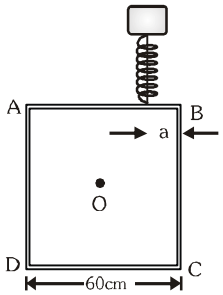
101. Four 2kg masses are connected by $\frac{1}{4}$ m long spokes to an axle as in shown figure. A force F of 24N acts on a lever $\frac{1}{2}$ m long to produce an angular acceleration α. Determine the magnitude of α.



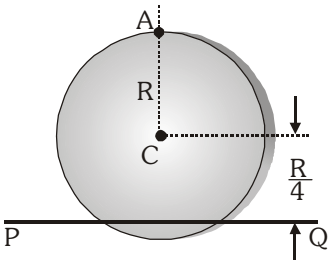
102. A thin rod is passing through the centre of a sphere. The rod is fixed to a vertical axis and the sphere is made to roll on a surface with friction. The radius of the sphere is r, the mass is m and the length of the rod is ℓ. The rod is rotating with an angular velocity ω_0. Find the energy of the sphere in terms of ω_0, m, ℓ and r. Assume the rod to be of negligible mass.



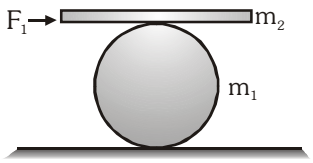
103. A square frame is formed by four rods, each of length ℓ = 60 cm. Mass of two rods AB and BC is m = 25/18 kg each while that of rods AD and CD is 2kg each. The frame is free to rotate about a fixed horizontal axis passing through its geometric centre O shown in figure. A spring is placed on the rod AB at a distance a = 15 cm from B. The spring is held vertical and a block is placed on upper end of the spring so that rod AB is horizontal. Calculate mass M of the block.



104. A uniform circular disc has radius R and mass m. A particle, also of mass m, is fixed at a point A on the edge of the disc as shown in the figure. The disc can rotate freely about a horizontal chord PQ that is at a distance $\frac{R}{4}$ from the centre C of the disc. The line AC is perpendicular to PQ. Initially the disc is held vertical with the point A at its highest position. It is then allowed to fall, so that it starts rotation about PQ. Find the linear speed of the particle as it reaches its lower position. ***[IIT-JEE 1998]***



105*. A man pushes a cylinder of mass m_1 with the help of a plank of mass m_2 as shown. There is no slipping at any contact. The horizontal component of the force applied by the man is F, Find :



(i) the acceleration of the plank and the centre of mass of the cylinder and

(ii) the magnitude and directions of frictional forces at contact points. ***[IIT-JEE 1999]***

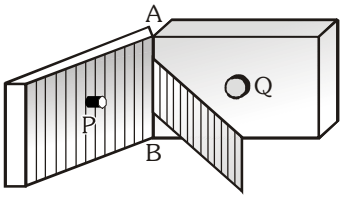
106. A rod AB of mass M and length L is lying on a horizontal frictionless surface. A particle of mass m travelling along the surface hits the end A of the rod with a velocity v_0 in a direction perpendicular to AB. The collision is elastic. After the collision the particle comes to rest. ***[IIT-JEE 2000]***

(i) Find the ratio $\frac{m}{M}$

(ii) A point P on the rod is at rest immediately after collision. Find the distance AP.

(iii) Find the linear speed of the point P after a time $\frac{\pi L}{3V_0}$ after the collision.

107*. Two heavy metallic plates are joined together at 90° to each other. A laminar sheet of mass 30 kg is hinged at the line AB joining the two heavy metallic plates. The hinges are frictionless. The moment of inertia of the laminar sheet about an axis parallel to AB and passing through its centre of mass is 1.2 kg-m^2. Two rubber obstacles P and Q are fixed, one on each metallic plate at a distance 0.5 m from the line AB. This distance is chosen, so that the reaction due to the hinges on the laminar sheet is zero during the impact. Initially the laminar sheet hits one of the obstacles with an angular velocity 1 rad/s and turns back. If the impulse on the sheet due to each obstacle is 6 N-s. ***[IIT-JEE 2001]***

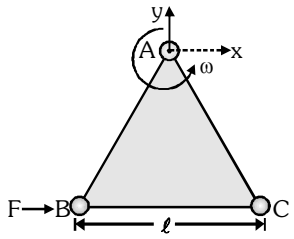


(i) Find the location of the centre of mass of the laminar sheet from AB.

(ii) At what angular velocity does the laminar sheet come back after the first impact.

(iii) After how many impact, does the laminar sheet come to rest.

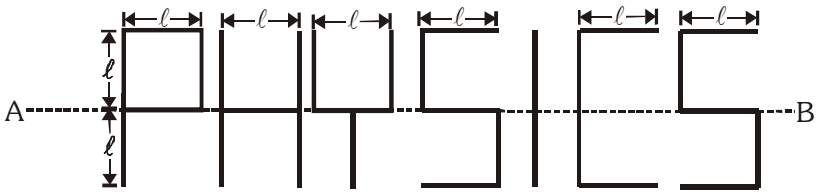
108*. Three particles A, B and C each of mass m, are connected to each other by three massless rigid rods to form a rigid, equilateral triangular body of side ℓ. This body is placed on a horizontal frictionless table (x-y plane) and is hinged to it at the point A, so that it can move without friction about the vertical axis through A (see figure). The body is set into rotational motion on the table about A with a constant angular velocity ω. ***[IIT-JEE 2002]***



(i) Find the magnitude of the horizontal force exerted by the hinge on the body.

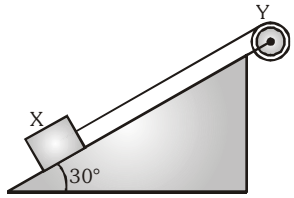
(ii) At time T, when the side BC is parallel to the x-axis, a force F is applied on B along BC (as shown). Obtain the x-component and the y-component of the force exerted by the hinge on the body, immediately after time T.

109. Find out the moment of inertia of the following structure (written as ***PHYSICS***) about axis AB and made of thin uniform rods of the mass per unit length λ.



110. Two uniform rods A and B of length 0.6 m each and of masses 0.01 kg and 0.02 kg respectively are rigidly joined end to end. The combination is pivoted at the lighter end, P as shown in figure. Such that it can freely rotate about point P in a vertical plane. A small object of mass 0.05 kg, moving horizontally, hits the lower end of the combination and sticks to it. What should be the velocity of the object, so that the system could just be raised to the horizontal position.

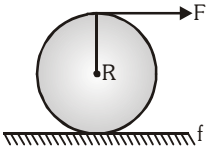
111*. A block X of mass 0.5 kg is held by a long massless string on a frictionless inclined plane of inclination 30° to the horizontal. The string is wound on a uniform solid cylindrical drum Y of mass 2 kg and of radius 0.2 m as shown in figure. The drum is given an initial angular velocity such that the block X starts moving up the plane.



(i) Find the tension in the string during the motion.

(ii) At a certain instant of time the magnitude of the angular velocity of Y is 10 rad s^{-1}. Calculate the distance travelled by X from that instant of time until it comes to rest.

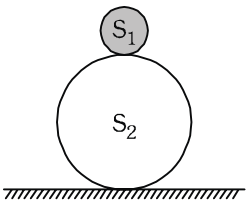
112. A tangential force F acts at the top of a thin spherical shell of mass m and radius R. Find the acceleration of the shell if it rolls without slipping.



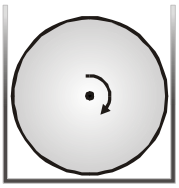
113. A moving particle in X - Y plane has its angular momentum in Z-direction only. Prove it.

114. A solid cylinder of mass 5 kg and radius 30 cm, and free to rotate about its axis, receives an angular impulse of 3 kg $m^2 s^{-1}$ initially followed by a similar impulse after every 4s. What is the angular speed of the cylinder after 30s of the initial impulse ? The cylinder is at rest initially.

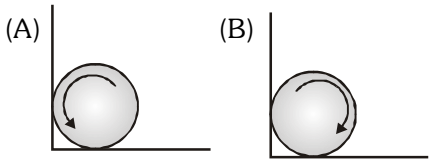
115*. S_2 is a fixed rough sphere and S_1 is a solid sphere. S_1 is given a negligible velocity, so that it starts moving on the sphere S_2. It rolls without slipping. Find the angle formed with the vertical, by the line joining the centres of S_1 and S_2 when S_1 leaves S_2.



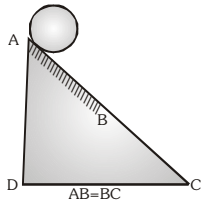
116*. A solid sphere of mass 5 kg and radius 1 m after rotating with angular speed $\omega_0 = 40$ rad/s is placed between two smooth walls on a rough ground. Distance between the walls is slightly greater than the diameter of the sphere. Coefficient of friction between the sphere and the ground is $\mu = 0.1$. Find the time after sphere will stop rotating.



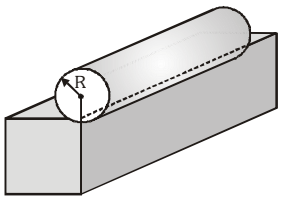
117. A sphere is placed rotating with its centre initially at rest in a corner as shown in figure (A) & (B). Coefficient of friction between all surfaces and the sphere is $\frac{1}{3}$. Find the ratio of the frictional force $\frac{f_a}{f_b}$ by ground in situations (A) & (B)



118*. Portion AB of the wedge shown in figure is rough and BC is smooth. A solid cylinder rolls without slipping from A to B. The ratio of translational kinetic energy to rotational kinetic energy, when the cylinder reaches point C is



119*. A rectangular rigid fixed block has a long horizontal edge. A solid homogeneous cylinder of radius R is placed horizontally at rest with its length parallel to the edge such that the axis of the cylinder and the edge of the block are in the same vertical plane as shown in figure. There is sufficient friction present at the edge, so that a very small displacement causes the cylinder to roll of the edge without slipping. Determine :

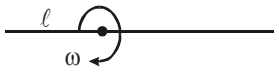


(i) The angle θ_C through which the cylinder rotates before it leaves contact with the edge.

(ii) The speed of the centre of mass of the cylinder before leaving contact with the edge and

(iii) The ratio of the translational to rotational kinetic energies of the cylinder when its centre of mass is in horizontal line with the edge.

120. A uniform rod of length 4ℓ and mass m is free to rotate about a horizontal axis passing through a point distance ℓ from its one end. When the rod is horizontal, its angular velocity is ω as shown in figure. Calculate



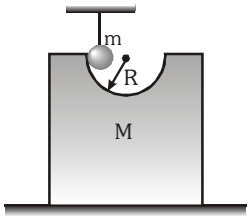
(i) reaction of axis at this instant,

(ii) acceleration of centre of mass of the rod at this instant,

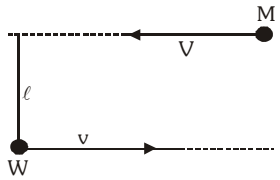
(iii) reaction of axis and acceleration of centre of mass of the rod when rod becomes vertical for the first time.

(iv) minimum value of ω so that centre of rod can complete circular motion.

121*. A semi circular track of radius R = 62.5 cm is cut in a block. Mass of block, having track, is M = 1 kg and rests over a smooth horizontal floor. A cylinder of radius r = 10 cm and mass m = 0.5 kg is hanging by thread such that axis of cylinder and track are in same level and surface of cylinder is in contact with the track as shown in figure. When the thread is burnt, cylinder starts to move down the track. Sufficient friction exists between surface of cylinder and track, so that cylinder does not slip. Calculate velocity of axis of cylinder and velocity of the block when it reaches bottom of the track. Also find force applied by block on the floor at the moment. (g = 10 m/s^2)



122. A man and a woman skate towards each other on smooth ice, but in parallel lines. The distance between the lines is ℓ. The mass of the man is M and that of the woman is m. The velocity of the man is given by V and that of the woman by v. The woman holds a stick of length ℓ and negligible mass. The stick is directed normal to the direction of motion as shown in the figure. When the couple passes each other, the man grasps the stick and the couple move together, each of them holding different ends of the stick.



(i) What is the angular velocity of the rod after the couple begin moving together ?

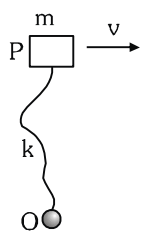
(ii) The couple start moving towards each other by pulling the stick until the distance between them is $\ell_0 (\ell_0 < \ell)$. What is the velocity of the centre of mass now ?

(iii) What is the angular velocity of the couple now ?

(iv) What is the work done by the couple as they move from ℓ to ℓ_0 ?

123. A small ring of mass m is threaded on a horizontal smooth rod which is rotating about its end with constant angular velocity ω. The ring is initially located at near the axis of rotation. When the distance of the ring from the axis becomes r, then find the power required to rotate the system with same angular velocity.

124*. A 500 g block P rests on a frictionless horizontal table at a distance of 400 mm from a fixed pin O. The block is attached to pin O by an elastic cord of force constant k = 100 N/m and of underformed length 900 mm. If the block is set in motion perpendicularly, determine:

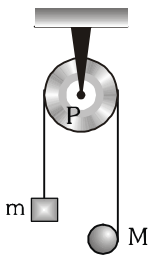


(a) the speed in the begining for which the distance from O to the block P will reach the maximum value of 1.2 m.

(b) the speed when OP = 1.2 m

(c) the radius of curvature of the path of the block when OP = 1.2 m

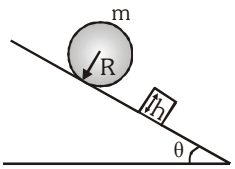
125*. A massless string passes over a massless fixed ideal pulley P and carries a block of mass m = 1 kg at one end. The other end of the string is wound up on the circumference of a solid cylinder of mass M = 2 kg which hangs as shown.



(i) Find the acceleration of the centre of mass of M. Slipping is absent. [Take g = 10 m/s^2]

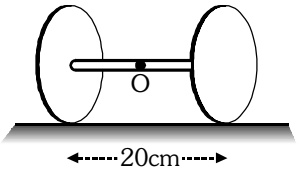
(ii) Find out the acceleration of m.

126*.Find minimum height of obstacle so that the sphere can stay in equilibrium



127*. Determine the minimum co-efficient of friction between a thin uniform rod and a floor at which a person can slowly lift the rod from the floor without slipping, to the vertical position applying to its end a force always perpendicular to its length.

128*. Two thin circular disc of mass 2 kg and radius 10 cm each are joined by a rigid massless rod of length 20 cm. The axis of the rod is along the perpendicular to the planes of the disc through their centres. This object is kept on a truck in such a way that the axis of the object is horizontal and perpendicular to the direction of motion of the truck. Its friction with the floor of the truck is large enough, so that the object can roll on the truck without slipping.



Take x-axis as the direction of motion of the truck and z-axis as the vertically upwards direction. If the truck has an acceleration 9 m/s^2, calculate :

(i) the force of friction on each disc and

(ii) the magnitude and direction of the frictional torque acting on each disc about the centre of mass O of the object. Express the torque in the vector form in terms of unit vector $\hat{i}$, $\hat{j}$ and $\hat{k}$ in x, y and z-directions.

129*. A carpet of mass M made of inextensible material is rolled along its length in the form of a cylinder of radius R and is kept on a rough floor. The carpet starts unrolling without sliding on the floor when a negligibly small push is given to it. Calculate the horizontal velocity of the axis of the cylindrical part of the carpet when its radius reduces to $\frac{R}{2}$. (Neglect vertical component of velocity of centre of mass)

* * * * *

ANSWERS

- ***True and False***

1.	False	**2.**	False	**3.**	False	**4.**	True	**5.**	True
6.	True								

- ***Fill in the Blanks***

7. –3 **8.** $\frac{mg}{6}$, up **9.** $\left(\frac{d-x}{d}\right)w$, $\frac{xw}{d}$ **10.** $4.8\,Ma^2$

11. $\frac{1}{2}MRA\omega^2$ **12.** (60) **13.** $\frac{M\omega_0}{M+6m}$

- ***Assertion–Reason***

14.	D	**15.**	D	**16.**	A	**17.**	A	**18.**	B
19.	D	**20.**	D	**21.**	A	**22.**	D	**23.**	D

- ***Single Choice Correct***

24*.	B	**25*.**	C	**26*.**	C	**27.**	A	**28*.**	C
29.	C	**30.**	C	**31.**	B	**32.**	B	**33.**	B
34.	B	**35.**	D	**36.**	C	**37.**	D	**38.**	C
39.	D	**40.**	B	**41.**	C	**42.**	D	**43.**	C
44.	B	**45.**	B	**46.**	A	**47.**	C	**48.**	C
49.	B	**50.**	C	**51.**	D	**52.**	A	**53.**	B
54.	C	**55.**	A	**56.**	A	**57.**	A	**58.**	B
59.	A	**60.**	A	**61.**	B	**62.**	A		

- ***Multiple Choice Correct***

63*.	ACD	**64*.**	ABC	**65*.**	AD	**66*.**	ABC	**67.**	CD
68.	D	**69.**	ABC	**70*.**	AB				

- ***Match the Column***

71. (A) q,t,u (B) q,t,u (C) q,t,u
72. (A) q, (B) s, (C) q, (D) q
73. (A) q, (B) r, (C) p (D) r
74. (A) p,q,r (B) p,q,r (C) p,q (D) p,q,r

- ***Comprehension***

Comprehension-1 :	**75.**	B	**76.**	A					
Comprehension-2 :	**77.**	A	**78.**	C					
Comprehension-3 :	**79.**	D	**80.**	B					
Comprehension-4 :	**81.**	C	**82.**	A					
Comprehension-5 :	**83.**	A	**84.**	C	**85.**	B	**86.**	C	

Comprehension-6 :	***87.***	D	***88.***	C			
Comprehension-7 :	***89.***	ABC	***90.***	C	***91.***	BCD	***92.*** ACD
Comprehension-8 :	***93.***	C	***94.***	B			
Comprehension-9 :	***95.***	A	***96.***	D	***97.***	D	
Comprehension-10 :	***98.***	ABCD	***99.***	BC			

- ***Subjective Questions***

100. (i) $\frac{12v}{7\ell}$ (ii) 3.5 m/s

101. 12 rad/s^2

102. $\frac{1}{2}\left(\frac{2}{5}mr^2 + m\ell^2\right)\omega^2 + \frac{1}{2}\left(\frac{2}{5}mr^2\right)\omega_0^2$ where $\omega_0 = \frac{v}{r} = \frac{\ell\omega}{r}$

103. $\frac{11}{9}$ kg

104. $\sqrt{5gR}$

105. (i) $a_{cm} = \frac{4F}{3m_1 + 8m_2}$, $a_{plank} = \frac{8F}{3m_1 + 8m_2}$ (ii) $\frac{3m_1F}{(3m_1 + 8m_2)}$, $\frac{m_1F}{(3m_1 + 8m_2)}$

106. (i) $\frac{1}{4}$ (ii) $\frac{2}{3}L$ (iii) $\frac{v_0}{2\sqrt{2}}$

107. (i) 0.1 m (ii) 1 rad/s (iii) Laminar sheet will never come to rest

108. (i) $\sqrt{3}m\omega^2\ell$ (ii) $F_x = -\frac{F}{4}$, $F_y = \sqrt{3}\ m\omega^2\ell$

109. $13\lambda\ell^3$

110. 6.3 m/s

111. (i) 1.63 N (ii) 1.22 m

112. $\frac{6F}{5m}$

114. 106.7 rad/s

115. $\theta = \cos^{-1}\left(\frac{10}{17}\right)$

116. 16 sec.

117. 9/10

118. 5

119. (i) $\theta = \cos^{-1}\left(\frac{4}{7}\right)$ (ii) $\sqrt{\frac{4gR}{7}}$ (iii) 6

120. (i) $\frac{4}{7}mg\sqrt{1 + \left(\frac{7\ell\omega^2}{4g}\right)^2}$ (ii) $\sqrt{\left(\frac{3g}{7}\right)^2 + \left(\ell^2\omega\right)^2}$ (iii) $\left(\frac{13}{7}mg + m\ell\omega^2\right)$, $\left(\frac{6g}{7}\right) + \ell\omega^2$ (iv) $\sqrt{\frac{6g}{7\ell}}$

121. 2 m/s, 1 m/s, 13.57 N

122. (i) $\frac{V+v}{\ell}$ (ii) $\frac{MV - mv}{M+m}$ (iii) $\left(\frac{V+v}{\ell}\right)\left(\frac{\ell}{\ell_0}\right)^2$ (iv) $\frac{1}{2}\frac{Mm}{M+m}(V+v)^2\left[1 - \frac{\ell}{\ell_0}\right]$

123. $2m\omega^3r^2$

124. (a) 4.5 m/s (b) 1.5 m/s (c) 3.75 cm

125. (i) 6 m/s^2 ↓, (ii) 2 m/s^2 ↓

126. $R(1 - \cos\theta)$

127. $\frac{1}{2\sqrt{2}}$

128. (i) $6\hat{i}$ N (ii) $0.6\left(-\hat{j} \pm \hat{k}\right)$, 0.85 Nm

129. $\sqrt{\frac{14Rg}{3}}$

GRAVITATION

True/False

1. Gravitational force is a conservative and central force.

2. For bounded system, potential energy must be negative.

3. Two air bubbles in water attract each other.

Fill in the blanks

4. The escape velocity for a planet is v_e. A particle starts from rest at a large distance from the planet, reaches the planet only under gravitational attraction, and passes through a smooth tunnel through its centre. Its speed at the centre of the planet will be .....

5. An exploratory rocket of mass m is in orbit about the Sun of mass M_s at a radius $\frac{R_{Es}}{10}$ (R_{Es} = distance of Sun from Earth). To exit from this orbit, it fires its engine over a short period of time. This quickly doubles the velocity of rocket while its mass reduces to half due to fuel consumption. Immediately after firing the engine, the kinetic energy of the rocket is .....

6. Two point masses each of mass m separated by a large distance are attracted towards each other due to gravitational interaction . If they start from rest then speed of each mass when they are separated by distance r is .....

7. The numerical value of the angular velocity of rotation of the Earth should be ..... rad/s in order to make the effective acceleration due to gravity at equator equal to zero.

8. According to Kepler's second law, the radius vector to a planet from the Sun sweeps out equal areas in equal intervals of time. This law is consequence of the conservation of .....

9. The ratio of Earth's orbital angular momentum (about the Sun) to its mass is 4.4×10^{15} m^2/s. The area enclosed by Earth's orbit approximately ..... m^2.

10. A particle is projected vertically upwards from the surface of Earth (radius R) with a kinetic energy equal to half of the minimum value needed for it to escape. The height to which it rises above the surface of Earth is .....

Assertion & Reason Type

These questions contains, Statement 1 (assertion) and Statement 2 (reason).

(A) Statement–1 is True, Statement–2 is True ; Statement–2 is a correct explanation for Statement–1
(B) Statement–1 is True, Statement–2 is True ; Statement–2 is not a correct explanation for Statement–1
(C) Statement–1 is True, Statement–2 is False.
(D) Statement–1 is False, Statement–2 is True.

11. ***Statement – 1 :*** Two satellites A & B are in the same orbit around the Earth, B being behind A. B cannot overtake A by increasing its speed.
and
Statement – 2 : It will then go into a different orbit.

12. ***Statement – 1 :*** The acceleration of a particle near the Earth surface differs slightly from the gravitational acceleration $a_g = GM/R^2$.
and
Statement – 2 : The Earth is not a uniform sphere and because the Earth rotates.

13. ***Statement – 1 :*** Kepler's law of areas is equivalent to the law of conservation of angular momentum.
and
Statement – 2 : Areal velocity $\frac{dA}{dt} = \frac{L}{2m}$ = constant

14. ***Statement – 1 :*** A satellite is moving in a circular orbit of the Earth. If the gravitational pull suddenly disappears, then it moves with the same speed tangential to the original orbit.
and
Statement – 2 : The orbital speed of a satellite increases with the increase in radius of the orbit.

15. ***Statement – 1 :*** A person feels weightlessness in an artificial satellite of the Earth. However a person on the Moon (natural satellite) feels his weight.
and
Statement – 2 : Artificial satellite is a freely falling body and on the Moon surface, the weight is mainly due to Moon's gravitational attraction.

16. ***Statement – 1 :*** Moon cannot be used as a satellite for communication.
and
Statement – 2 : Moon doesn't move in the equatorial plane of the Earth.

17. ***Statement – 1 :*** Moon has no atmosphere.
and
Statement – 2 : Due to less gravity Moon is unable to retain its atmosphere.

18. ***Statement – 1 :*** Pendulum clock stops working on the spaceship.
and
Statement – 2 : Pendulum of the pendulum clock falls down on the spaceship.

19. ***Statement – 1 :*** Escape velocity is independent of the angle of projection.
and
Statement – 2 : Escape velocity for vertical projection from the surface of Earth is $\sqrt{\frac{2GM}{R}}$.

20. ***Statement – 1 :*** The plane of the orbit of an artificial satellite must contain the centre of the Earth.
and
Statement – 2 : For an artificial satellite, the necessary centripetal force is provided by gravity.

21. ***Statement – 1 :*** When a planet approaches the point which is farthest from the Sun, its orbital speed decreases.
and
Statement – 2 : Work done on the planet by the gravitational force exerted by the Sun is negative.

Multiple Choice Correct

22. Gravitational potential difference between surface of a planet and a point situated at a height of 20m above its surface is 2 joule/kg. If gravitational field is uniform, then the work done in taking a 5kg body of height 4 meter above surface will be :–
(A) 2J (B) 20J (C) 40J (D) 10J

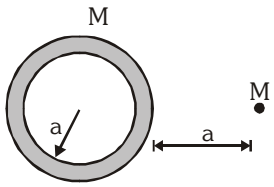
23. In a certain region of space, the gravitational field is given by $-\frac{k}{r}$, where r is the distance and k is a constant. If the gravitational potential at $r = r_0$ be V_0, then what is the expression for the gravitational potential (V) :–
(A) $k \log_e \left(\frac{r}{r_0}\right)$ (B) $k \log_e \left(\frac{r_0}{r}\right)$ (C) $V_0 + k \log_e \left(\frac{r}{r_0}\right)$ (D) $V_0 + k \log_e \left(\frac{r_0}{r}\right)$

24. Two metallic balls of mass m are suspended by two strings of length L. The distance between upper ends is ℓ. The angle at which the string will be inclined with vertical due to attraction, is (m<<M, where M is the mass of Earth):
(A) $\tan^{-1}\frac{Gm}{g\ell^2}$ (B) $\tan^{-1}\frac{Gm}{gL^2}$ (C) $\tan^{-1}\frac{Gm}{g\ell}$ (D) $\tan^{-1}\frac{Gm}{gL}$

25. If there were a smaller gravitational effect, which of the following forces do you think would alter in some respect.
(A) Viscous force (B) Archimedes uplift (C) Electrostatic force (D) Magnetic force

26. Select the correct alternative :–
(A) The gravitational field inside a spherical cavity, within a spherical planet must be non zero and uniform
(B) When a body is projected horizontally at an appreciable large height above the Earth, with a velocity less than for a circular orbit, it will fall to the Earth along a parabolic path
(C) A body of zero total mechanical energy placed in a gravitational field will escape the field
(D) Earth's satellite must be in equatorial plane

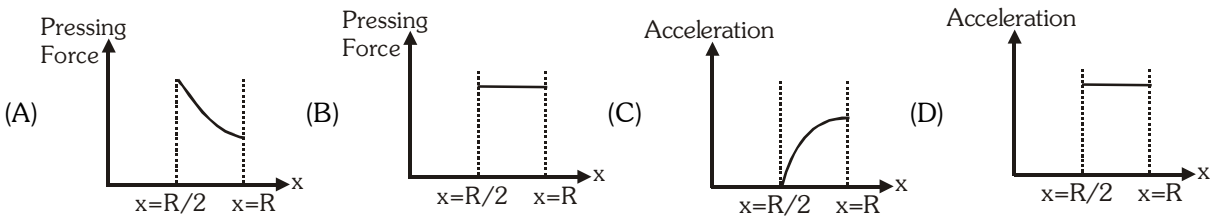
27. A particle of mass M is at a distance a from surface of a thin spherical shell of equal mass and having radius a



(A) Gravitational field and potential both are zero at centre of the shell
(B) Gravitational field is zero not only inside the shell but at a point outside the shell also
(C) Inside the shell, gravitational field alone is zero
(D) Neither gravitational field nor gravitational potential is zero inside the shell

28. When a satellite in a circular orbit around the Earth enters the atmospheric region, it encounters small air resistance to its motion. Then
(A) Its kinetic energy increases (B) Its kinetic energy decreases
(C) Its angular momentum about the Earth decreases (D) Its period of revolution around the Earth increases

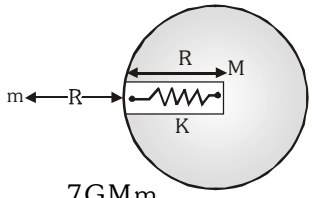
29. A tunnel is dug along a chord of the Earth at a perpendicular distance R/2 from the Earth's centre. The wall of the tunnel may be assumed to be frictionless. A particle is released from one end of the tunnel. The pressing force by the particle on the wall, and the acceleration of the particle varies with x (distance of the particle from the centre) according to :



30. Gravitational potential at the centre of curvature of a hemispherical bowl of radius R and mass M is V :–
(A) Gravitational potential at the centre of curvature of a thin uniform wire of mass M, bent into a semicircle of radius R, is also equal to V
(B) In part (A) if the same wire is bent into a quarter of a circle then also the gravitational potential at the centre of curvature will be V
(C) In part (A) if the wire mass is non uniformly distributed along its length audit is bent into a semicircle of radius R, gravitational potential at the centre is V
(D) None of these

31. Suppose a smooth tunnel is dug along a straight line joining two points on the surface of the Earth and a particle is dropped from rest at its one end. Assume that mass of Earth is uniformly distributed over its volume. Then
(A) The particle will emerge from the other end with velocity $\sqrt{\frac{GM_e}{2R_e}}$ where M_e and R_e are Earth's mass and radius respectively
(B) The particle will come to rest at centre of the tunnel because at this position, particle is closest to Earth centre.
(C) Potential energy of the particle will be equal to zero at centre of tunnel if it is along tunnel's diameter
(D) Acceleration of the particle will be proportional to its distance from midpoint of the tunnel

32. A small ball of mass 'm' is released at a height 'R' above the Earth surface, as shown in the figure. If the maximum depth of the ball to which it goes is R/2 inside the Earth through a narrow grove before coming to rest momentarily. The grove, contain an ideal spring of spring constant K and natural length R, the value of K is (R is radius of Earth and M mass of Earth)



(A) $\frac{3GMm}{R^3}$ (B) $\frac{6GMm}{R^3}$ (C) $\frac{9GMm}{R^3}$ (D) $\frac{7GMm}{R^3}$

33. A particle of mass m is transferred from the centre of the base of a uniform solid hemisphere of mass M and radius R to infinity. The work performed in the process by the gravitational force exerted on the particle by the hemisphere is

(A) $\frac{GMm}{R}$ (B) $-\frac{1}{2}\frac{GMm}{R}$ (C) $-\frac{3}{2}\frac{GMm}{R}$ (D) $-\frac{3}{4}\frac{GMm}{R}$

34. Masses and radii of Earth and Moon are M_1, M_2 and R_1, R_2 respectively. The distance between their centre is 'd'. The minimum velocity given to mass 'M' from the mid point of line joining their centre so that it will escape :–

(A) $\sqrt{\frac{4G(M_1+M_2)}{d}}$ (B) $\sqrt{\frac{4G}{d}\frac{M_1M_2}{(M_1+M_2)}}$ (C) $\sqrt{\frac{2G}{d}\left(\frac{M_1+M_2}{M_1M_2}\right)}$ (D) $\sqrt{\frac{2G}{d}(M_1+M_2)}$

35. A satellite is in a circular orbit very close to the surface of a planet. At some point it is given an impulse along its direction of motion, causing its velocity to increase n times. It now goes into an elliptical orbit. The maximum possible value of n for this to occur is

(A) 2 (B) $\sqrt{2}$ (C) $\sqrt{2}+1$ (D) $\frac{1}{\sqrt{2}-1}$

Match the Column

36. A satellite is in a circular equatorial orbit of radius 7000 km around the Earth. If it is transferred to a circular orbit of double the radius

Column I	Column II
(A) Angular momentum	(p) Increases
(B) Area of Earth covered by satellite signal	(q) Decreases
(C) Potential energy	(r) Becomes double
(D) Kinetic energy	(s) Becomes half

Comprehension

Two stars bound together by gravity orbit each other because of their mutual attraction. Such a pair of stars is referred to as a binary star system. One type of binary system is that of a black hole and a companion star. The black hole is a star that has collapsed on itself and is so massive that not even light rays can escape its gravitational pull. Therefore when describing the relative motion of a black hole and a companion star, the motion of the black hole can be assumed negligible compared to that of the companion.

The orbit of the companion star is either elliptical with the black hole at one of the foci or circular with the black hole at the centre. The gravitational potential energy is given by U = – GmM/r, where G is the universal gravitational constant, m is the mass of the companion star, M is the mass of the block hole, and r is the distance between the centre of the companion star and the centre of the black hole. Since the gravitational force is conservative, the companion star's total mechanical energy is a constant. Because of the periodic nature of the orbit, there is a simple relation between the average kinetic energy <K> of the companion star and its average potential energy <U>. In particular, <K> = <–U/2>.

Two special points along the orbit are single out by astronomers. Parigee is the point at which the companion star is closest to the black hole, and apogee is the point at which is the farthest from the black hole.

37. For circular orbits the potential energy of the companion star is constant throughout the orbit. If the radius of the orbit doubles, what is the new value of the velocity of the companion star ?

(A) It is 1/2 of the old value (B) It is $1/\sqrt{2}$ of the old value

(C) It is the same as old value (D) It is double the old value

38. Which of the following prevents the companion star from leaving its orbit and falling into the black hole ?
(A) The centripetal force
(B) The gravitational force
(C) The companion star's potential energy
(D) The companion star's kinetic energy

Subjetive Questions

39. The gravitational field in a region is given by $\vec{E} = (3\hat{i} - 4\hat{j})$ N/kg. Find out the work done (in joule) in displacing a particle by 1 m, along the line $4y = 3x + 9$:

40. A thin spherical shell of total mass M and radius R is held fixed. There is a small hole in the shell. A mass m is released from rest a distance R from the hole along a line that passes through the hole and also through the centre of the shell. This mass subsequently moves under the gravitational force of the shell. How long does the mass take to travel from the hole to the point diametrically opposite.

41. Find the potential energy of the gravitational interaction of a point mass of mass m and a thin uniform rod of mass M and length ℓ , if they are located along a straight line such that the point mass is at a distance 'a' from one end. Also find the force of their interaction.

42. A comet orbits the Sun in a highly elliptical orbit. Does the comet have a constant
(i) linear speed, (ii) angular speed, (iii) angular momentum, (iv) kinetic energy, (v) potential energy, (vi) total energy throughout its orbit ? Neglect any mass loss of the comet when it comes very close to the Sun.

43. A small satellite revolves around a heavy planet in a circular orbit. At certain point in its orbit a sharp impulse acts on it and instantaneously increases its kinetic energy to 'k' (<2) times without change in its direction of motion. Show that in its subsequent motion the ratio of its maximum and minimum distances from the planet is $\frac{k}{2-k}$, assuming the mass of the satellite is negligibly small as compared to that of the planet.

44. A satellite of mass m is in an elliptical orbit around the Earth of mass M (M>>m). The speed of the satellite at its nearest point to the Earth (perigee) is $\sqrt{\frac{6GM}{5R}}$ where R = its closest distance to the Earth. It is desired to transfer this satellite into a circular orbit around the Earth of radius equal its largest distance from the Earth. Find the increase in its speed to be imparted at the apogee (farthest point on the elliptical orbit).

45. A body is launched from the Earth's surface a angle $\alpha = 30^0$ to the horizontal at a speed $v_0 = \sqrt{\frac{1.5GM}{R}}$.
Neglecting air resistance and Earth's rotation, find (i) the height to which the body will rise. (ii) The radius of curvature of trajectory at its top point.

46. Distance between the centres of two starts is 10a. The masses of these stars are M and 16M and their radii a and 2a respectively. A body of mass m is fired straight from the surface of the larger star towards the surface of the smaller star. What should be its minimum initial speed to reach the surface of the smaller star ? Obtain the expression in terms of G, M and a.

47. The minimum and maximum distances of a satellite from the centre of the Earth are 2R and 4R respectively, where R is the radius of Earth and M is the mass of the Earth. Find radius of curvature at the point of minimum distance.

48. A particle takes n seconds less and acquires a velocity u m/sec. higher at one place than at another place in falling through the same distance. Calculate the product of the acceleration due to gravity at these two places.

49. A satellite of mass M_s is orbiting the Earth in a circular orbit of radius R_s. It starts losing energy slowly at a constant rate C due to friction. If M_e and R_e denote the mass and radius of the Earth respectively, show that the satellite falls on the Earth in a limit time t given by $t = \frac{GM_SM_e}{2C}\left(\frac{1}{R_e} - \frac{1}{R_S}\right)$

50. A rocket starts vertically upwards with speed v_0. Show that its speed v at a height h is given by

$$v_0^2 - v^2 = \left[(2gh)/\left(1+\frac{h}{R}\right)\right]$$

Where R is the radius of the Earth. Hence deduce the maximum height reached by a rocket fired with speed equal to 90% of escape velocity.

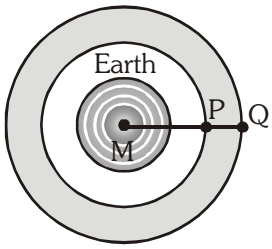
51. A cord of length 64 m is used to connect a 100 kg astronaut to spaceship whose mass is much larger than that of the astronaut. Estimate the value of the tension in the cord. Assume that the spaceship is orbiting near Earth surface. Assume that the spaceship and the astronaut fall on a straight line from the Earth centre. The radius of the Earth is 6400 km.

52. A remote sensing satellite is revolving in an orbit of radius x on the equator of Earth. Find the area on Earth surface in which satellite can not send message.

53. Calculate the distance from the surface of the Earth at which above and below the surface, acceleration due to gravity is the same.

54. A body moving radially away from a planet of mass M, when at distance r from planet, explodes in such a way that two of its many fragments move in mutually perpendicular circular orbits around the planet. What will be
(i) Then velocity in circular orbits ?
(ii) Maximum distance between the two fragments before collision and
(iii) Magnitude of their relative velocity just before they collide ?

55. A satellite P is revolving around the Earth at a height h= radius of Earth (R) above equator. Another satellite Q is at a height 2h revolving in opposite direction. At an instant the two are at same vertical line passing through centre of sphere.
Find the least time of after which again they are in this situation.



56. The fastest possible rate of rotation of a planet is that for which the gravitational force on material at the equator barely provides the centripetal force needed for the rotation. (Why?)

(i) Show then that the corresponding shortest period of rotation is given by $T = \sqrt{\frac{3\pi}{G\rho}}$ where ρ is the density of the planet, assumed to be homogeneous.
(ii) Evaluate the rotation period assuming a density of 3.0 gm/cm^3, typical of many planets, satellites, and asteroids. No such object is found to be spinning with a period shorter than found by this analysis.

57. In a particular double star system, two stars of mass 3.22×10^{30} kg each revolve about their common centre of mass, 1.12×10^{11} m away.
(i) Calculate their common period of revolution, in years.
(ii) Suppose that a meteoroid (small solid particle in space) passes through this centre of mass moving at right angles to the orbital plane of the stars. What must its speed be if it is to escape from the gravitational field of the double star?

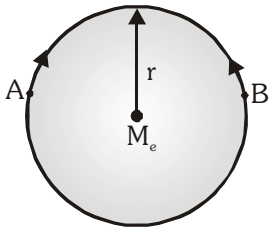
58. Assume that a tunnel is dug across the Earth (radius =R) passing through its centre. Find the time a particle takes to reach centre of Earth if it is projected into the tunnel from surface of Earth with speed needed for it to escape the gravitational field of Earth.

59. Ajay can throw a ball at a speed on Earth which can cross a river of width 10 m. Ajay reaches on an imaginary planet whose mean density is twice of the Earth. Find out the maximum possible radius of planet so that if Ajay throws the ball at same speed it may escape from planet. Given radius of Earth $= 6.4 \times 10^6$ m:

60. A particle takes a time t_1 to move down a straight tunnel from the surface of Earth to its centre. If gravity were to remain constant this time would be t_2. Calculate the ratio $\frac{t_1}{t_2}$

61. A satellite close to the Earth is in orbit above the equator with a period of rotation of 1.5 hours. If it is above a point P on the equator at some time, it will be above P again after time.....

62. Consider two satellites A and B of equal mass m, moving in the same circular orbit of radius r around the Earth E but in opposite sense of rotation and therefore on a collision course (see figure).



(i) In terms of G, M_e, m and r find the total mechanical energy $E_A + E_B$ of the two satellite plus Earth system before collision.

(ii) If the collision is completely inelastic so that wreckage remains as one piece of tangled material (mass =2m), find the total mechanical energy immediately after collision.

(iii) Describe the subsequent motion of the wreckage.

ANSWERS

- ***True and False***

1. True **2.** False **3.** True

- ***Fill in the Blanks***

4. $\sqrt{1.5}v_e$ **5.** $\frac{10GM_s m}{R_{E_S}}$ **6.** $\sqrt{\frac{GM}{r}}$ **7.** 1.25×10^{-3}

8. angular momentum **9.** 6.94×10^{22} **10.** h=R

- ***Assertion–Reason***

11. (A) **12.** (A) **13.** (A) **14.** (C) **15.** (A)
16. (A) **17.** (A) **18.** (C) **19.** (B) **20.** (A)
21. (C)

- ***Multiple Choice Correct***

22. A **23.** D **24.** A **25.** B **26.** C **27.** D **28.** ABCD
29. AD **30.** AC **31.** D **32.** D **33.** C **34.** A **35.** B

- ***Match the Column***

36. (A)-p; (B)-p; (C)-p,s; (D)-q,s

- ***Comprehension***

37. B **38.** D

- ***Subjective Questions***

39. 0 **40.** $2\sqrt{\frac{R^3}{GM}}$ **41.** $-\frac{GMm}{\ell}\log_e\left(1+\frac{\ell}{a}\right)$

42. All quantities vary over an orbit except angular momentum and total energy

43. **44.** $\sqrt{\frac{GM}{R}}\left[\sqrt{\frac{2}{3}}-\sqrt{\frac{8}{15}}\right]$ **45.** (i) $h=\left(\frac{\sqrt{7}}{2}+1\right)R$, (ii) 1.13 R **46.** $\frac{3}{2}\sqrt{\frac{5GM}{a}}$

47. $\frac{8R}{3}$ **48.** $\left(\frac{u}{n}\right)^2$ **50.** 4.26 R **51.** 3×10^{-2}N

52. $\left[1-\frac{\sqrt{x^2-R^2}}{x}\right]4\pi R^2$ **53.** $\left(\frac{\sqrt{5}-1}{2}\right)R$ **54.** (i) $\sqrt{\frac{GM}{r}}$ (ii) $r\sqrt{2}$ (iii) $\sqrt{\frac{2GM}{r}}$

55. $\frac{2\pi R^{3/2}6\sqrt{6}}{\sqrt{GM}\left(2\sqrt{2}+3\sqrt{3}\right)}$ **56.** (ii) 1.9 h

57. (i) $T=4\pi\sqrt{\frac{r^3}{Gm}}$ (ii) $v=\sqrt{\frac{4Gm}{r}}$, $r=\frac{d}{2}$ **58.** $T=\sin^{-1}\left(\frac{1}{\sqrt{3}}\right)\sqrt{\frac{R_e}{g}}$

59. 4 Km **60.** $\frac{\pi}{2\sqrt{2}}$

61. 1.6 hours if it is rotating from west to east, $\frac{24}{17}$ hours if it is rotating east to west.

62. (i) $\frac{-GmM_e}{r}$, (ii) $-\frac{2GmM_e}{r}$ (iii) free fall

KTG & THERMODYNAMICS

True / False

1. The root mean square speeds of the molecules of different ideal gases, maintained at the same temperature are the same.

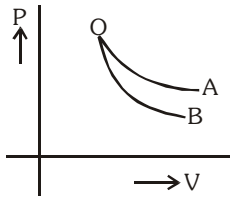
2. The root mean square (rms) speed of oxygen molecules (O_2) at a certain temperature T (degree absolute) is v. If the temperature is doubled and oxygen gas dissociates into atomic oxygen, the rms speed remains unchanged.

3. At a given temperature, the specific heat of a gas at a constant pressure is always greater than its specific heat at constant volume.

4. Given samples of 1 c.c. of hydrogen and 1 c.c. of oxygen, both at N.T.P. Oxygen sample has a larger molecules.

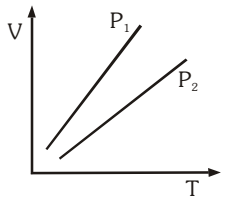
5. A piece of metal is hammered. Its internal energy increase.

6. The curve A and B in fig. show P–V graphs for an isothermal and an adiabatic process for an ideal gas. The isothermal process is represented by the curve A.



7. Temperature of body can be raised without heating.

8. The volume V versus temperature T graphs for a certain amount of a perfect gas at two pressure P_1 and P_2 are as shown in figure. It follows from the graphs that P_1 is greater than P_2.



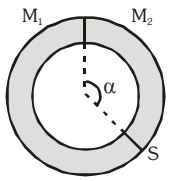
Fill in the blanks

9. One mole of a monoatomic ideal gas is mixed with one mole of a diatomic ideal gas. The molar specific heat of the mixture at constant volume is .....

10. A container of volume 1 m^3 is divided into two equal parts by a partition. One part has an ideal gas at 300 K and the other part is vacuum. The whole system is thermally isolated from the surroundings When the partition is removed, the gas expands to occupy the whole volume. Its temperature will now be .....

11. An ideal gas with pressure P, volume V and temperature T is expended isothermally to a volume 2V and a final pressure P_i. If the same gas is expanded adiabatically to a volume 2V, the final pressure is P_a. The ratio of the specific heats of the gas is 1.67. The ratio $\frac{P_a}{P_i}$ is .....

12. A ring shaped tube contains two ideal gases with equal masses and relative molar masses $M_1 = 32$ and $M_2 = 28$. The gases are separated by one fixed partition and another movable stopper S which can move freely without friction inside the ring. The angle α as shown in the figure is .....degrees.



13. If the degrees of freedom of a gas are f, then $\frac{2C_V}{C_P - C_V}$ will be equal to .....

Assertion-Reason

In each of the following questions, a Statement of Assertion (A) is given followed by a corresponding Statement of Reason (R) just below it . Of the Statements mark the correct answer as

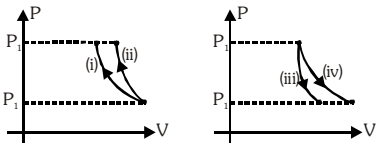
(A) Statement–1 is True, Statement–2 is True ; Statement–2 is a correct explanation for Statement–1
(B) Statement–1 is True, Statement–2 is True ; Statement–2 is not a correct explanation for Statement–1
(C) Statement–1 is True, Statement–2 is False.
(D) Statement–1 is False, Statement–2 is True.

14. ***Statement–1*** : A real gas behaves as an ideal gas at high temperature and low pressure.
and
Statement–2 : Liquid state of an ideal gas is impossible.

15. ***Statement–1*** : The ratio $\frac{C_P}{C_V}$ for a monatomic gas is more than for a diatomic gas.
and
Statement–2 : The molecules of a monatomic gas have more degrees of freedom than those of a diatomic gas.

16. ***Statement–1*** : In adiabatic expansion of monoatomic ideal gas, if volume increases by 24% then pressure decreases by 40%.
and
Statement–2 : For adiabatic process $PV^{\gamma} = \text{constant}$

17. ***Statement–1*** : In following figure curve (i) and (iv) represent isothermal process while (ii) & (iii) represent adiabatic process.



and
Statement–2 : The adiabatic at any point has a steeper slope than the isothermal through the same point.

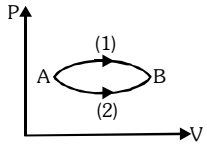
18. ***Statement–1*** : Air quickly leaking out of a balloon becomes cooler.
and
Statement–2 : The leaking air undergoes adiabatic expansion.

19. ***Statement–1*** : Absolute zero temperature is not the temperature of zero energy.
and
Statement–2 : Only the internal kinetic energy of the molecules is represented by temperature.

20. ***Statement–1*** : An ideal gas has infinitely many molar specific heats.
and
Statement–2 : Specific heat is amount of heat needed to raise the temperature of 1 mole of gas by 1 K.

21. ***Statement–1*** : The steam at 100°C causes more severe burn to human body than the water at 100°C.
and
Statement–2 : The steam has greater internal energy due to latent heat of vaporization.

22. ***Statement–1*** : A gas is taken from state A to state B through two different paths. Molar specific heat capacity in path (1) is more as compared to (2).



and
Statement–2 : Specific heat $C = \frac{Q}{n\Delta T}$ & $Q = \Delta U + W$ and W is equal to area under P–V diagram.

23. ***Statement–1*** : On sudden expansion a gas cools.
and
Statement–2 : On sudden expansion, no heat is supplied to system and hence gas does work at the expense of its internal energy.

24. ***Statement–1*** : The isothermal curves never intersect each other.
and
Statement–2 : The isothermal change are done slowly, so the isothermal curves have very little slope.

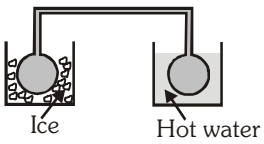
25. ***Statement–1*** : In a process if initial volume is equal to the final volume, work done by the gas is zero.
and
Statement–2 : In an isochoric process work done by the gas is zero.

26. ***Statement–1 :*** When a bottle of cold carbonated drink is opened, a slight fog forms around the opening.
and
Statement–2 : Adiabatic expansion of the gas causes lowering of temperature and condensation of water vapours.

27. ***Statement–1*** : When an electric fan is switched on in a closed room, the air of the room is cooled.
and
Statement–2 : When fan is switched on, the speed of the air molecules will increase.

Single Choice Correct

28. Two identical glass bulbs are interconnected by a thin glass tube at 0°C. A gas is filled at N.T.P. in these bulb is placed in ice and another bulb is placed in hot bath, then the pressure of the gas becomes 1.5 times. The temperature of hot
bath will be :–



(A) 100°C (B) 182°C (C) 256°C (D) 546°C

29. Four containers are filled with monoatomic ideal gases. For each container, the number of moles, the mass of an individual atom and the rms speed of the atoms are expressed in terms of n, m and v_{rms} respectively. If T_A, T_B, T_C and T_D are their temperatures respectively then which one of the options correctly represents the order ?

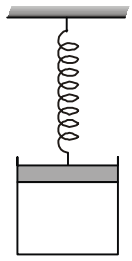
	A	B	C	D
Number of moles	n	3n	2n	n
Mass	4m	m	3m	2m
Rms speed	v_{rms}	$2v_{rms}$	v_{rms}	$2v_{rms}$
Temperature	T_A	T_B	T_C	T_D

(A) $T_B = T_C > T_A > T_D$ (B) $T_D > T_A > T_C > T_B$ (C) $T_D > T_A = T_B > T_C$ (D) $T_B > T_C > T_A > T_D$

30. The density in grams per litre of ethylene (C_2H_4) at STP is :–
(A) 1.25 (B) 2.50 (C) 3.75 (D) 5.25

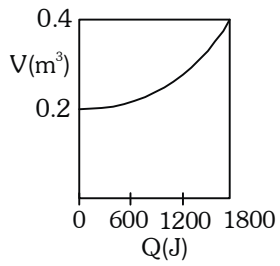
31. Some of the thermodynamic parameters are state variables while some are process variables. Some grouping of the parameters are given. Choose the correct one.
(A) State variables : Temperature, No of moles
Process variables : Internal energy, work done by the gas.
(B) State variables : Volume, Temperature
Process variables : Internal energy, work done by the gas.
(C) State variables : Work done by the gas, heat rejected by the gas
Process variables : Temperature, volume.
(D) State variables : Internal energy, volume
Process variables : Work done by the gas, heat absorbed by the gas.

32. One mole of an ideal gas is kept enclosed under a light piston (area = 10^{-2} m^2) connected by a compressed spring (spring constant 100 N/m). The volume of gas is 0.83 m^3 and its temperature is 100 K. The gas is heated so that it compresses the spring further by 0.1 m. The work done by the gas in the process is: (Take R = 8.3 J/K-mole and suppose there is no atmosphere).



(A) 3 J (B) 6 J (C) 9 J (D) 1.5 J

33. 1 mole of an ideal gas undergoes an isothermal expansion as energy is added to it as heat Q. Graph shows the volume V versus Q. The gas temperature is nearly equal to : (use R = 8.31 J/K mole)



(A) 208.4 K (B) 268.2 K (C) 312.6 K (D) 353.8 K

Multiple Choice Correct

34. Which of the following statements is/are correct ?
(A) A gas has two specific heats only
(B) A material will have only one specific heat, if and only if its coefficient of thermal expansion is equal to zero.
(C) A gas has infinite number of specific heats.
(D) None of these

35. Three closed vessels A, B and C at the same temperature T and contain gases which obey the Maxwellian distribution of velocities. Vessel A contains only O_2, B only N_2 and C a mixture of equal quantities of O_2 and N_2. If the average speed of the O_2 molecules in vessel A is v_1, that of the N_2 molecules in vessel B is v_2, the average speed of O_2 molecules in vessel C is where M is the mass of an oxygen molecule:–

(A) $(v_1+v_2)/2$ (B) v_1 (C) $(v_1 v_2)^{1/2}$ (D) $\sqrt{3kT/M}$

36. During experiment, an ideal gas is found to obey a condition P^2/ρ= constant [ρ = density of the gas]. The gas is initially at temperature T, pressure P and density ρ . The gas expands such that density changes to $\rho/2$

(A) The pressure of the gas changes to $\sqrt{2}$ P
(B) The temperature of the gas changes to $\sqrt{2}$ T
(C) The graph of the above process on the P–T diagram is parabola
(D) The graph of the above process on the P–T diagram is hyperbola

37. An ideal gas can be expanded from an initial state to a certain volume through two different processes (i) PV^2 = constant and (ii) $P = KV^2$ where K is a positive constant. Then:–
(A) Final temperature in (i) will be greater than in (ii)
(B) Final temperature in (ii) will be greater than in (i)
(C) Total heat given to the gas in (i) case is greater than in (ii)
(D) Total heat given to the gas in (ii) case is greater than in (i)

38. When unit mass of water boils to become steam at 100^0C, it absorbs Q amount of heat. The densities of water and steam at 100^0C are ρ_1 and ρ_2 respectively and the atmospheric pressure is P_0. The increase in internal energy of the water is:–

(A) Q (B) $Q+P_0\left(\frac{1}{\rho_1}-\frac{1}{\rho_2}\right)$ (C) $Q+P_0\left(\frac{1}{\rho_2}-\frac{1}{\rho_1}\right)$ (D) $Q-P_0\left(\frac{1}{\rho_1}+\frac{1}{\rho_2}\right)$

39. At temperature T, N molecules of gas A each having mass m and at the same temperature 2 N molecules of gas B each having mass 2 m are filled in a container. The mean square velocity of molecules of gas B is v^2 and x component of mean square velocity of molecules of gas A is w^2. The ratio of w^2/v^2 is :–
(A) 1 (B) 2 (C) 1/3 (D) 2/3

40. A vessel is partitioned in two equal halves by a fixed diathermic separator. Two different ideal gases are filled in left (L) and right (R) halves. The rms speed of the molecules in L part is equal to the mean speed of molecules in the R part. Then the ratio of the mass of a molecule in L part to that of a molecule in R part is:–

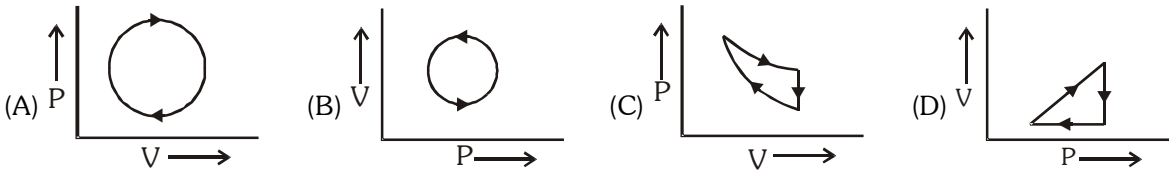
(A) $\sqrt{\frac{3}{2}}$ (B) $\sqrt{\pi/4}$ (C) $\sqrt{2/3}$ (D) $3\pi/8$

41. N(<100) molecules of a gas have velocities 1,2,3.... N, km/s respectively. Then:–
(A) rms speed and average speed of molecules are same
(B) Ratio of rms speed to average speed is $\frac{\sqrt{(2N+1)(N+1)}}{6N}$
(C) Ratio of rms speed to average speed is $\frac{\sqrt{(2N+1)(N+1)}}{6}$
(D) Ratio of rms speed to average speed of a molecule $\frac{2}{\sqrt{6}}\sqrt{\frac{(2N+1)}{(N+1)}}$

42. Let $\bar{v}$, v_{rms} and v_p respectively denote the mean speed, the root–mean–square speed, and the most probable speed of the molecules in an ideal monoatomic gas at absolute temperature T. The mass of a molecule is m :–

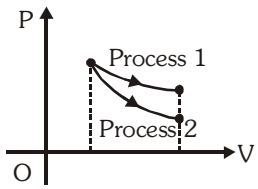
(A) No molecule can have speed greater than v_{rms}
(B) No molecule can have speed less than $\frac{v_p}{\sqrt{2}}$
(C) $v_p < \bar{v} < v_{rms}$
(D) The average kinetic energy of a molecule is $\frac{3}{4}mv_p^2$

43. The following are the P–V diagrams for cyclic processes for a gas. In which of these processes is heat absorbed by the gas ?



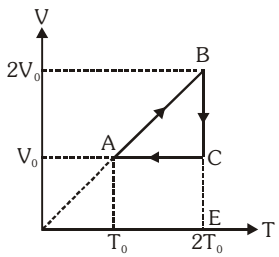
44. An ideal gas is heated from temperature T_1 to T_2 under various conditions. The correct statement(s) is/are:–
(A) $\Delta U = nC_V(T_2 - T_1)$ for isobaric, isochoric and adiabatic process
(B) Work is done at expense of internal energy in an adiabatic process and both have equal values
(C) $\Delta U = 0$ for an isothermal process
(D) C = 0 for an adiabatic process

45. The indicator diagram for two process 1 and 2 carried on an ideal gas is shown in figure.If m_1 and m_2 be the magnitude slopes $\left(\frac{dP}{dV}\right)$ for process 1 and process 2 respectively, then:–



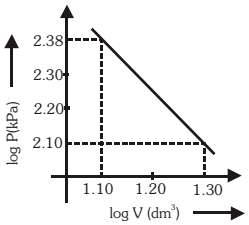
(A) $m_1=m_2$
(B) $m_1>m_2$
(C) $m_1<m_2$
(D) $m_2C_V=m_1C_P$

46. An ideal monoatomic gas undergoes a cycle process ABCA as shown in the fig. The ratio of heat absorbed during AB to the work done on the gas during BC is:–



(A) $\frac{5}{2\ell n2}$
(B) $\frac{5}{3}$
(C) $\frac{5}{4\ell n2}$
(D) $\frac{5}{6}$

47. Logarithms of readings of pressure and volume for an ideal gas were plotted on a graph as shown in Figure. By measuring the gradient, It can be shown that the gas may be :–



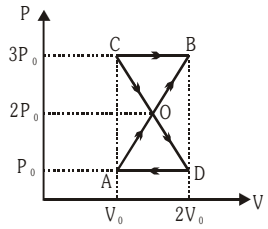
(A) Monoatomic and undergoing an adiabatic change.

(B) Monoatomic and undergoing an isothermal change.

(C) Diatomic and undergoing an adiabatic change.

(D) Triatomic and undergoing an isothermal change.

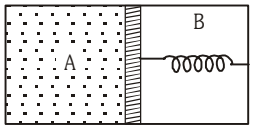
48. A thermodynamic system undergoes cyclic process ABCDA as shown in figure. The work done by the system is :–



(A) P_0V_0 (B) $2P_0V_0$

(C) $\frac{P_0V_0}{2}$ (D) zero

49. A thermally insulated chamber of volume $2V_0$ is divided by a frictionless piston of area S into two equal parts A and B. Part A has an ideal gas at pressure P_0 and temperature T_0 and in part B is vacuum. A massless spring of force constant k is connected with piston and the wall of the container as shown. Initially spring is unstretched. Gas in chamber A is allowed to expand. Let in equilibrium spring is compressed by x_0. Then:–

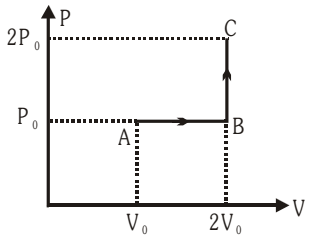


(A) Final pressure of the gas is $\frac{kx_0}{S}$ (B) Work done by the gas is $\frac{1}{2}kx_0^2$

(C) Change in internal energy of the gas is $\frac{1}{2}kx_0^2$

(D) Temperature of the gas is decreased.

50. One mole of an ideal monatomic gas is taken from A to C along the path ABC. The temperature of the gas at A is T_0. For the process ABC :–



(A) Work done by the gas is RT_0

(B) Change in internal energy of the gas is $\frac{11}{2}RT_0$

(C) Heat absorbed by the gas is $\frac{11}{2}RT_0$ (D) Heat absorbed by the gas is $\frac{13}{2}RT_0$

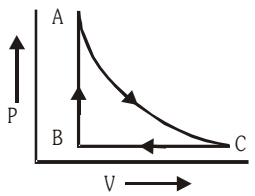
51. Two cylinders A and B fitted with piston contain the equal amount of an ideal diatomic gas at 300K. The piston of A is free to move, while that of B is held fixed. The same amount of heat is given to the gas in each cylinder. If the rise in temperature of the gas in A is 30K, then the rise in the temperature of the gas in B is:–

(A) 30 K (B) 10 K (C) 50 K (D) 42 K

52. One mole of an ideal gas at an initial temperature of T K does 6 R joules of work adiabatically. If the ratio of specific heats of this gas at constant pressure and at constant volume is 5/3, the final temperature of gas will be:–

(A) (T + 2.4) K (B) (T – 2.4) K (C) (T + 4) K (D) (T – 4) K

53. One mole of ideal gas undergoes a cyclic process ACBA as shown in figure. Process AC is adiabatic. The temperatures at A, B and C are 300, 600 and 450K respectively:–



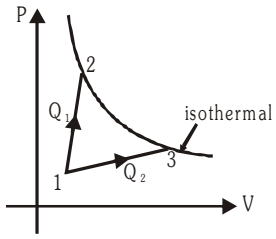
(A) In process CA change in internal energy is 225R.

(B) In process AB change in internal energy is –150R.

(C) In process BC change in internal energy is –225R.

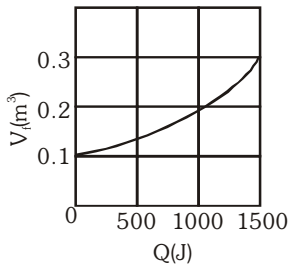
(D) Change in internal energy during the whole cyclic process is +150R.

54. A gas takes part in two processes in which it is heated from the same initial state 1 to the same final temperature. The processes are shown on the P–V diagram by the straight line 1–2 and 1–3.2 and 3 are the points on the same isothermal curve. Q_1 and Q_2 are the heat transfer along the two processes. Then :–



(A) $Q_1 = Q_2$ (B) $Q_1 < Q_2$
(C) $Q_1 > Q_2$ (D) insufficient data

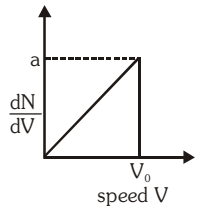
55. Suppose 0.5 mole of an ideal gas undergoes an isothermal expansion as energy is added to it as heat Q. Graph shows the final volume V_f versus Q.



The temperature of the gas is :– (use $\ell n\, 9 = 2$ and $R = \frac{25}{3}$ J/mol-K)

(A) 293 K (B) 360 K
(C) 386 K (D) 412 K

56. Graph shows a hypothetical speed distribution for a sample of N gas particle



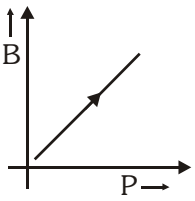
(for $V > V_0$; $\frac{dN}{dV} = 0$)

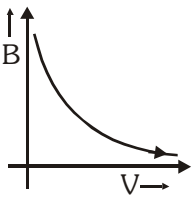
(A) The value of V_0 is 2N.
(B) The ratio V_{avg}/V_0 is equal to 2/3.
(C) The ratio V_{rms}/V_0 is equal to $1/\sqrt{2}$
(D) Three fourth of the total particle has a speed between $0.5\,V_0$ and V_0.

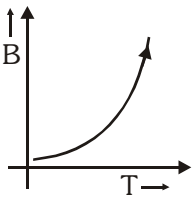
57. n moles of an ideal triatomic linear gas undergoes a process in which the temperature changes with volume as $T = k_1V^2$ where k_1 is a constant. Choose incorrect alternative:–

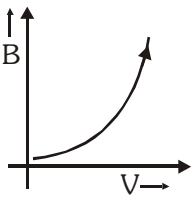
(A) At normal temperature $C_v = \frac{5}{2}R$
(B) At any temperature $C_p - C_v = R$
(C) At normal temperature molar heat capacity C=3R
(D) At any temperature molar heat capacity C=3R

58. A sample of gas follows process represented by PV^2 = constant. Bulk modulus for this process is B, then which of the following graph is correct?

(A) 

(B) 

(C) 

(D) 

59. Four moles of hydrogen, two moles of helium and one mole of water vapour form an ideal gas mixture. What is the molar specific heat at constant pressure of mixture ?

(A) $\frac{16}{7}R$ (B) $\frac{23}{7}R$ (C) $\frac{19}{7}R$ (D) $\frac{26}{7}R$

60. A inert gas obeys the law PV^x = constant. For what value of x, it has negative molar specific heat–

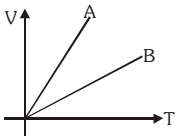
(A) $x > 1.67$ (B) $x < 1.67$ (C) $1 < x < 1.4$ (D) $1 < x < 1.67$

Match the Column

61.

	Column I		Column II
(A)	In $P = \frac{2}{3}E$, E is	(p)	Change in internal energy is only in isochoric process
(B)	In U=3RT for an monoatomic gas U is	(q)	Translational kinetic energy of unit volume
(C)	In $W = P(V_f - V_i)$, W is	(r)	Internal energy of one mole
(D)	In $\Delta U = nC_v\Delta T$, ΔU is	(s)	Work done in isobaric process
		(t)	None

62. In the V–T graph shown in figure:

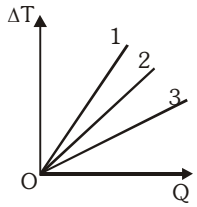


	Column I		Column II
(A)	Gas A is ... and gas B is ...	(p)	monoatomic, diatomic
(B)	P_A / P_B is	(q)	diatomic, monoatomic
(C)	n_A / n_B is	(r)	> 1
		(s)	< 1
		(t)	cannot say any thing

63. For one mole of a monoatomic gas :–

	Column I		Column II
(A)	Isothermal bulk modulus	(p)	$-\frac{RT}{V^2}$
(B)	Adiabatic bulk modulus	(q)	$-\frac{5P}{3V}$
(C)	Slope of P–V graph in isothermal process	(r)	T/V
(D)	Slope of P–V graph in adiabatic process	(s)	4T/3V
		(t)	None

64. The straight lines in the figure depict the variations in temperature ΔT as a function of the amount of heat supplied Q in different process involving the change of state of a monoatomic and a diatomic ideal gas. The initial states (P,V,T) of the two gases are the same. Match the processes as described, with the straight lines in the graph as numbered.

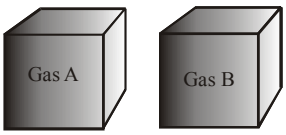


	Column-I		Column-II
(A)	Isobaric process of monoatomic gas.	(p)	1
(B)	Isobaric process of diatomic gas	(q)	2
(C)	Isochoric process of monoatomic gas	(r)	3
(D)	Isochoric process of diatomic gas	(s)	x-axis (i.e. 'Q' axis)

Comprehension

Comprehension-2

Two closed identical conducting containers are found in the laboratory of an old scientist. For the verification of the gas some experiments are performed on the two boxes and the results are noted.



Experiment 1. When the two containers are weighed W_A = 225 g, W_B = 160 g and mass of evacuated container W_c=100g.

Experiment 2. When the two containers are given same amount of heat same temperature rise is recorded. The pressure change found are ΔP_A = 2.5 atm. ΔP_B = 1.5 atm

Required data for unknown gas :

Mono (molar mass)	He 4g	Ne 20g	Ar 40g	Kr 84g	Xe 131g	Rd 222g
Dia (molar mass)	H_2 2g	F_2 19g	N_2 28g	O_2 32g	Cl_2 71g	

65. Identify the type of gas filled in container A and B respectively
(A) Mono, Mono (B) Dia, Dia (C) Mono, Dia (D) Dia, Mono

66. Identify the gas filled in the container A and B
(A) N_2, Ne (B) He, H_2 (C) O_2, Ar (D) Ar, O_2

67. Total number of molecules in 'A' (Here N_A = avagadro number)
(A) $\frac{125}{64}N_A$ (B) 3.125 N_A (C) $\frac{125}{28}N_A$ (D) 31.25 N_A

68. The initial internal energy of the gas in container 'A', If the containers were at room temperature 300K initially.
(A) 1406.25 cal (B) 1000 cal (C) 2812.5 cal (D) None of these

69. If the gases have initial temperature 300 K and they are mixed in an adiabatic container having the same volume as the previous containers. Now the temperature of the mixture is T and pressure is P. Then
(A) $P > P_A$, $T > 300$ K (B) $P > P_B$, $T = 300$ K
(C) $P < P_A$, $T = 300$ K (D) $P > P_A$. $T < 300$ K

Comprehension-5

Entropy (S) is a thermodynamic variable like pressure P, volume V and temperature T. Entropy of a thermodynamic system is a measure of disorder of molecular motion. Greater is disorder, greater is entropy. Change in entropy of a thermodynamic system is the ratio of heat supplied to absolute temperature. In an adiabatic reversible process, entropy remains constant while in any irreversible process entropy increases. In nature the processes are irreversible; therefore entropy of universe is continuously increasing.

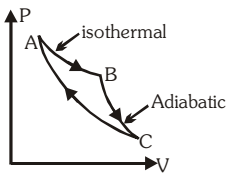
70. The unit of entropy in S–I system is–
(A) cal/K (B) joule/kg (C) joule/K (D) kilocal/°C

71. When milk is heated, its entropy :
(A) increases (B) decreases (C) remains unchanged (D) may decrease or increase

72. After a long–long time, the energy available for work will be :
(A) as much as present value (B) much less than present value
(C) much more than present value (D) can not say

Comprehension-6

A cyclic process for an ideal gas is shown in figure. Given W_{AB} = +700 J, W_{BC} = +400 J, Q_{CA} =–100J.



73. Find ΔU_{BC}
(A) –700 J (B) –400 J (C) –100 J (D) 400 J

74. Find W_{CA}

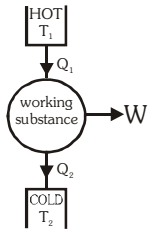
(A) –500 J (B) 500 J (C) 400 J (D) –400 J

75. The efficiency of the cycle is -

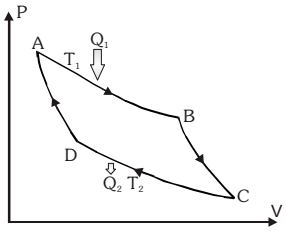
(A) 100% (B) 83.44% (C) 85.71% (D) 81.11%

Comprehension-7.

The efficiency of a heat engine is defined as the ratio of the mechanical work done by the engine in one cycle to the heat absorbed from the high temperature source. $\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$ Cornot devised an ideal engine which is based on a reversible cycle of four operations in succession : isothermal expansion, adiabatic expansion, isothermal compression and adiabatic compression.



For carnot cycle $\frac{Q_1}{T_1} = \frac{Q_2}{T_2}$. Thus $\eta = \frac{Q_1 - Q_2}{Q_1} = \frac{T_1 - T_2}{T_1}$ According to carnot theorem "No irreversible engine can have efficiency greater than carnot reversible engine working between same hot and cold reservoirs".



76. A carnot engine whose low temperature reservoir is at 7°C has an efficiency of 50%. It is desired to increase the efficiency to 70%. By how many degrees should the temperature of the high temperature reservoir be increased?

(A) 273 K (B) $\frac{1120}{3}$K (C) 140 K (D) None of these

77. An inventor claims to have developed an engine working between 600K and 300K capable of having an efficiency of 52%, then-

(A) It is impossible (B) It is possible (C) It is nearly possible (D) Data is insufficient

78. Efficiency of a carnot's cycle change from $\frac{1}{6}$ to $\frac{1}{3}$ when source temperature is raised by 100 K. The temperature of the sink is-

(A) $\frac{1000}{3}$K (B) $\frac{500}{3}$K (C) 250 K (D) 100 K

Subjetive Questions

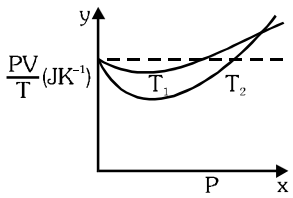
79. Two glass bulbs of equal volume are connected by a narrow tube and are filled with a gas at 0°C and a pressure of 76 cm of mercury. One of the bulbs is then placed in melting ice and the other is placed in a water bath maintained at 62°C. What is the new value of the pressure inside the bulbs ? The volume of the connecting tube is negligible.

80. A thin tube of uniform cross–section is sealed at both ends. It lies horizontally, the middle 5 cm containing mercury and the two equal ends containing air at the same pressure P. When the tube is held at an angle of 60° with the vertical direction, the length of the air column above and below the mercury column are 46 cm and 44.5 cm respectively. Calculate the pressure P in centimetres of mercury. (The temperature of the system is kept at 30°C).

81. A closed container of volume 0.2 m^3 contains a mixture of neon and argon gases, at a temperature of 27°C and pressure of 1×10^5 Nm^{-2}. The total mass of the mixture is 28 g. If the molar masses of neon and argon are 20 and 40 g mol^{-1} respectively, find the masses of the individual gases in the container assuming them to be ideal (Universal gas constant R = 8.314 J/mol–K).

82. An oxygen cylinder of volume 30 litres has an initial gauge pressure of 15 atm and a temperature of 27° C. After some oxygen is with drawn from the cylinder, the gauge pressure drops to 11 atm and its temperature drops to 17°C. Estimate the mass of oxygen taken out of the cylinder. (R = 8.31 J mol^{-1} K^{-1}, molecular mass of O_2 = 32 u.)

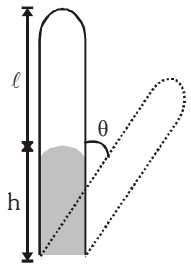
83. Figure shows plot of PV/T versus P for 1.00×10^{-3} kg of oxygen gas at two different temperatures.



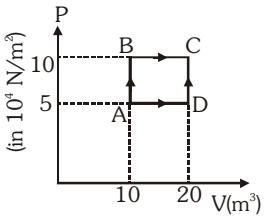
(i) What does the dotted plot signify ?
(ii) Which is true. $T_1 > T_2$ or $T_1 < T_2$?
(iii) What is the value of PV/T where the curves meet on the y–axis ?

84. One gram mole of oxygen at 27°C and one atmospheric pressure is enclosed in a vessel. (i) Assuming the molecules to be moving with v_{rms}, find the number of collisions per second which the molecules make with one square metre area of the vessel wall. (ii) The vessel is next thermally insulated and moved with a constant speed v_0. It is then suddenly stopped. The process results in a rise of the temperature of the gas by 1°C. Calculate the speed v_0.

85. An ideal gas is enclosed in a tube and is held in the vertical position with the closed end upward. The length of the pellet of mercury entrapping the gas is h = 10 cm and the length of the tube occupied by gas is ℓ = 40 cm. Calculate the length occupied by the gas when it is turned through $\theta = 60^0$ and 90^0. Atmospheric pressure, H = 76 cm of mercury.

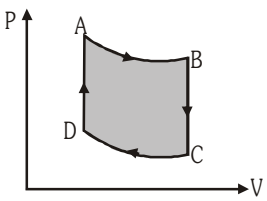


86. A sample of 2 kg monoatomic helium (assumed ideal) is taken from A to C through the process ABC and another sample of 2 kg of the same gas is taken through the process ADC (see fig). Given molecular mass of helium = 4.



(i) What is the temperature of helium in each of the states A, B, C and D ?
(ii) Is there any way of telling afterwards which sample of helium went through the process ABC and which went through the process ADC ? Write Yes and No.
(iii) How much is the heat involved in the process ABC and ADC ?

87. On mole of a monoatomic ideal gas is taken through the cycle shown in figure.



A → B : Adiabatic expansion
B → C : Cooling at constant volume
C → D : Adiabatic compression
D → A : Heating at constant volume

The pressure and temperature at A, B, etc., are denoted by P_A, T_A, P_B, T_B etc., respectively. Given that T_A = 1000 K, $P_B = \left(\frac{2}{3}\right)P_A$ and $P_C = \left(\frac{1}{3}\right)P_A$.

Calculate the following quantities : (i) The work done by the gas in the process A → B (ii) The heat lost by the gas in the process B → C (iii) The temperature T_D. (Given : $\left(\frac{2}{3}\right)^{2/5} = 0.85$)

88. Three moles of an ideal gas ($C_P = \frac{7}{2}R$) at pressure, P_A and temperature T_A is isothermally expanded to twice its initial volume. It is then compressed at constant pressure to its original volume. Finally gas is compressed at constant volume to its original pressure P_A.

(i) Sketch P–V and P–T diagrams for the complete process.

(ii) Calculate the net work done by the gas, and net heat supplied to the gas during the complete process.

89. An ideal gas having initial pressure P, volume V and temperature T is allowed to expand adiabatically until its volume becomes 5.66 V while its temperature falls to $\frac{T}{2}$.

(i) How many degrees of freedom do gas molecules have ?

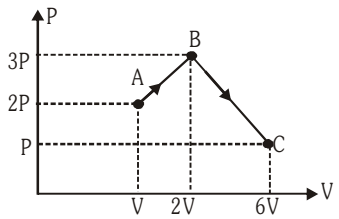
(ii) Obtain the work done by the gas during the expansion as a function of the initial pressure P and volume V. [Take $(5.66)^{0.4} = 2$]

90. Two moles of helium gas ($\gamma = 5/3$) are initially at temperature 27°C and occupy a volume of 20 L. The gas is first expanded at constant pressure until the volume is doubled. Then it undergoes an adiabatic change until the temperature returns to its initial value. (i) Sketch the process on a P–V diagram (ii) What are the final volume and pressure of the gas ? (iii) What is the work done by the gas ?

91. An ideal gas has a specific heat at constant pressure $C_P = \frac{5R}{2}$. The gas is kept in a closed vessel of volume 0.0083 m^3, at a temperature of 300 K and a pressure of 1.6×10^6 N/m^2. An amount of 2.49×10^4 J of heat energy is supplied to the gas. Calculate the final temperature and pressure of the gas.

92. A gaseous mixture enclosed in a vessel of volume V consists of one gram mole of gas A with $\gamma = \frac{C_P}{C_V} = \frac{5}{3}$) an another gas B with $\gamma = \frac{7}{5}$ at a certain temperature T. The gram molecular weights of the gases A and B are 4 and 32 respectively. The gases A and B do not react with each other and are assumed to be ideal. The gaseous mixture follows the equation $PV^{19/13}$ = constant, in adiabatic process. Find the number of gram moles of the gas B in the gaseous mixture.

93. One mole of monoatomic ideal gas undergoes a process ABC as shown in figure. The maximum temperature of the gas during the process ABC is in the form $\frac{xPV}{R}$. Find x.



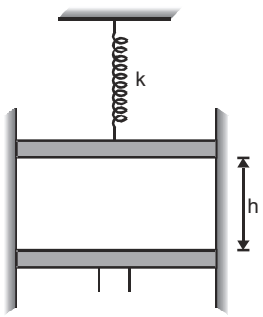
94. An ideal monoatomic gas occupies volume 10^{-3} m^3 at temperature 3K and pressure 10^3 Pa. The internal energy of the gas is taken to be zero at this point. It undergoes the following cycle : The temperature is raised to 300 K at constant volume, the gas is then expanded adiabatically till the temperature is 3K, followed by isothermal compression to the original volume. Plot the process on a PV diagram. Calculate (i) The work done and the heat transferred in each process and the internal energy at the end of each process, (ii) The thermal efficiency of the cycle.

95. One mole of an ideal gas is heated isobarically from the freezing point to the boiling point of water each under normal pressure. Find out the work done by the gas and the change in its internal energy. The amount of heat involved is 1kJ.

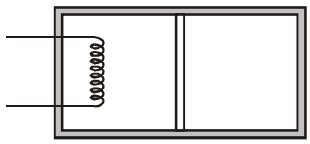
96. A vertical cylinder of cross–sectional area 0.1 m^2 closed at both ends is fitted with a frictionless piston of mass M dividing the cylinder into two parts. Each part contains one mole of an ideal gas in equilibrium at 300K. The volume of the upper part is 0.1 m^3 and that of the lower part is 0.05 m^3. What force must be applied to the piston so that the volumes of the two parts remain unchanged when the temperature is increased to 500K?

97. There is a soap bubble of radius 2.4×10^{-4} m in air cylinder which is originally at the pressure of 10^5 Nm^{-2}. The air in the cylinder is now compressed isothermally until the radius of the bubble is halved. Calculate now the pressure of air in the cylinder. The surface tension of the soap film is 0.08 N/m.

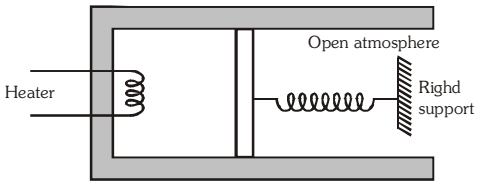
98. An ideal gas at NTP is enclosed in a adiabatic vertical cylinder having area of cross section A = 27 cm^2, between two light movable pistons as shown in the figure. Spring with force constant k = 3700 N/cm is in a relaxed state initially. Now the lower piston is moved upwards a height $\frac{h}{2}$, h being the initial length of gas column. It is observed that the upper piston moves up by a distance $\frac{h}{16}$. Find h taking γ for the gas to be 1.5. Also find the final temperature of the gas.



99. The rectangular box shows in figure has a partition which can slide without friction along the length of the box. Initially each of the two chambers of the box has one mole of a monoatomic ideal gas (γ = 5/3) at a pressure P_0, volume V_0 and temperature T_0. The chamber on the left is slowly heated by an electric heater. The walls of the box and the partition are thermally insulated. Heat loss through the lead wires of the heater is negligible. The gas in the left chamber expands pushing the partition until the final pressure in both chambers becomes $\frac{243P_0}{32}$. Determine (i) the final temperature of the gas in each chamber and (ii) the work done by the gas in the right chamber.

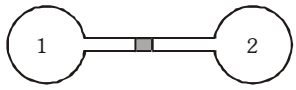


100. An ideal monoatomic gas is confined in a cylinder by a spring–located position of cross–section 8.0×10^{-3} m^2. Initially the gas is at 300 K and occupies a volume of 2.4×10^{-3} m^3 and the spring is in its relaxed (unstretched, uncompressed) state. The gas is heated by a small electric heater until the piston moves out slowly by 0.1 m. Calculate the final temperature of the gas and the heat supplied (in joules) by the heater. The force constant of the spring is 8000 N/m, and the atmospheric pressure 1.0×10^5 Nm^{-2}. The cylinder and the piston are thermally insulated. The piston is massless and there is no friction between the piston and the cylinder. Neglect heat loss through the lead wires of the heater. The heat capacity of the heater coil is negligible. Assume the spring to the massless.

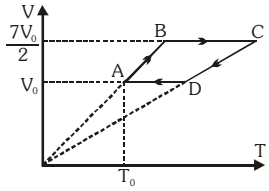


101. One mole of a diatomic ideal gas ($\gamma = 1.4$) is taken through a cyclic process starting from point A. The process $A \rightarrow B$ is an adiabatic compression. $B \rightarrow C$ is isobaric expansion, $C \rightarrow D$ an adiabatic expansion and $D \rightarrow A$ is isochoric. The volume ratio are $\frac{V_A}{V_B} = 16$ and $\frac{V_C}{V_D} = 2$ and the temperature at A is $T_A = 300$ K. Calculate the temperature of the gas at the points B and D and find the efficiency of the cycle.

102. Two spherical flasks having total volume $V_0 = 1.0$ L containing air are connected by a tube diameter d = 6 mm and length $\lambda = 1$m. A small droplet of mercury contained in the tube is at its middle at 0°C. By what distance do the mercury droplets move if the flask 1 is heated by 2°C while flask 2 is cooled by 2°C. Ignore any expansion of flask wall.



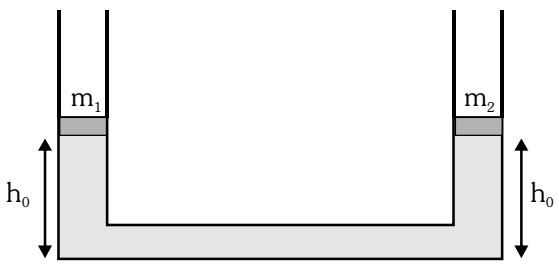
103. A sample of an ideal non linear triatomic gas has a pressure P_0 and temperature T_0 taken through the cycle as shown starting from A. Pressure for process $C \rightarrow D$ is 3 times P_0. Calculate heat absorbed in the cycle and work done.



104. Two moles of an ideal monoatomic gas are confined within a cylinder by a massless and frictionless spring loaded piston of cross–sectional area 4×10^{-3} m^2. The spring is, initially in its relaxed state. Now the gas is heated by an electric heater, placed inside the cylinder, for some time. During this time, the gas expands and does 50 J of work in moving the piston through a distance 0.10 m. The temperature of the gas increases by 50 K. Calculate the spring constant and the heat supplied by the heater.

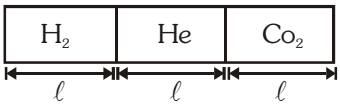
105. A weightless piston divides a thermally insulated cylinder into two parts of volumes V and 3V.2 moles of an ideal gas at pressure P=2 atmosphere are confined to the part with volume V=1 litre. The remainder of the cylinder is evacuated. The piston is now released and the gas expands to fill the entire space of the cylinder. The piston is then pressed back to the initial position. Find the increase in internal energy in the process and final temperature of the gas. The ratio of the specific heat of the gas $\gamma = 1.5$.

106. Two vertical cylinders are connected by a small tube at the bottom. It contains a gas at constant temperature. Initially the pistons are located at the same height. The diameters of the two cylinders are different. Outside the cylinder the space is vacuum. Gravitational acceleration is g. $h_0 = 20$ cm, $m_1 = 2$ kg and $m_2 = 1$ kg. The pistons are initially in equilibrium. If the masses of the piston are interchanged then find the height difference between the two pistons when they are again in equilibrium. Assume constant temperature.

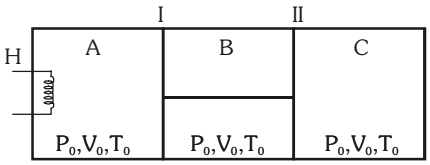


107. A barometer is faulty. When the true barometer reading are 73 cm and 75 cm of Hg, the faulty barometer reads 69 cm and 70 cm respectively (i) What is the total length of the barometer tube? (ii) What is the true reading when the faulty barometer reads 69.5 cm? (iii) What is the faulty barometer reading when the true barometer reads 74 cm?

108. A non–conducting cylindrical vessel of length 3ℓ is placed horizontally & is divided into three parts by two easily moving piston having low thermal conductivity as shown in figure. These parts contains H_2, He and CO_2 gas at initial temp. $\theta_1 = 372^0C, \theta_2 = -15^0C$ and $\theta_3 = 157^0C$ respectively. If initial length and pressure of each part are ℓ and P_0 respectively, calculate final pressure and length of each part. Use : $\gamma_{CO_2} = 7/5$.



109. The figure shows an insulated cylinder divided into three parts, A, B & C. Pistons I and II are connected by a rigid rod and can move without friction inside the cylinder. Piston I is perfectly conducting while piston II is perfectly insulating. The initial state of the gas $(\gamma = 1.5)$ present in each compartment A, B and C is as shown. Now, compartment A is slowly given heat through a heater H such that the final volume of C becomes $\frac{4V_0}{9}$. Assume the gas to be ideal and find. (i) final pressure in each compartment A,B and C (ii) final temperatures in each compartment A,B and C (iii) heat supplied by the heater (iv) work done by gas in A and B (v) heat flowing across piston I



110. An ideal diatomic gas undergoes a process in which its internal energy relates to the volume as $U = a\sqrt{V}$, where a is a constant. (i) find the work performed by the gas and the amount of heat to be transferred to this gas to increase its internal energy by 100J. (ii) find the molar specific heat of the gas for this process.

ANSWERS

- ***True and False***

1. F **2**. F **3**. T **4**. F **5**. T
6. T **7**. T **8**. F

- ***Fill in the Blanks***

9. 2R **10**. Temp. remains constant **11**. 0.628 **12**. 192° **13**. f

- ***Assertion–Reason***

14. (B) **15**. (C) **16**. (D) **17**. (A) **18**. (A)
19. (D) **20**. (B) **21**. (A) **22**. (A) **23**. (A)
24. (C) **25**. (D) **26**. (A) **27**. (D)

- ***Single Choice Correct***

28. (D) **29.** (C) **30.** (A) **31.** (D) **32.** (D)
33. (C)

- ***Multiple Choice Correct***

Que.	34	35	36	37	38	39	40	41	42	43
Ans.	B,C	B	B,D	B,D	B	D	D	D	C,D	A,B,C
Que.	44	45	46	47	48	49	50	51	52	53
Ans.	A,B,C,D	C,D	C	C	D	A,D	A,C	D	D	A
Que.	54	55	56	57	58	59	60			
Ans.	B	B	A,B,C,D	D	A,B,C	A	D			

- ***Match the Column***

61. (A) q (B) t (C) s (D) t **62**. (A) t (B) t (C) t
63. (A) t (B) t (C) p (D) q **64**. (A) q (B) r (C) p (D) q

- ***Comprehension***

Comp-2: **65**. (C) **66**. (D) **67**. (B) **68**. (C) **69**. (B)
Comp-5: **70**. (C) **71**. (A) **72**. (B)
Comp-6: **73**. (B) **74**. (A) **75**. (C)
Comp-7: **76**. (B) **77**. (A) **78**. (A)

- ***Subjective Questions***

79. 83.83 cm of Hg

80. 75.4 cm of Hg

81. M_{neon} = 4.074 g M_{orgon} = 23.926 g

82. 0.139 kg

83. (i) ideal gas behaviour (ii) $T_1 > T_2$ (iii) 0.26 JK^{-1}

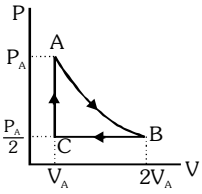
84. (i) 1.96×10^{27} (ii) 36 m/s

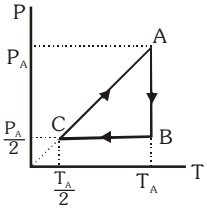
85. 37.2 cm, 34.7 cm

86. (i) T_A = 120.34 K, T_B = 240.68 K, T_C = 481.36 K, T_D = 240.68 K (ii) No
(iii) $Q_{ABC}=3.25 \times 10^6$ J, $Q_{ADC} = 2.75 \times 10^6$ J

87. (i) 1870.65 J (ii) – 5300.175 J (iii) 500 K

88. (i)

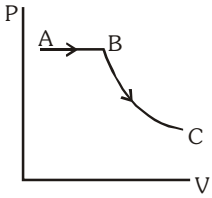




(ii) 0.58 RT_A

89. (i) f=5 (ii) W=12.3 PV

90. (i)



(ii) 113 L, 0.44×10^5 N/m^2, (iii) 12471 J

91. 675 K, 3.6×10^6 N/m^2

92. 2 mole

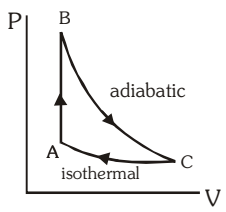
93. x=8

94. (i) For process A $\rightarrow$ W=0, Q = 148.5 J, U=148.5 J

For process B $\rightarrow$ W = 148.5 J, Q=0, U= –148.5 J

For process C $\rightarrow$ W= –6.9 J, Q=–6.9 J, U=0

(ii) η =0.954



95. 831.4 J, 168.6 J

96. 1662.8 N

97. 8.08×10^5 Pa

98. 5.92 m, 364 K

99. (i) T_1 = 12.94 T_0 T_2 = 2.25 T_0 (ii) –1.875 RT_0

100. 800 K, 720 T

101. T_B = 909K, T_D = 5511.15 K, 41.5%

102. 0.259

103. $31P_0V_0$, $-5P_0V_0$

104. 2000 N/m, 1295 J

105. 400 J, $2T_0$

106. 30 cm

107. 74 cm, 73.94 cm, 69.52 cm

108. $\frac{13}{12}P_0$, $\ell_1 = 0.6\,\ell$, $\ell_2 = 1.5\,\ell$, $\ell_3 = 0.9\,\ell$

109. (i) $P_A = P_C = \frac{27}{8}P_0$, $P_B = \frac{21}{4}P_0$ (ii) $T_A = T_B = \frac{21}{4}T_0$, $T_C = \frac{3}{2}T_0$ (iii) 18 P_0V_0
(iv) $W_A = P_0V_0$, W_B=0(v) $\frac{17}{2}P_0V_0$

110. (i) 80J, 180 J (ii) 4.5 R

True / False

1. Two spheres of the same material have radii 1m and 4m temperature 4000K and 2000K respectively. The energy radiated per second by the first sphere is greater than that by the second.

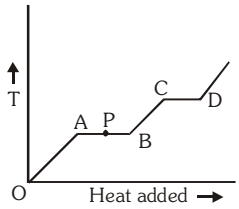
2. Tea gets cooled, when sugar is added to it.

3. If a bimetallic strip is heated it will bend towards the metal with higher thermal expansion coefficient.

4. A bottle is filled with water at 30°C and opening at moon than water will be boil.

Fill in the blanks

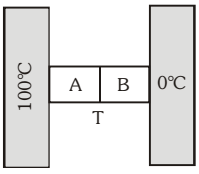
5. The variation of temperature of a material as heat is given to it a constant rate is shown in the figure. The material is solid state at the point O. The state of the material at the point P is.....



6. The earth receives at its surface radiation from the sun at the rate of 1400 Wm^{-2}. The distance of the centre of the sun from the surface of the earth is 1.5×10^{11} m and the radius of the sun is 7×10^{8} m. Treating the sun as a black body, it follows from the above data that its surface temperature is .....K.

7. A solid copper sphere (density ρ and specific heat c) of radius r at an initial temperature 200 K is suspended inside a chamber whose walls are at almost 0 K. The time required for the temperature of the sphere to drop to 100 K is .....

8. Two metal cubes A and B of same size are arranged as shown in figure. The extreme ends of the combination are maintained at the indicated temperatures. The arrangement is thermally insulated. The coefficients of thermal conductivity of A and B are 300 W/m°C and 200 W/m°C, respectively. After steady state is reached the temperature T of the interface will be .....



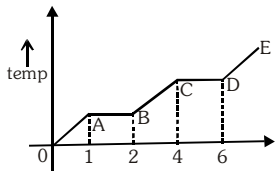
9. A gas thermometer is used as a standard thermometer for measurement of temperature. When the gas container of the thermometer is immersed in water at its triple point 273.16 K, the pressure in the gas thermometer reads 3.0×10^{4} N/m^{2}. When the gas container of the same thermometer is immersed in another system, the gas pressure reads 3.5×10^{4} N/m^{2}. The temperature of this system is therefore.....°C.

10. Earth receives 1400 W/m^{2} of solar power. If all the solar energy falling on a lens of area 0.2 m^{2} is focused onto a block of ice of mass 280 g, the time taken to melt the ice will be ..... minutes. (Latent heat of fusion of ice = 3.3×10^{5} J/kg)

Assertion-Reason

In each of the following questions, a Statement of Assertion (A) is given followed by a corresponding Statement of Reason (R) just below it . Of the Statements mark the correct answer as
(A) Statement–1 is True, Statement–2 is True ; Statement–2 is a correct explanation for Statement–1
(B) Statement–1 is True, Statement–2 is True ; Statement–2 is not a correct explanation for Statement–1
(C) Statement–1 is True, Statement–2 is False.
(D) Statement–1 is False, Statement–2 is True.

11. ***Statement–1*** : A solid material is supplied heat at a constant rate. The temp. of the material is changing with the heat input as shown in figure. Latent heat of vaporization of substance is double that of fusion (given CD = 2AB).



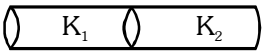
and
Statement–2 : $L_f \propto AB$ and $L_v \propto CD$

12. ***Statement–1*** : Water kept in an open vessel will quickly evaporate on the surface of the Moon.
and
Statement–2 : The temperature at the surface of the moon is much higher than boiling point of water at Earth.

13. ***Statement–1*** : Change in internal energy in the melting process is due to change in internal potential energy.
and
Statement–2 : This is because in melting, distance between molecules increase but temperature remains constant.

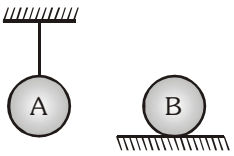
14. ***Statement–1*** : The bulb of one thermometer is spherical while that of the other is cylindrical. Both have equal amount of mercury. The response of the cylindrical bulb thermometer will be quicker.
and
Statement–2 : Heat conduction in a body is directly proportional to cross–sectional area.

15. ***Statement–1*** : Two solid cylindrical rods of identical size and different thermal conductivity K_1 and K_2 are connected in series. Then the equivalent thermal conductivity of two rod system is less than the value of thermal conductivity of either rod.



and
Statement–2 : For two cylindrical rods of identical size and different thermal conductivity K_1 and K_2 connected in series, the equivalent thermal conductivity K is given by $\frac{2}{K} = \frac{1}{K_1} + \frac{1}{K_2}$

16. ***Statement–1*** : Equal amount of heat is supplied to two identical spheres A & B (see figure). The increment in temperature for sphere A is more than sphere B.



and
Statement–2 : Work done due to gravity on sphere A is positive while on sphere B is negative.

17. ***Statement–1*** : Temperatures near the sea–coast are moderate.
and
Statement–2 : Water has a high thermal conductivity compared to ice.

18. ***Statement–1*** : A cloudy night is hotter than a clear sky night.
and
Statement–2 : Clouds are bad absorbers of heat.

19. ***Statement–1*** : When hot water is poured in a beaker of thick glass, the beaker cracks.
and
Statement–2 : Glass is a bad conductor of heat and outer surface of the beaker does not expand.

20. ***Statement–1*** : Potential energy of water at 0°C is more than ice at 0°C.
and
Statement–2 : Heat given to melt ice at 0°C is used up in increasing the potential energy of water molecules formed at 0°C.

21. ***Statement–1 :*** Snow is better insulator than ice.
and
Statement–2 : Snow contain air packet and air is a bad conductor of heat.

22. ***Statement–1 :*** Animals curl into a ball, when they feel very cold.
and
Statement–2 : Animals by curling their body reduces the surface area.

23. ***Statement–1 :*** A sphere, a cube and a thin circular plate made of same material and of same mass are initially heated to 200°C, the plate will cool at fastest rate.
and
Statement–2 : Rate of cooling $= \frac{\rho A \sigma}{ms}(T^4 - T_0^4) \propto$ surface area. Surface area is maximum for circular plate.

24. ***Statement–1 :*** High thermal conductivity of metals is due to presence of free electrons.
and
Statement–2 : Electrons at same temperature have very high average velocity than atoms.

25. ***Statement–1 :*** Liquids usually expand more than solids.
and
Statement–2 : The intermolecular forces in liquids are weaker than in solids.

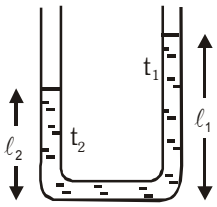
26. ***Statement–1 :*** Water is considered unsuitable for use in thermometers.
and
Statement–2 : Thermal Expansion of water is non uniform.

27. ***Statement–1 :*** Temperature of a rod is increased and again cooled to same initial temperature then its final length is equal to original length provided there is no deformation take place.
and
Statement–2 : For a small temperature change, length of a rod varies as $\ell = \ell_0(1+\alpha\Delta T)$ provided $\alpha\Delta T << 1$. Here symbol have their usual meaning.

28. ***Statement–1 :*** Coolant coils are fitted at the top of a refrigerator, for formation of convection current.
and
Statement–2 : Air becomes denser on cooling.

Single Choice Correct

29. In a vertical U–tube containing a liquid, the two arms are maintained at different temperatures, t_1 and t_2. The liquid columns in the two arms have heights ℓ_1 and ℓ_2 respectively. The coefficient of volume expansion of the liquid is equal to:–



(A) $\frac{\ell_1 - \ell_2}{\ell_2 t_1 - \ell_1 t_2}$ (B) $\frac{\ell_1 - \ell_2}{\ell_1 t_1 - \ell_2 t_2}$

(C) $\frac{\ell_1 + \ell_2}{\ell_2 t_1 + \ell_1 t_2}$ (D) $\frac{\ell_1 + \ell_2}{\ell_1 t_1 + \ell_2 t_2}$

30. The coefficient of linear expansion 'α' of a rod of length 2m varies with the distance x from the end of the rod as $\alpha = \alpha_0 + \alpha_1 x$ where $\alpha_0 = 1.76 \times 10^{-5}$ °C^{-1} and $\alpha_1 = 1.2 \times 10^{-6}$m^{-1} °C^{-1}. The increase in the length of the rod, when heated through 100°C is:–
(A) 2cm (B) 3.76mm (C) 1.2 mm (D) None of these

31. The area of cross–section of rod is given by $A = A_0 (1 + \alpha x)$ where A_0 & α are constant and x is the distance from one end. If the thermal conductivity of the material is K, what is the thermal resistance of the rod if its length is ℓ_0?
(A) $KA_0\alpha\, \ell n(1 + \alpha\ell_0)$ (B) $\frac{1}{KA_0\alpha}\ell n(1+\alpha\ell_0)$ (C) $\frac{\alpha}{KA_0}\ell n(1+\alpha\ell_0)$ (D) $\frac{KA_0}{\alpha}\ell n(1+\alpha\ell_0)$

32. 250 g of water and an equal volume of alcohol of mass 200 g are placed successively in the same calorimeter and cools from 60°C to 55°C in 130 sec and 67 sec respectively. If the water equivalent of the calorimeter is 10 g then the specific heat of alcohol in cal/g°C is :–
(A) 1.30 (B) 0.67 (C) 0.62 (D) 0.985

33. The weight of a person is 60 kg. If he gets 10 calories of heat through food and the efficiency of his body is 28%, then upto what height he can climb ? Take g = 10 m s^{-2}
(A) 100 cm (B) 1.96 cm (C) 400 cm (D) 1000 cm

34. If H_C, H_K and H_F are heat required to raise the temperature of one gram of water by one degree in Celsius, Kelvin and Fahrenheit temperature scales respectively then :–
(A) $H_K > H_C > H_F$ (B) $H_F > H_C > H_K$ (C) $H_K = H_C > H_F$ (D) $H_K = H_C = H_F$

35. If mass–energy equivalence is taken into account, when water is cooled to form ice, the mass of water should:–
(***Note :*** The mass energy of an object is the energy equivalent of its mass, as given by $E = mc^2$, where m = mass of object & c = speed of light)
(A) increase (B) remain unchanged
(C) decrease (D) first increase then decrease

36. If the intermolecular forces vanish away, the volume occupied by the molecules contained in 4.5 kg. water at standard temperature and pressure will be given by :–
(A) 5.6 m^3 (B) 4.5 m^3 (C) 11.2 litre (D) 11.2 m^3

37. A refrigerator converts 100 g of water at 25°C into ice at – 10°C in one hour and 50 minutes. The quantity of heat removed per minute is:– (Specific heat of ice = 0.5 cal/g°C, latent heat of fusion = 80 cal/g)
(A) 50 cal (B) 100 cal (C) 200 cal (D) 75 cal

Multiple Choice Correct

38. The emissive power of a black body at T=300 K is 100 Watt/m^2. Consider a body B of area A = 10 m^2, coefficient of reflectivity r = 0.3 and coefficient of transmission t=0.5. Its temperature is 300 K. Then which of the following is incorrect:–
(A) The emissive power of B is 20 W/m^2 (B) The emissive power of B is 200 W/m^2
(C) The power emitted by B is 200 Watt (D) The emissivity of B is = 0.2

39. A metallic sphere having radius 0.08 m and mass m = 10 kg is heated to a temperature of 227°C and suspended inside a box whose walls are at a temperature of 27°C. The maximum rate at which its temperature will fall is:– (Take e = 1, Stefan's constant σ = 5.8 x 10^{-8} Wm^{-2} K^{-4} and specific heat of the metal s = 90 cal/kg/deg, J = 4.2 J/Calorie)
(A) 0.055 °C/s (B) 0.066 °C/s (C) 0.044 °C/s (D) 0.03 °C/s

40. A hollow copper sphere & a hollow copper cube of same surface area & negligible thickness, are filled with warm water of same temperature and placed in an enclosure of constant temperature, a few degrees below that of the bodies. Then in the beginning :–
(A) The rate of energy lost by the sphere is greater than that by the cube
(B) The rate of energy lost by the two are equal
(C) The rate of energy lost by the sphere is less than that by the cube
(D) The rate of fall of temperature for sphere is less than that for the cube .

41. Two long, thin, solid cylinders are identical in size, but they are made of different substances with two different thermal conductivities. The two cylinders are connected in series between a reservoir at temperature T_{hot} and a reservoir at temperature T_{cold}. The temperature at the boundary between the two cylinders is T_b. One can conclude that:–

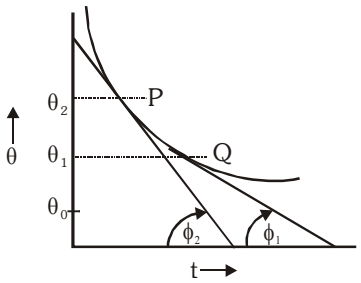
(A) T_b is closer to T_{hot} than it is to T_{cold}.

(B) T_b is closer to T_{cold} than it is to T_{hot}.

(C) T_b is closer to the temp. of the reservoir that is in contact with the cylinder with the lower thermal conductivity.

(D) T_b is closer to the temp. of the reservoir that is in contact with the cylinder with the higher thermal conductivity.

42. A body cools in a surrounding which is at a constant temperature of θ_0. Assume that it obeys Newton's law of cooling. Its temperature θ is plotted against time t. Tangent are drawn to the curve at the points $P(\theta = \theta_2)$ and $Q(\theta = \theta_1)$. These tangents meet the time axis at angles of ϕ_2 and ϕ_1 as shown, then:–



(A) $\dfrac{\tan\phi_2}{\tan\phi_1} = \dfrac{\theta_1 - \theta_0}{\theta_2 - \theta_0}$

(B) $\dfrac{\tan\phi_2}{\tan\phi_1} = \dfrac{\theta_2 - \theta_0}{\theta_1 - \theta_0}$

(C) $\dfrac{\tan\phi_1}{\tan\phi_2} = \dfrac{\theta_1}{\theta_2}$

(D) $\dfrac{\tan\phi_1}{\tan\phi_2} = \dfrac{\theta_2}{\theta_1}$

43. A spherical body with an initial temperature T_1 is allowed to cool in surroundings at temperature T_0 ($<T_1$). The mass of the body is m, its gram specific heat is c, density ρ, area A. If σ be the Stefan's constant then the temperature T of the body at time t can be best represented by:–

(A) $T = (T_1 - T_0)\, e^{-kt}$ where $k = \dfrac{12\sigma A T_0^3}{r\rho c}$

(B) $T = (T_1 - T_0)\, \ell n\,(kt)$ where $k = \dfrac{\sigma A T_0}{mc^3}$

(C) $T = T_0 + (T_1 - T_0)\, e^{-kt}$ where $k = \dfrac{12\sigma T_0^3}{r\rho c}$

(D) $T = T_1 e^{-kt} - T_0$ where $k = \dfrac{\sigma A T_0^3}{r\rho c}$

44. A rod of length L with sides fully insulated is of a material whose thermal conductivity varies with temperature as $K = \dfrac{\alpha}{T}$, where α is a constant. The ends of the rod are kept at temperature T_1 and T_2. The temperature T at x, where x is the distance from the end whose temperature is T_1 is:–

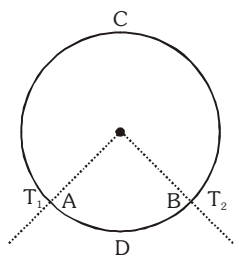
(A) $T_1\left(\dfrac{T_2}{T_1}\right)^{\frac{x}{L}}$

(B) $\dfrac{x}{L}\ell n\dfrac{T_2}{T_1}$

(C) $T_1 e^{\frac{T_2 x}{T_1 L}}$

(D) $T_1 + \dfrac{T_2 - T_1}{L}x$

45. A ring consisting of two parts ADB and ACB of same conductivity k carries an amount of heat H. The ADB part is now replaced with another metal keeping the temperatures T_1 and T_2 constant. The heat carried increases to 2H. What should be the conductivity of the new ADB part? Given $\dfrac{ACB}{ADB} = 3$



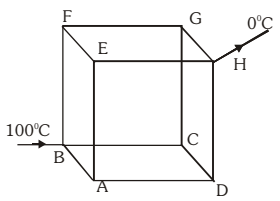
(A) $\dfrac{7}{3}k$

(B) 2k

(C) $\dfrac{5}{2}k$

(D) 3k

46. Twelve conducting rods form the sides of a uniform cube of side ℓ. If in steady state, B and H ends of the cube are at 100°C and 0°C respectively. Find the temperature of the junction 'A' :–



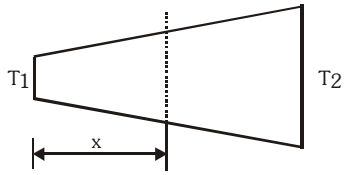
(A) 80°C

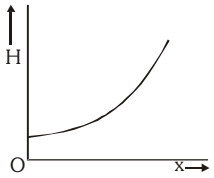
(B) 60°C

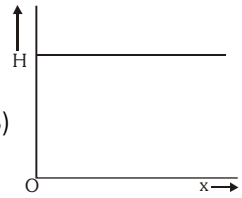
(C) 40°C

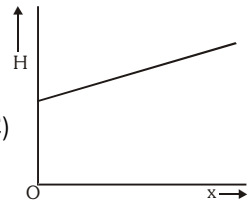
(D) 70°C

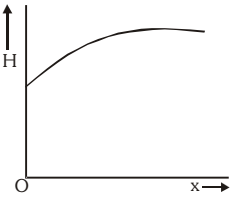
47. Radius of a conductor increases uniformly from left end to right end as shown in Fig. Material of the conductor is isotropic and its curved surface is thermally isolated from surrounding. Its ends are maintained at temperatures T_1 and T_2 ($T_1 > T_2$). If, in steady state, heat flow rate is equal to H, then which of the following graphs is correct ?



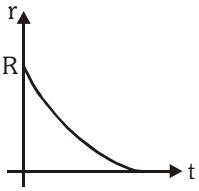
(A) 

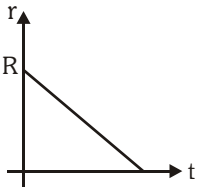
(B) 

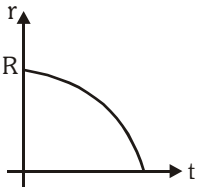
(C) 

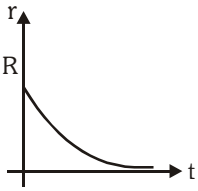
(D) 

48. A sphere of ice at 0^0C having initial radius R is placed in an environment having ambient temperature > 0^0C. The ice melts uniformly, such that shape remains spherical. After a time 't' the radius of the sphere has reduced to r. Which graph best depicts r(t)

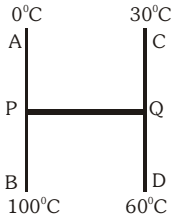
(A) 

(B) 

c) 

(D) 

49. Three identical rods AB, CD and PQ are joined as shown. P and Q are mid points of AB and CD respectively. Ends A, B, C and D are maintained at 0^0C, 100^0C, 30^0C and 60^0C respectively. The direction of heat flow in PQ is:–



(A) From P to Q (B) From Q to P
(C) Heat does not flow in PQ (D) Data not sufficient

50. Three bodies A, B and C have equal surface area and thermal emissivities in the ratio $e_A : e_B : e_C = 1 : \frac{1}{2} : \frac{1}{4}$.

All the three bodies are radiating at same rate. Their wavelengths corresponding to maximum intensity are λ_A, λ_B and λ_C respectively and their temperatures are T_A, T_B and T_C on kelvin scale, then select the incorrect statement

(A) $\sqrt{T_A T_C} = T_B$ (B) $\sqrt{\lambda_A \lambda_C} = \lambda_B$ (C) $\sqrt{e_A T_A}\ \sqrt{e_C T_C} = e_B T_B$ (D) $\sqrt{e_A \lambda_A T_A . e_B \lambda_B T_B} = e_C \lambda_C T_C$

51. A and B are two points on a uniform metal ring whose centre is C. The angle ACB = θ. A and B maintained at two different constant temperatures. When θ = 180°, the rate of total heat flow from A to B is 1.2 W. When θ = 90°, this rate will be:–
(A) 0.6 W (B) 0.9 W (C) 1.6 W (D) 1.8 W

52. In a 10–metre–deep lake, the bottom is at a constant temperature of 4°C. The air temperature is constant at –4°C. The thermal conductivity of ice is 3 times that of water. Neglecting the expansion of water on freezing, the maximum thickness of ice will be:–
(A) 7.5 m (B) 6 m (C) 5 m (D) 2.5 m

53. The solar constant for the earth is Σ. The surface temperature of the sun is T K. The sun subtends an angle θ at the earth:–
(A) $\Sigma \propto T^4$ (B) $\Sigma \propto T^2$ (C) $\Sigma \propto \theta^2$ (D) $\Sigma \propto \theta$

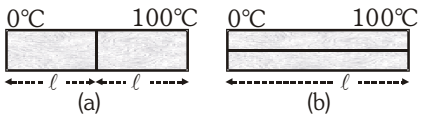
54. A system S receives heat continuously from an electrical heater of power 10W. The temperature of S becomes constant at 50°C when the surrounding temperature is 20°C. After the heater is switched off, S cools from 35.1°C to 34.9°C in 1 minute. The heat capacity of S is:–
(A) 100 J/°C (B) 300 J/°C (C) 750 J/°C (D) 1500 J/°C

55. If the absorption coefficient and reflection coefficient of a surface of a body are 0.4 and 0.6 respectively then:–
(A) Emissive power will be 0.2
(B) Transmission power will be 0.2
(C) Body will be totally transparent
(D) Body will be totally opaque.

56. Temperature of black body is 3000K when black body cools, then change in wevelength $\Delta\lambda = 9$ micron corresponding to maximum energy density. Now temperature of black body is :–
(A) 300 K (B) 2700 K (C) 270 K (D) 1800 K

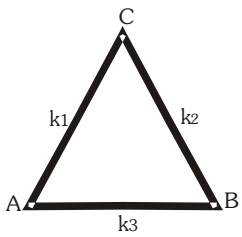
57. Two Plates of equal areas are placed in contact with each other. Their thickness are 2cm and 3cm respectively. Temperature of external surface of first plate is –25° C and that of external surface of second plate is 25° C What will be temperature of contact surface if the plates :–
(i) Are of same material (ii) Have thermal Conductivity in ratio 2 : 3.
(A) (i) –5°C (ii) 0°C (B) (i) 5°C (ii) 0°C (C) (i) 0°C (ii) –5°C (D) None of these

58. Two identical square rods of metal are welded end to end as shown in figure (a) 20 calories of heat flows through it in 4 minutes. If the rods are welded as shown in figure (b), the same amount of heat will flow through the rods in :



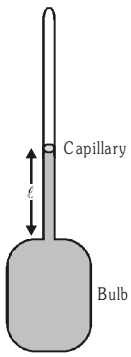
(A) 1 minute (B) 2 minutes (C) 4 minutes (D) 16 minutes

59. Three rods of same dimensions are arranged as shown in the figure. They have thermal conductivities k_1, k_2 & k_3. The points A and B are maintained at different temperatures. For the heat to flow at the same rate along ACB and AB :–



(A) $k_3 = 2(k_1 + k_2)$
(B) $k_3 = \dfrac{k_1k_2}{k_1 + k_2}$
(C) $k_3 = k_1 + k_2$
(D) $k_3 = \dfrac{1}{2}(k_1 + k_2)$

60. In a mercury–glass thermometer the cross–section of the capillary portion is A_0 and the volume of the bulb is V_0 at 273 K. If α and γ are the coefficients of linear and cubical expansion coefficients of glass and mercury respectively then length of mercury in the capillary at temperature t°C is (Ignore the increase in cross–sectional area of capillary)



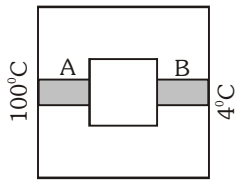
(A) $\dfrac{V_0}{A_0}(\gamma - 3\alpha)t$
(B) $\dfrac{V_0}{A_0}(2\gamma - 3\alpha)t$
(C) $\dfrac{V_0}{A_0}(\gamma - 3\alpha)(t + 273)$
(D) $\dfrac{V_0\gamma t}{A_0}$

61. 5g of steam at 100°C is mixed with 10 g of ice at 0°C. Choose correct alternative/s) :–(Given s_{water} = 1 cal/g°C, L_F = 80 cal/g, L_V = 540 cal/g)
(A) Equilibrium temperature of mixture is 160°C
(B) Equilibrium temperature of mixture is 100^0C
(C) At equilibrium, mixture contain $13\frac{1}{3}$ g of water
(D) At equilibrium, mixture contain $1\frac{2}{3}$ g of steam

62. A thermally insulated vessel contains some water at 0^0C. The vessel is connected to a vacuum pump to pump out water vapour. This results in some water getting frozen. It is given latent heat of vaporization of water at 0°C = 21×10^5 J/kg and latent heat of freezing of water = 3.36×10^5 J/kg. The maximum percentage amount of water that will be solidified in this manner will be:–

(A) 86.2% (B) 33.6% (C) 21% (D) 24.36%

63. A closed cubical box made of perfectly insulating material has walls of thickness 8 cm and the only way for heat to enter or leave the box is through two solid metal plugs A and B, each of cross–sectional area 12 cm^2 and length 8 cm fixed in the opposite walls of the box as shown in the figure. Outer surface A is kept at 100°C while the outer surface B is kept at 4°C. The thermal conductivity of the material of the plugs is 0.5 $cals^{-1}cm^{-1}$ ($°C^{-1}$). A source of energy generating 36 $cals^{-1}$ is enclosed inside the box. The equilibrium temperature of the inner surface of the box (assuming that it is same at all points on the inner surface) is:–



(A) 38°C (B) 57°C (C) 76°C (D) 85°C

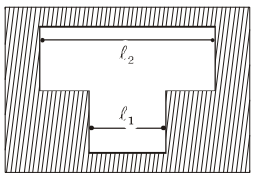
64. The temperature of an isotropic cubical solid of length ℓ_0, density ρ_0 and coefficient of linear expansion α is increased by 20°C. Then at higher temperature, to a good approximation:–

(A) Length is ℓ_0 $(1+20\alpha)$
(B) Total surface area is ℓ_0^2 $(1+40\alpha)$
(C) Total volume is ℓ_0^3 $(1+60\alpha)$
(D) Density is $\dfrac{\rho_0}{1+60\alpha}$

65. A glass rod when measured with a zinc scale, both being at 30°C, appears to be of length 100 cm. If the scale shows correct reading at 0°C, then the true length of glass rod at 30°C and 0°C are:–
($\alpha_{glass} = 8\times 10^{-6}$ °C^{-1}, $\alpha_{zinc} = 26 \times 10^{-6}$ K^{-1})

(A) 100.054 cm, 100.054 cm
(B) 100.078 cm, 100.078 cm
(C) 100.078 cm, 100.054 cm
(D) 100.054 cm, 100.078 cm

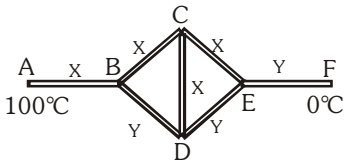
66. Two fine steel wires, fastened between the projections of a heavy brass bar, are just taut when the whole system is at 0°C. What is the tensile stress in the steel wires when the temperature of the system is raised by 200°C?
($\alpha_{brass} = 2 \times 10^{-5}$ °C^{-1}, $\alpha_{steel} = 1.2 \times 10^{-5}$ °C^{-1}, $Y_{steel} = 200$ GNm^{-2})



(A) 3.2 Nm^{-2}
(B) 3.2×10^8 Nm^{-2}
(C) 32×10^8 Nm^{-2}
(D) 0.48 Nm^{-2}

Match the Column

67. Four rods of material X and three rods of material Y are connected as shown in figure. All the rods are of identical lengths and cross-sectional area. Given thermal resistance of rod of material X, $R_x = R$ and thermal conductivities of materials are related by relation $K_Y = 2K_X$.

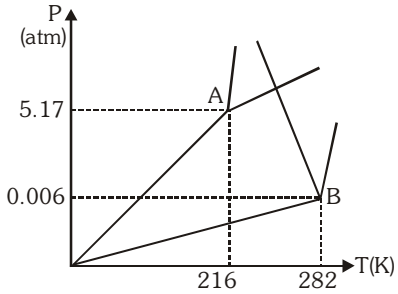


	Column I		Column II
(A)	Thermal resistance between B and E	(p)	$\frac{500}{13}$°C
(B)	Thermal resistance between A and F	(q)	$\frac{700}{13}$°C
(C)	Temperature of junction B	(r)	$\frac{2R}{3}$
(D)	Temperature of junction D	(s)	$\frac{13R}{6}$

Comprehension

Comprehension-1.

Each phase of a material can exist only in certain regions of pressure and temperature. P–T phase diagrams, in which pressure is plotted versus temperature, show the regions corresponding to various phases and phase transformations. P–V diagrams, on the other hand, can be used to study pressure volume relationships at a constant temperature.



If the liquid and gaseous phases of a pure substances are heated together in a closed container, both the temperature and the vapor pressure will increase until a point is reached at which the two phases can no longer be distinguished from one another. The temperature and pressure at which this occurs are called the critical temperature and pressure. Exceeding either of these parameters, by itself, will cause the gas/liquid phase transition to disappear. If the other variable is then changed as well, while the first variable is maintained above its critical point, a gradual transition will occur between the gaseous and liquid phases, with no clear boundary. (The liquid and solid phases, on the other hand, maintain a distinct boundary at all pressures above the triple point.) Shown in figure is a combined P–T phase diagram for materials A and B.

68. If heat is added to solids A and B, each in a container that is open to the atmosphere :–
(A) A will boil and B will melt
(B) A will sublime and B will melt, then boil
(C) A will melt and B will sublime
(D) Both A and B will first melt, then boil

69. Which is true about the substances in figure ?
(A) At 2 atm pressure and 220 K temperature, A is a gas and B is solid
(B) At 6 atm pressure and 280 K temperature, A is a gas and B is a solid
(C) At 5 atm pressure and 100 K temperature, A is a gas and B is a solid
(D) At 4 atm pressure and 300 K temperature, both A and B are liquids

Comprehension-2

Solids and liquids both expand on heating. The density of substance decreases on expanding according to the relation

$\rho_2 = \dfrac{\rho_1}{1+\gamma(T_2 - T_1)}$, where, $\rho_1 \rightarrow$ density at T_1, $\rho_2 \rightarrow$ density at T_2, $\gamma \rightarrow$ coefficient of volume expansion of substances.

When a solid is submerged in a liquid, liquid exerts an upward force on solid which is equal to the weight of liquid displaced by submerged part of solid.

Solid will float or sink depends on relative densities of solid and liquid.

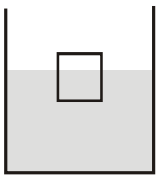
A cubical block of solid floats in a liquid with half of its volume submerged in liquid as shown in figure (at temperature T)

$\alpha_S \rightarrow$ Coefficient of linear expansion of solid

$\gamma_L \rightarrow$ Coefficient of volume expansion of liquid

$\rho_S \rightarrow$ Density of solid at temperature T

$\rho_L \rightarrow$ Density of liquid at temperature T



70. The relation between densities of solid and liquid at temperature T is
(A) $\rho_S = 2\rho_L$
(B) $\rho_S = (1/2)\rho_L$
(C) $\rho_S = \rho_L$
(D) $\rho_S = (1/4)\rho_L$

71. If temperature of system increases, then fraction of solid submerged in liquid
(A) increases
(B) decreases
(C) remains the same
(D) inadequate information

72. Imagine friction submerged does not change on increasing temperature the relation between γ_L and α_S is

(A) $\gamma_L = 3\alpha_S$ (B) $\gamma_L = 2\alpha_S$ (C) $\gamma_L = 4\alpha_S$ (D) $\gamma_L = (3/2)\alpha_S$

73. Imagine the depth of the block submerged in the liquid does not change on increasing temperature then

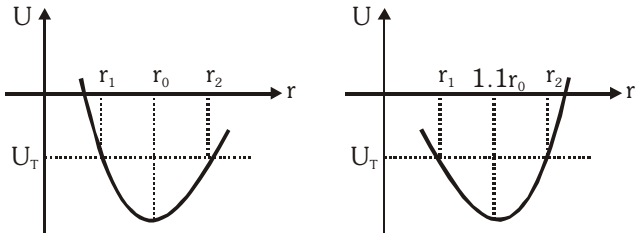
(A) $\gamma_L = 2\alpha$ (B) $\gamma_L = 3\alpha$ (C) $\gamma_L = (3/2)\alpha$ (D) $\gamma_L = (4/3)\alpha$

74. Assume block does not expand on heating. The temperature at which the block just begins to sink in liquid is

(A) $T + \frac{1}{\gamma_L}$ (B) $T + \frac{1}{(2\gamma_L)}$ (C) $T + \frac{2}{(\gamma_L)}$ (D) $T + \frac{\gamma_L}{2}$

Comprehension-3.

Consider a hypothetical situation where we are comparing the properties of two crystals made of atom A and atom B. Potential energy (U) v/s interatomic separation (r) graph for atom A and atom B is shown in figure (i) and (ii) and respectively.



(i) (ii)

75. Choose correct statement

(A) Volume of A and B expand on heating
(B) Volume of A and B contract on heating
(C) A expands on heating and B contracts on heating
(D) A contracts on heating and B expands on heating

76. When we heat the crystal of either atoms, the atom undergo oscillation. Choose correct statement for atoms of crystal A

(A) Their equilibrium position remains unchanged but average separation decreases
(B) Their equilibrium position remains unchanged but average separation increases
(C) Their separation at equilibrium position as well as average separation increases
(D) Their separation at equilibrium position decreases but average separation increases

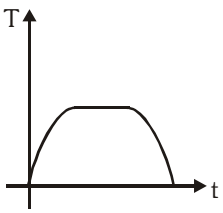
77. It is seen that the potential energy can reach a maximum value of U_T at temperature T=10K. If r_1 and r_2 are 0.9999 r_0 and 1.0003 r_0 for atoms of crystal A, its approximate coefficient of linear expansion can be :–

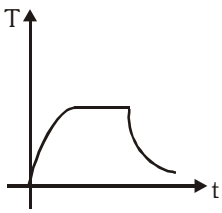
(A) 4×10^{-5} /K (B) 1×10^{-5} /K (C) 2×10^{-5} /K (D) 3×10^{-5} /K

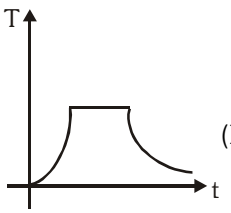
Comprehension-4.

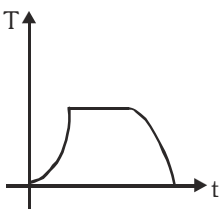
In a home experiment, Ram brings a new electric kettle with unknown power rating. He puts 1 litre water in the kettle and switches on. But to his dismay, the temperature becomes constants at 60^0C after some time. The room temperature is 20^0C. Ram gets bored and switches off the kettle. He sees that during first 20 s water cools down by 2^0C.

78. Which is the best graph for temperature v/s time?

(A)


(B)


(C)


(D)


79. What is the wattage of the kettle

(A) 840W (B) 1W (C) 100W (D) 420 W

80. What is the time taken for the water to cool to 40^0C. (Approx)

(A) 510 s (B) 270 s (C) 120 s (D) 410 s

Comprehension-5.

Most substances contract on freezing. However, water does not belong to this category. We know that water expands on freezing. Further, coefficient of volume expansion of water in the temperature range from 0°C to 4°C is negative and above 4°C it is positive. This behaviour of water shapes the freezing of lakes as the atmospheric temperature goes down and it is still above 4°C.

81. As the atmospheric temperature goes down, but it is still above 4°C
(A) Cooled water at the surface flows downward because of its greater density
(B) Cooled water at the surface does not flow downward and remains at the surface because its smaller density
(C) Cooled water at the surface, through it remains on the surface because of its smaller density, will conduct heat from the interior to the atmosphere
(D) Cooled water at the surface flows to the bottom because of its smaller density

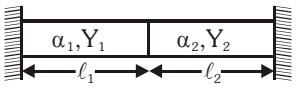
82. As the atmospheric temperature goes below 4°C
(A) Cooled water at the surface flows downward because of its greater density
(B) Cooled water at the surface does not flow downward and remains at the surface because of its smaller density
(C) Cooled water at the surface downward because of its smaller density
(D) Temperature of water in the lake reduces with depth

83. If the atmospheric temperature is below 0°C and ice begins to form at t = 0, thickness of ice sheet formed up to a time 't' will be directly proportional to a time 't' will be directly proportional to
(A) t^4 (B) t^2 (C) t (D) $t^{1/2}$

84. If the atmospheric temperature is below 0°C
(A) Ice will form from the bottom upward and the plants and animals in the lake will be displaced to the upper part of the lake.
(B) Ice will form in a random manner throughout the volume of the lake and with the passage of time, different segments of ice will join together to result in a collective ice mass
(C) Ice will form from the surface downward and plant and animal life will survive in the water beneath
(D) Water in the lake does not freeze. In fact, water in the atmosphere freezes and fall into the lake and floats on the surface of lake as ice.

Comprehension-6

Two rods of equal cross sections area are joined end the end as shown in figure. These are supported between two rigid vertical walls. Initially the rods are unstrained.



85. If temperature of system is increased by ΔT then junction will not shift if–
(A) $Y_1\alpha_1 = Y_2\alpha_2$ (B) $Y_1\alpha_1\ell_1 = Y_2\alpha_2\ell_2$ (C) $\alpha_1 = \alpha_2$ (D) $Y_2\alpha_1\ell_1 = Y_1\alpha_2\ell_2$

86. If temperature of system is increased by ΔT then thermal stress developed in first rod–
(A) is equal to thermal stress developed in second rod
(B) is greater than thermal stress developed in second rod
(C) is less than thermal stress developed in second rod
(D) None of these

87. If temperature of system is increased by ΔT then shifting in junction if $Y_1\alpha_1 > Y_2\alpha_2$ is given by–
(A) $\dfrac{\ell_1\ell_2(Y_1\alpha_2 - Y_2\alpha_1)}{Y_1\ell_1 + Y_2\ell_2}$ (B) $\dfrac{\ell_1\ell_2(Y_1\alpha_1 - Y_2\alpha_2)}{Y_1\ell_2 + Y_2\ell_1}$ (C) $\dfrac{\ell_1\ell_2(Y_1\alpha_1 - Y_2\alpha_2)}{Y_1\ell_1 + Y_2\ell_2}$ (D) None of these

Subjetive Questions

88. ***Answer the following questions in brief :***

(i) A poor emitter has a large reflectivity. Explain why.

(ii) A copper tumbler feels much colder than a wooden block on a cold day. Explain why.

(iii) The earth would become so cold that life is not possible on it in the absence of the atmosphere. Explain why?

(iv) Why clear nights are cooler than cloudy nights ?

(v) Why does a piece of red glass when heated and taken out glow with green light ?

(vi) Why does the earth not become as hot as the sun although it has been receiving heat from the sun for ages ?

(vii) Animals curl into a ball when they are very cool. Why ?

(viii) Heat is generated continuously in an electric heater but its temperature becomes constant after some time. Explain why ?

(ix) A piece of paper wrapped tightly on a wooden rod is observed to get charred quickly when held over a flame as compared to a similar piece of paper when wrapped on a brass rod. Explain why ?

(x) Liquid in a metallic pot boils quickly whose base is made black and rough than in a pot whose base is highly polished. Why ?

89. In an industrial process 10 kg of water per hour is to be heated from 20^0C to 80^0C. To do this, steam at 150^0C is passed from a boiler into a copper coil immersed in water. The steam condenses in the coil and is returned to the boiler as water at 90^0C. How many kg of steam are required per hour? Specific heat of steam = 1 kilocal $kg^{-1}{}^0C^{-1}$. Latent heat of steam = 540 kilocal kg^1.

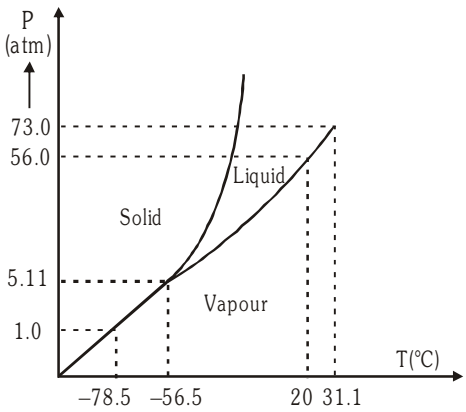
90. Aluminium container of mass 10 g contains 200 g of ice at -20^0C. Heat is added to the system at the rate of 100 calories per second. What is the temperature of the system after four minutes? Draw a rough sketch showing the variation of the temperature of the system as a function of time. Given :
Specific heat of ice = 0.5 cal g^{-1} $(^0C)^{-1}$
Specific heat of aluminium = 0.2 cal g^{-1} $(^0C)^{-1}$
Latent heat of fusion of ice = 80 cal g^{-1}

91. The temperature of equal masses of three different liquids A, B and C are 12^0C, 19^0C and 28^0C respectively. The temperature when A and B are mixed is 16^0C and when B and C are mixed it is 23^0C. What will be the temperature when A and C are mixed?

92. A lead bullet just melts when stopped by an obstacle. Assuming that 25 percent of the heat is absorbed by the obstacle, find the velocity of the bullet if its initial temperature is 27°C.
(Melting point of lead = 327°C, Specific heat of lead = 0.03 cal/g°C,
Latent heat of fusion of lead = 6 cal/g, J = 4.2 J/cal.

93. The temperature of 100 g of water is to be raised from 24°C to 90°C by adding steam to it. Calculate the mass of the steam required for this purpose.

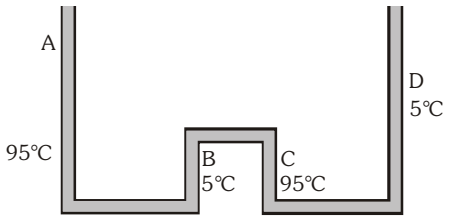
94. Answer the following questions based on the P–T phase diagram of carbon dioxide



(i) At what temperature and pressure can the solid, liquid and vapour phases of CO_2 co–exist in equilibrium
(ii) What is the effect of decrease of pressure on the fusion and boiling point of CO_2?
(iii) What are the critical temperature and pressure for CO_2? What is their significance?
(iv) Is CO_2 solid, liquid or gas at (a) –70 °C under 1 atm, (b) – 60 °C under 10 atm, (c) 15 °C under 56 atm?

95. A cylindrical block of length 0.4 m and area of cross–section 0.04 m^2 is placed coaxially on a thin metal disc of mass 0.4 kg and of the same cross–section. The upper face of the cylinder is maintained at a constant temperature of 400 K and the initial temperature of the disc is 300 K. If the thermal conductivity of the material of the cylinder is 10 V/mK and the specific heat capacity of the material of the disc is 600 J/kg–K, how long will it take for the temperature of the disc of increase to 350 K? Assume, for purposes of calculation, the thermal conductivity of the disc to be very high and the system to be thermally insulated except for the upper face of the cylinder.

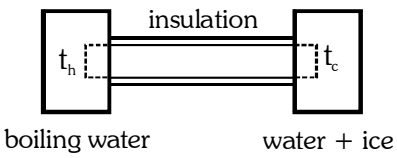
96. The apparatus shown in figure consists of four glass columns connected by horizontal sections. The height of two central columns B and C are 49 cm each. The two outer columns A and D are open to the atmosphere. A and C are maintained at a temperature of 95°C while the columns B and D are maintained at 5°C. The height of the liquid in A and D measured from the base line are 52.8 cm and 51 cm respectively. Determine the coefficient of thermal expansion of the liquid.



97. A double–pane window used for insulating a room thermally from outside consists of two glass sheets each of area 1 m^2 and thickness 0.01 m separated by a 0.05 m thick stagnant air space. In the steady state, the room glass interface and the glass–outdoor interface are at constant temperatures of 27°C and 0°C respectively. Calculate the rate of heat flow through the window pane. Also find the temperatures of other interfaces. Given thermal conductivities of glass and air as 0.8 and 0.08 W $m^{-1}K^{-1}$ respectively.

98. A solid aluminium sphere and a solid copper sphere of twice the radius are heated to the same temperature and are allowed to cool under identical surrounding temperatures. Assume that the emissivity of both the spheres is the same. If the ratio of the rate of fall of temperature of the aluminium sphere to the rate of fall of temperatue of the copper sphere is x then find the value of 100x. The specific heat capacity of aluminium = 900 J/kg–°C and that of copper = 360 J/kg–°C. The density of copper = 3.4 times the density of aluminium.

99. An insulated container is filled with a mixture of water and ice at t_c = 0°C. Another container is filled with water that is continuously boiling at t_h = 100 °C. In a series of experiments, the containers are connected by various thick rods that pass through the walls of container. The rod is insulated in such a way that there is no heat loss to surrounding. In experiment 1, a copper rod is used, and the ice melts in T_1 = 20 min. In experiment 2, a steel rod of same cross-section and length is used and the same amout of ice melts in T_2 = 60 minutes. Now if both the rods are connected in series, find the time (in minutes) in which same amount of ice shall melt.



100. A sphere and a cube of same material and same total surface area are placed in same evacuated space after they are heated to same temperature. The ratio of their initial rate of cooling in space is $\left(\frac{\pi^2}{36}\right)^{\frac{n}{32}}$ then n is :

ANSWERS

- ***True and False***

1. False **2**. True **3**. False **4**. True

- ***Fill in the Blanks***

5. partly solid and partly liquid **6**. 5803 **7**. 1.71 prc **8**. 60^0C
9. 45.68^0C **10**. 5.5

- ***Assertion–Reason***

11. (A) **12**. (C) **13**. (A) **14**. (A) **15**. (D)
16. (A) **17**. (C) **18**. (A) **19**. (A) **20**. (A)
21. (A) **22**. (A) **23**. (A) **24**. (C) **25**. (A)
26. (A) **27**. (B) **28**. (A)

- ***Single Choice Correct***

29. (A) **30.** (B) **31.** (B) **32.** (C) **33.** (B)
34. (C) **35.** (C) **36.** (A) **37.** (B)

- ***Multiple Choice Correct***

Que.	38	39	40	41	42	43	44	45	46	47
Ans.	B	B	B,D	D	B	C	A	A	B	B
Que.	48	49	50	51	52	53	54	55	56	57
Ans.	B	A	D	C	A	A,C	D	D	A	A
Que.	58	59	60	61	62	63	64	65	66	
Ans.	A	B	A	B,C,D	A	C	A,C,D	C	B	

- ***Match the Column***

67. (A) r (B) s (C) q (D) p

- ***Comprehension***

Comp.-1 : **68**. (B) **69**. (A)
Comp.-2 : **70**. (B) **71**. (A) **72**. (A) **73**. (A) **74**. (A)
Comp.-3 : **75.** (C) **76**. (B) **77**. (C)
Comp.-4 : **78**. (B) **79**. (D) **80.** (B)
Comp.-5 : **81**. (A) **82**. (B) **83**. (D) **84**. (C)
Comp.-6 : **85**. (B) **86**. (A) **87**. (B)

- ***Subjective Questions***

88. ***(i)*** According to Kirchoff's law, a good absorber is a good emitter. Since a body with large reflectivity is a poor absorber, so it will also be a poor emitter.

(ii) Copper is a good conductor of heat, whereas a wood is a bad conductor of heat. When copper tumbler is touched, the heat will flow from our body which is at higher temperature than the copper tumbler and hence we feel cold. In case of wooden tray, no heat is transferred from our body to the tray and hence we do not feel cold.

(iii) The atmosphere of earth behaves as an insulating envelop to infra red radiations, which do not allow the whole heat received by earth during day time to escape from it during night. But if there is no atmosphere, then the whole heat radiated by earth will leave its surface and it becomes too cold.

(iv) On a clear night, the earth radiates energy into space at a rate proportional to the fourth power of its temperature (about 300 K). The incoming radiation from space is very small because its average temperature is near absolute zero. On the other hand with cloud over, the earth radiates at 300 K, but the radiation is absorbed in the clouds, which radiate energy back to earth again the radiation is trapped, like the green house effect.

(v) A red glass absorbs green light strongly at room temperature. When it is heated, it emits green light, thus satisfying Kirchoff's law.

(vi) Because during day time it receives the heat but it radiates the heat during nights.

(vii) The energy radiates per unit time is directly proportional to the surface area of the body. By curling into a ball, the surface area of the body of the animals decreases and hence loss of heat is reduced.

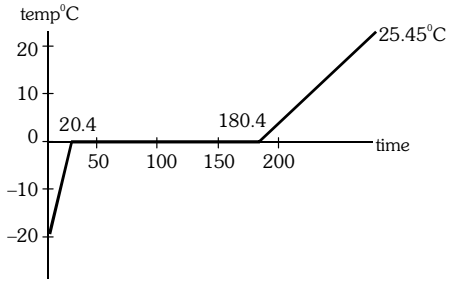
(viii) This is because the rate at which heat is generated becomes equal to the rate at which heat is lost by radiation (i.e., steady state) after some time when the heater is switched on.

(ix) Wood is a bad conductor of heat and is unable to conduct away the heat. So the paper quickly reaches its ignition temp. and is charred. On the other hand, brass is a good conductor of heat and conducts away the heat quickly. So the paper does not reach its ignition point easily.

(x) Black and rough surface is a good absorber of heat than the polished surface. That is why liquid in metallic pot boils quickly whose base is made black and rough.

89. 1 kg

90.



91. 20.3 ^{0}C

92. 12. 96 ms^{-1}

93. 12 g

94. (i) –56.6^{0}C, 5.11 atm (ii) both decrease (iii) 31.1^{0}C, 73 atm (iv) (a) vapour (b) solid (c) liquid

95. 166. 32 S

96. 2/3 × 10^{-4} /°C

97. 41.6 W, 26.48^{0}C, 0.52^{0}C

98. 272

99. 80 min.

100. 8

FLUIDS

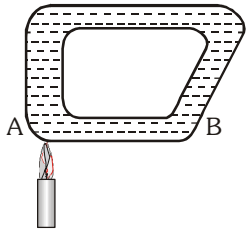
True/False

1. The blood pressure in humans is lower at the feet than at the brain.

2. If instead of fresh water, sea water is filled in a tank, then the velocity of efflux is changed.

3. A soda water bottle is falling freely, then the bubbles of the gas rise in the water of the bottle.

4. Water in a closed tube (see fig.) is heated with one arm vertically placed above a lamp. Water will begin to circulate along the tube in counter–clockwise direction.



5. A block of ice with a lead shot embedded in it is floating on water contained in a vessel. The temperature of the system is maintained at 0°C as the ice melts. When the ice melts completely the level of water in the vessel rises.

Assertion & Reason

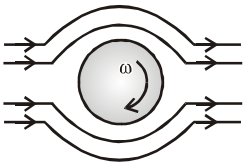
These questions contains, Statement 1 (assertion) and Statement II (reason).

(A) Statement–1 is true, Statement–2 is true ; Statement–2 is correct explanation for Statement–1.
(B) Statement–1 is true, Statement–2 is true ; Statement–2 is NOT a correct explanation for Statement–1
(C) Statement–1 is true, Statement–2 is false
(D) Statement–1 is false, Statement–2 is true

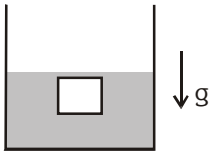
6. ***Statement–1*** : Roofs of buildings are blown off during a strong storm.
and
Statement–2 : Roofs of buildings becomes lighter during storm.

7. ***Statement–1*** : The stream of water emerging from a water tap "necks down" as it falls.
and
Statement–2 : The volume flow rate at different levels is same.

8. ***Statement–1*** : As wind flows left to right and a ball is spined as shown, there will be a lift of the ball.
and
Statement–2 : Decrease in velocity of air below the ball, increases the pressure more than that above the ball.



9. ***Statement–1*** : A block is immersed in a liquid inside a beaker, which is falling freely. Buoyant force acting on block is zero.
and
Statement–2 : In case of freely falling liquid there is no pressure difference between any two points.



10. ***Statement–1*** : An ice cube is floating in water in a vessel at 0^0C. When ice cube melts, level of water in the vessel remain same.
and
Statement–2 : Volume of melted ice is same as volume of water displaced by ice.

11. ***Statement–1*** : Weight of a empty balloon measured in air is w_1. If air at atmospheric pressure is filled inside balloon and again weight of balloon is measured. Weight of balloon is w_2 in second case. Then w_2 is equal to w_1.
and
Statement–2 : Upthrust is equal to weight of the fluid displaced by the body.

12. ***Statement–1*** : The size of a hydrogen balloon increases as it rises in air.
and
Statement–2 : The material of the balloon can be easily stretched.

13. ***Statement–1*** : Specific gravity of a fluid is a dimensionless quantity.
and
Statement–2 : It is the ratio of density of fluid to the density of water.

14. ***Statement–1*** : For Reynold number $R_e > 2000$, the flow of fluid is turbulent.
and
Statement–2 : Inertial forces are dominant compared to the viscous forces at such high Reynold numbers.

15. ***Statement–1*** : A solid sphere and a hollow sphere of same material are floating in a liquid. Radius of both the spheres are same. Percentage of volume immersed of both the spheres will be same.
and
Statement–2 : Upthrust acts on volume of liquid displaced. It has nothing to do whether the body is solid or hollow.

16. ***Statement–1*** : Upthrust on a solid block of iron when immersed in a lake will be less on the surface than on the bed of the lake.
and
Statement–2 : On the surface of the lake density of water will be less than that at the bed and upthrust depends on the density of liquid.

17. ***Statement–1*** : A ball allowed to swing in a region of uniform wind motion, will get an uplift.
and
Statement–2 : Due to swing of the ball in a region of uniform wind motion, the difference in a velocity of air flow is present between the lower and upper position of ball, leading to varying pressure.

18. ***Statement–1*** : The velocity of horizontal flow of a ideal liquid is smaller where pressure is large and vice versa.
and
Statement–2 : According to Barnoullis theorem for the stream line flow of an ideal liquid, the total energy per unit mass remains constant.

19. ***Statement–1*** : A gas filled balloon stops rising after it has attained a certain height in the sky.
and
Statement–2 : At the highest point, the density of air is such that the buoyant force on the balloon just equals its weight.

Single Choice Correct

20. To what height h should a cylindrical vessel of diameter d be filled with a liquid so that the total force on the vertical surface of the vessel be equal to the force on the bottom :–
(A) h = d (B) h = 2d (C) h = 3d (D) h = d/2

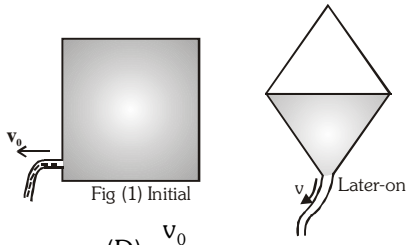
21. A U–tube is partially filled with water. Oil which does not mix with water is next poured into one side, until water rises by 25 cm on the other side. If the density of the oil is 0.8 g/cc, the oil level will stand higher than the water level by :–
(A) 6.25 cm (B) 12.50 cm (C) 18.75 cm (D) 25.00 cm

22. Streamline motion is that motion in which there is:–
(A) Only longitudinal velocity gradient (B) Only radial velocity gradient
(C) Longitudinal as well as radial velocity gradient (D) Neither longitudinal nor radial velocity gradient

23. 16 cm^3 of water flows per second through a capillary tube of radius a cm and of length ℓ cm when connected to a pressure head of h cm of water. If a tube of the same length and radius a/2 cm is connected to the same pressure head, the quantity of water flowing through the tube per second will be:–
(A) 16 cm^3 (B) 4cm^3 (C) 1 cm^3 (D) 8 cm^3

Multiple Choice Correct

24. A square box of water has a small hole located in one of the bottom corner. When the box is full and sitting on a level surface, complete opening of the hole results in a flow of water with a speed v_0, as shown in figure (1). When the box is tilted by 45° and half filled so that the hole is at the lowest point. Now the water will flow out with a speed of:

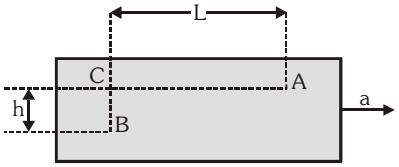


(A) v_0 (B) $\frac{v_0}{2}$ (C) $\frac{v_0}{\sqrt{2}}$ (D) $\frac{v_0}{\sqrt[4]{2}}$

25. Water filled in an empty tank of area 10 A through a tap of cross sectional area A. The speed of water flowing out of tap is given by v (m/s) = $10\left(1-\sin\frac{\pi}{30}t\right)$ where 't' is in seconds. The height of water level from the bottom of the tank at t = 15 second will be:

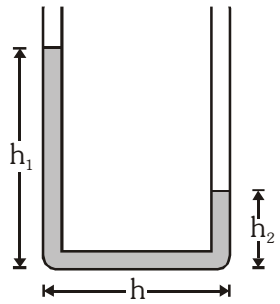
(A) 10m (B) $\left[15+\frac{30}{\pi}\right]$m (C) $\frac{5}{4}$m (D) $\left[15-\frac{30}{\pi}\right]$m

26. A sealed tank containing a liquid of density ρ moves with a horizontal acceleration a, as shown in the figure. The difference in pressure between the points A and B is–



(A) hρg (B) ℓρa (C) hρg – ℓρa (D) hρg + ℓρa

27. The U–tube shown has a uniform cross–section. A liquid is filled in the two arms up to heights h_1 and h_2, and then the liquid is allowed to move. Neglect viscosity and surface tension. When the levels equalize in the two arms, the liquid will–



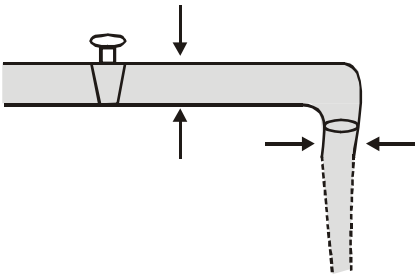
(A) be at rest

(B) be moving with an acceleration of $g\left(\frac{h_1-h_2}{h_1+h_2+h}\right)$

(C) be moving with a velocity of $(h_1-h_2)\sqrt{\frac{g}{2(h_1+h_2+h)}}$

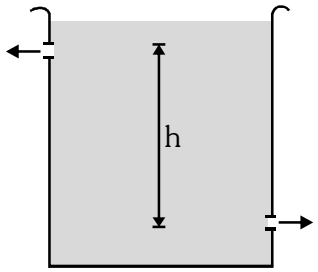
(D) exert a net force to the right on the tube

28. Water coming out of the mouth of a tap and falling vertically in streamline flow forms a tapering column, i.e., the area of cross–section of the liquid column decreases as it moves down. Which of the following is the most accurate explanation for this :-



(A) As the water moves down, its speed increases and hence its pressure decreases. It is then compressed by the atmosphere.
(B) Falling water tries to reach a terminal velocity and hence reduces the area of cross–section to balance upward and downward forces.
(C) The mass of water flowing past any cross–section must remain constant. Also, water is almost incompressible. Hence, the rate of volume flow must remain constant. As this is equal to velocity × area, the area decreases as velocity increases.
(D) The surface tension causes the exposed surface area of the liquid to decrease continuously.

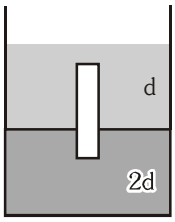
29. There are two identical small holes on the opposite sides of a tank containing a liquid. The tank is open at the top. The difference in height between the two holes is h. As the liquid comes out of the two holes, the tank will experience a net horizontal force proportional to–



(A) $\sqrt{h}$ (B) h
(C) $h^{3/2}$ (D) h^2

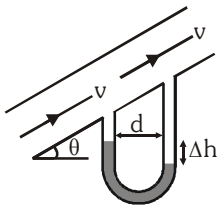
30. A U–tube of uniform cross–section is partially filled with a liquid I. Another liquid II which does not mix with liquid I is poured into one side. It is found that the liquid levels of the two sides of the tube are the same, while the level of liquid I has risen by 2 cm. If the specific gravity of liquid I is 1.1, the specific gravity of liquid II must be :–
(A) 1.12 (B) 1.1 (C) 1.05 (D) 1.0

31. A homogeneous solid cylinder of length L (L < H/2), cross–sectional area A/5 is immersed such that it floats with its axis vertical at the liquid–liquid interface with length L/4 in the denser liquid as shown in the figure. The lower density liquid is open to atmosphere having pressure P_0. Then, density D of solid is given by :



(A) $\frac{5}{4}d$ (B) $\frac{4}{5}d$ (C) 4d (D) $\frac{d}{5}$

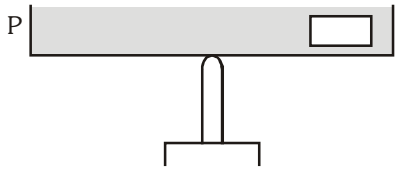
32. A mercury manometer is connected as shown in the figure. The difference in height Δh is : (symbols have usual meaning).



(A) $\frac{\rho d \cot\theta}{\rho_{Hg}}$ (B) $\frac{\rho d \tan\theta}{\rho_{Hg}}$

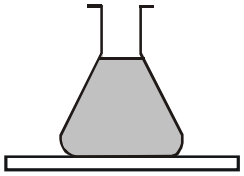
(C) $\frac{\rho d \sin\theta}{\rho_{Hg}}$ (D) None of these

33. An open pan P filled with water (density ρ_W) is placed on a vertical rod, maintaining equilibrium. A block of density ρ is placed on one side of the pan as shown. Water depth is more than height of the block.



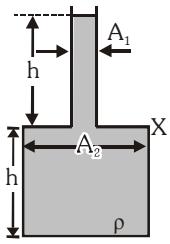
(A) Equilibrium will be maintained only if $\rho < \rho_w$
(B) Equilibrium will be maintained only $\rho \le \rho_w$
(C) Equilibrium will be maintained for all relations between ρ and ρ_w
(D) Equilibrium will not be maintained in all cases.

34. A massless conical flask filled with a liquid is kept on a table in a vacuum. The force exerted by the liquid on the base of the flask is W_1. The force exerted by the flask on the table is W_2.



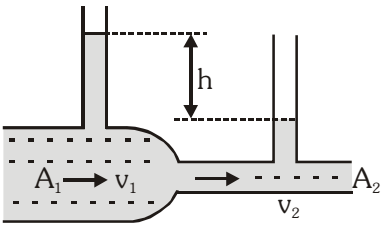
(A) $W_1 = W_2$
(B) $W_1 > W_2$
(C) $W_1 < W_2$
(D) The force exerted by the liquid on the walls of the flask is $(W_1 - W_2)$.

35. The vessel shown in the figure has two sections of areas of cross–section A_1 and A_2. A liquid of density ρ fills both the sections, up to a height h in each. Neglect atmospheric pressure:-



(A) The pressure at the base of the vessel is $2h\rho g$.
(B) The force exerted by the liquid on the base of the vessel is $2h\rho g A_2$.
(C) The weight of the liquid is $< 2h\rho g A_2$.
(D) The walls of the vessel at the level X exert a downward force $h\rho g\,(A_2 - A_1)$ on the liquid.

36. A liquid flows through a horizontal tube. The velocities of the liquid in the two sections, which have areas of cross–section A_1 and A_2, are v_1 and v_2 respectively. The difference in the levels of the liquid in the two vertical tubes is h –



(A) The volume of the liquid flowing through the tube in unit time is A_1v_1

(B) $v_2 - v_1 = \sqrt{2gh}$

(C) $v_2^2 - v_1^2 = 2gh$

(D) The energy per unit mass of the liquid is the same in both sections of the tube.

37. A vertical U–tube contains a liquid. The total length of the liquid column inside the tube is ℓ. When the liquid is in equilibrium, the liquid surface in one of the arms of the U–tube is pushed down slightly and released. The entire liquid column will undergo a periodic motion :–

(A) The motion is not simple harmonic motion.

(B) The motion is simple harmonic motion.

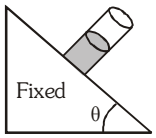
(C) If it undergoes simple harmonic motion, the time period will be $2\pi\sqrt{\frac{\ell}{g}}$

(D) It is undergoes simple harmonic motion, the time period will be $2\pi\sqrt{\frac{\ell}{2g}}$

38. A spherical ball of radius r and relative density 0.5 is floating in equilibrium in water with half of it immersed in water. The work done in pushing the ball down so that whole of it is just immersed in water is [ρ is the density of water] –

(A) 0.25 ρ rg (B) 0.5 ρ rg (C) $\frac{4}{3}\pi r^3\rho g$ (D) $\frac{5}{12}\pi r^4\rho g$

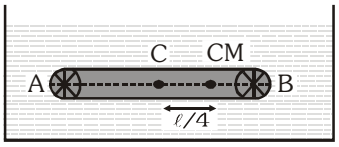
39. A cylindrical vessel filled with water is released on an inclined surface of angle θ as shown in figure. The friction coefficient of surface with vessel is $\mu(< \tan\theta)$. Then the constant angle made by the surface of water with the incline will be–



(A) $\tan^{-1}\mu$ (B) $\theta - \tan^{-1}\mu$

(C) $\theta + \tan^{-1}\mu$ (D) $\cot^{-1}\mu$

40. A non uniform cylinder of mass m, length ℓ and radius r is having its centre of mass at a distance $\ell/4$ from the centre and lying on the axis of the cylinder. The cylinder is kept in a liquid of uniform density ρ, The moment of inertia of the rod about the centre of mass is I. The angular acceleration of point A relative to point B just after the rod is released from the position shown in figure is :

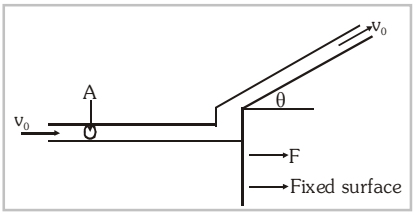


(A) $\frac{\pi\rho g\ell^2r^2}{I}$ (B) $\frac{\pi\rho g\ell^2r^2}{4I}$ (C) $\frac{\pi\rho g\ell^2r^2}{2I}$ (D) $\frac{3\pi\rho g\ell^2r^2}{4I}$

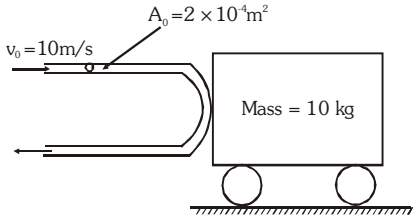
Comprehension

Comprehension-1

When jet of liquid strikes a fixed or moving surface, it exerts thrust on it due to rate of change of momentum.
$F = (\rho A v_0)v_0 - (\rho A v_0)v_0\cos\theta = \rho A v_0^2\,[1-\cos\theta]$



If surface is free and starts moving due to thrust of liquid, then at any instant, the above equation gets modified based on relative change of momentum with respect to surface. Let any instant the velocity of surface is u, then above equation becomes – $F = \rho A(v_0 - u)^2\,[1-\cos\theta]$



Based on above concept, in the below given figure, if the cart is frictionless and free to move in horizontal direction, then answer the following :Given cross–section area of jet = 2×10^{-4} m^2 velocity of jet v_0 = 10 m/s, density of liquid = 1000 kg/m^3, Mass of cart M = 10 kg:

41. Initially (t = 0) the force on the cart is equal to :
(A) 20 N (B) 40 N (C) 80 N (D) zero

42. Velocity of cart at t = 10 s. is equal to:
(A) 4 m/s (B) 6 m/s (C) 8 m/s (D) 5 m/s

43. In the above problem, what is the acceleration of cart at this instant –
(A) 1.6 m/s^2 (B) 1 m/s^2 (C) 0.64 m/s^2 (D) 0.16 m/s^2

44. The time at which velocity of cart becomes 2m/s, is equal to:
(A) 1.6 s (B) 2 s (C) 3.2 s (D) 4s

45. The power supplied to the cart, when its velocity becomes 5 m/s, is equal to :
(A) 100 W (B) 25 W (C) 50 W (D) 200 W

Comprehension-2

The human circulatory system can be thought of as a closed system of interconnecting pipes through which fluid is continuously circulated by two pumps. The two pumps, the right and left ventricles of the heart, work as simple two–stroke force pumps. The muscles of the heart regulate the force by contracting and relaxing. The contraction (systole) lasts about 0.2s, and a complete systole/diastole (contraction/relaxation) cycle lasts about 0.8 s.
For blood pressures and speeds in the normal range, the volume flow rate of blood through a blood vessel is directly proportional to the pressure difference over a length of the vessel and to the fourth power of the radius of the vessel.
The total mechanical energy per unit volume of blood just as it leaves the heart is : $E/V = \rho gh + P + \rho v^2$

46. Why is diastolic blood pressure much lower than systolic pressure ?
(***Note :*** A typical systole/diastole reading in mm Hg is 120/80)
(A) Because the heart exerts more force on the blood during diastole
(B) Because the heart exerts no force on the blood during diastole
(C) Because the radii of the blood vessels increase during diastole, while the force exerted by the heart on the blood remains the same.
(D) Because the radii of the blood vessels decrease during diastole, while the force exerted by the heart on the blood remains the same

47. Which of the following is a way to achieve approximately a 45% increase in the volume flow rate of blood through a blood vessel ?
(A) Increase the radius by 10%
(B) Increase the cross–sectional area of the vessel by 10%
(C) Decrease the change in pressure by 10%
(D) Decrease the speed of flow by 10%

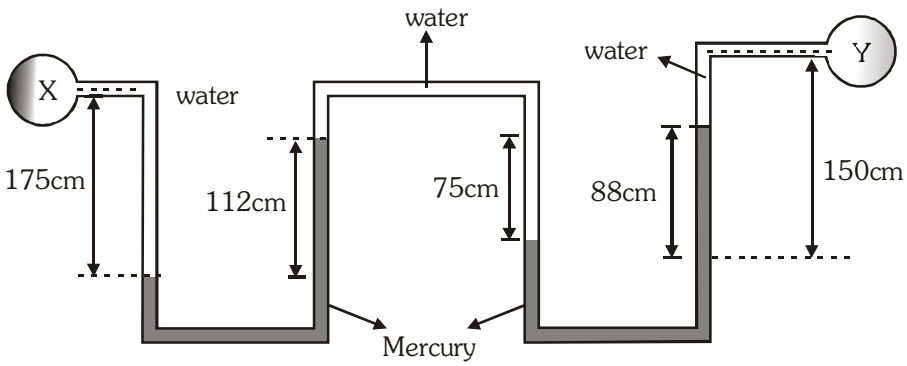
48. What is the gravitational potential energy of 8 cm^3 of blood in a 1.8 m tall man, in a blood vessel 0.3 m above his heart ? (***Note :*** The man's blood pressure is 1.3×10^4 N/m^2.)
(A) 1×10^{-4} J (B) 2.5×10^{-2} J (C) 301×10^3 J (D) 4×10^4 J

49. The blood pressure in a capillary bed is essentially zero, allowing blood to flow extremely slowly through the tissues in order to maximize exchange of gases nutrients, and waste products. What is the work on 200 cm^3 of blood against gravity to bring it to the capillaries to the brain, 50 cm above the heart ?
(A) 5145 J (B) 105 J (C) 10 J (D) 1 J

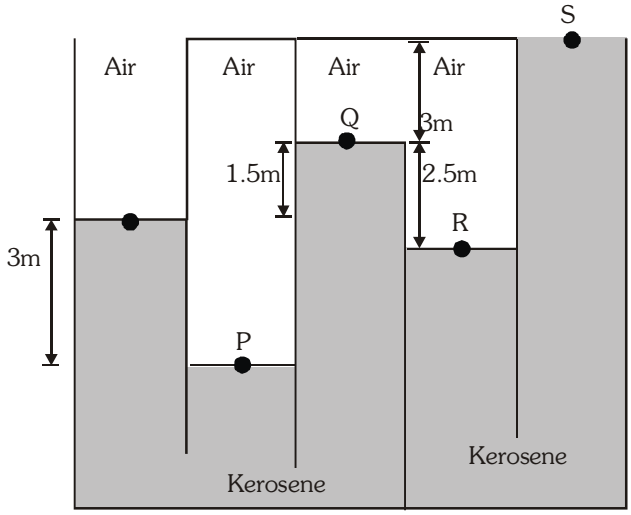
50. During intense exercise, the volume of blood pumped per second by an athlete's heart increases by a factor of 7, and his blood pressure increases by 20%/ By what factor does the power output of the heart increase during exercise ?
(A) 1.2 (B) 3.5 (C) 7 (D) 8.4

- ***Subjective Questions***

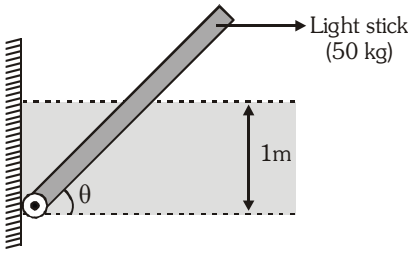
51. Two U–tube manometers are connected in series as shown in figure. Determine difference of pressure between X and Y. Take specific gravity of mercury as 13.6



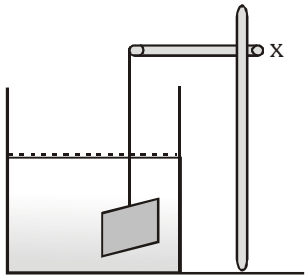
52. The container shown below holds kerosene and air as indicated. Compute the pressure at P, Q, R and S in KN/m^2. Take specific gravity of kerosene as 0.8



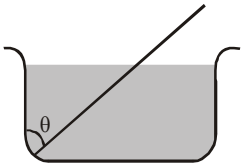
53. A light metal stick of square cross–section (5 cm × 5cm) and length '4m' mass 2.5 kg and is shown in the figure below. Determine its angle of inclination when the water surface is 1m above the hinge. What minimum depth of water above high will be required to bring the metal stick in vertical position.



54. A metallic plate having shape of a square is suspended as shown in figure. The plate is made to dip in water such that level of water is well above that of the plate. The point 'x' is then slowly raised at constant velocity. Sketch the variation of tension T in string with the displacement 'S' of point x.

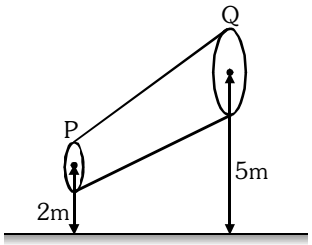


55. A wooden plank of length 1m and uniform cross–section is hinged at one end to the bottom of a tank as shown in figure. The tank is filled with water upto a height 0.5 m. The specific gravity of the plank is 0.5. Find the angle θ that the plank makes with the vertical in the equilibrium position. (exclude the cosθ = 0°).



56. A glass beaker is placed partially filled with water in a sink. It has a mass of 390 gm and an interior volume of 500 cm^3. When water starts filling the sink, it is found that if beaker is less than half full it will float. But if it is more than half full, it remains on the bottom of the sink, as the water rises to its rim. What is the density of the material of which the beaker is made ?

57. A non–viscous liquid of constant density 1000 kg/m^3 flows in streamline motion along a tube of variable cross–section. The tube is kept inclined in the vertical plane as shown in the figure. The area of cross–section of the tube at two points P and Q at height of 2 m and 5m metres are respectively 4×10^{-3} m^2 and 8×10^{-3} m^2. The velocity of the liquid at point P is 1 m/s. Find the work done per unit volume by the pressure and the gravity forces as the fluid flows from point P to Q.

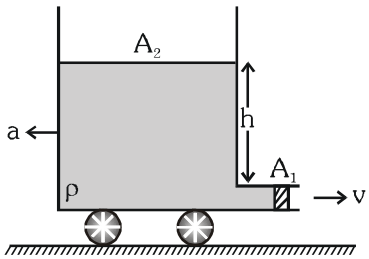


58. A large open top container of negligible mass and uniform cross–sectional area A has a small holes of cross–sectional area $\frac{A}{100}$ in its side wall near the bottom. The container contains a liquid of density ρ and mass m_0. Assuming that the liquid starts flowing out horizontally through the hole at t = 0. Calculate :

(i) the acceleration of the container and

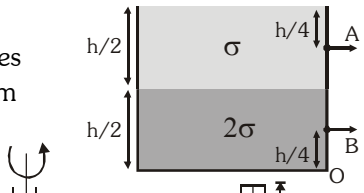
(ii) its velocity when 75% of the liquid has drained out.

59. In a movable container shown in figure a liquid of density ρ is filled up to a height h. The upper & lower tube cross sectional areas are A_2 & A_1 respectively ($A_2 >> A_1$). If the liquid leaves out the container through the tube of cross–sectional area A_1 then find –

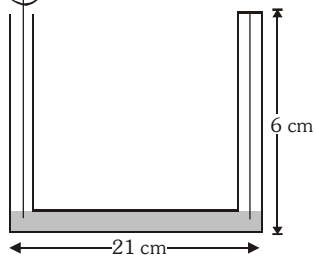


(i) Velocity of liquid coming out. (ii) Backward acceleration of the container.

60. A large tank is filled with two liquids of specific gravities 2σ and σ. Two holes are made on the wall of the tank as shown. Find the ratio of the distance from O of the points on the ground where the jets from holes A & B strike.



61. Length of horizontal arm of a uniform cross–section U–tube is ℓ=21 cm and ends of both of the vertical arms are open to surrounding of pressure 10500 N/m^2. A liquid of density $\rho = 10^3$ kg/m^3 is poured into the tube such that liquid just fills the horizontal part of the tube. Now one of the open ends is sealed and the tube is then rotated about a vertical axis passing through the other vertical arm with angular velocity $\omega_0 = 10$ rad/s. If length of each vertical arm be a = 6 cm. Calculate the length of air column in the sealed arm : [g = 10m/s^2]



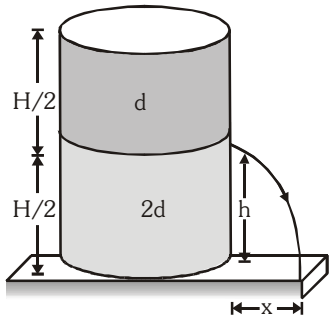
62. A ball of density d is dropped on to a horizontal solid surface. It bounces elastically from the surface and returns to its original position in a time t_1. Next, the ball is released and it falls through the same height before striking the surface of a liquid of density d_L.

(i) If $d < d_L$, obtain an expression (in terms of d, t_1 and d_L) for the time t_2 the ball takes to come back to the position from which it was released.

(ii) is the motion of the ball simple harmonic ?

(iii) If $d = d_L$, how does the speed of the ball depend on its depth inside the liquid ? Neglect all frictional and other dissipative forces. Assume the depth of the liquid to be large.

63. A container of large uniform cross–sectional area A resting on a horizontal surface, holds two immiscible, non–viscous and incompressible liquids of densities d and 2d, each of height $\frac{H}{2}$ as shown in figure. The lower density liquid is open to the atmosphere having pressure P_0.



(i) A homogeneous solid cylinder of length $L\left(L < \frac{H}{2}\right)$, cross–sectional area $\frac{A}{5}$ is immersed such that if floats with its axis vertical at the liquid–liquid interface with length $\frac{L}{4}$ in the denser liquid. Determine:

(a) the density D of the solid, (b) the total pressure at the bottom of the container.

(ii) The cylinder is removed and the original arrangement is restored. A tiny hole of area s (s<<A) is punched on the vertical side of the container at a height h $\left(h < \frac{H}{2}\right)$. Determine :

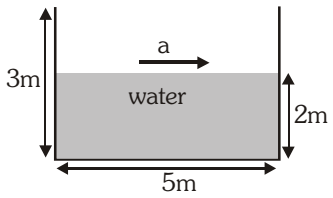
(a) the initial speed of efflux of the liquid at the hole

(b) the horizontal distance x travelled by the liquid initially, and

(c) the height h_m at which the hole should be punched so that the liquid travels the maximum distance x_m initially. Also calculate x_m. (Neglect the air resistance in these calculations)

64. A solid block of volume $V = 10^{-3}$ m^3 and density d = 800 kg/m^3 is tied to one end of a string, the other end of which is tied to the bottom of the vessel. The vessel contains 2 immiscible liquids of densities $\rho_1 = 1000$ kg/m^3 and $\rho_2 = 1500$ kg/m^3. The solid block is immersed with 2/5th of its volume in the liquid of higher density & 3/5th in the liquid of lower density. The vessel is placed in an elevator which is moving up with an acceleration of a = g/2. Find the tension in the string. [g = 10 m/s^2]

65. An open rectangular tank 5 m x 4m x 3m high containing water upto a height of 2m is accelerated horizontally along the longer side.



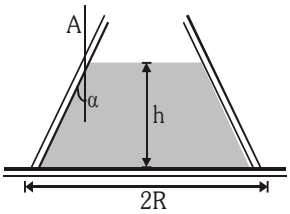
(i) Determine the maximum acceleration that can be given without spilling the water.

(ii) Calculate the percentage of water split over, if this acceleration is increased by 20%.

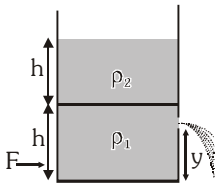
(iii) If initially, the tank is closed at the top and is accelerated horizontally by 9m/s^2, find the gauge pressure at the bottom of the front and rear walls of the tank.

66. A ship sailing from sea into a river sinks X mm and on discharging the cargo rises Y mm. On proceeding again into sea the ship rises the Z mm. Find the specific gravity of sea–water assuming the faces of ship are vertically along the line of sea–water.

67. A conical vessel without a bottom stands on a table. A liquid is poured with the vessel & as the level reaches h, the pressure of the liquid raises the vessel. The radius of the base of the vessel is R and half angle of the cone is α and the weight of the vessel is W. What is the density of the liquid?



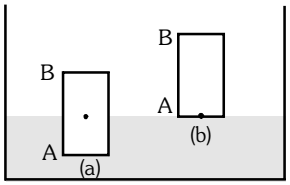
68. A cylindrical tank having cross–sectional area A = 0.5 m^2 is filled with two liquids of densities ρ_1 = 900 kgm^{-3} & ρ_2 =600 kgm^{-3}, to a height h = 60 cm as shown in the figure. A small hole having area a = 5 cm^2 is made in right vertical wall at a height y = 20 cm from the bottom. Calculate



(i) velocity of efflux.
(ii) horizontal force F to keep the cylinder in static equilibrium, if it is placed on a smooth horizontal plane
(iii) Minimum and maximum value of F to keep the cylinder at rest. The coefficient of friction between cylinder and the plane is μ = 0.1
(iv) velocity of the top most layer of the liquid column and also the velocity of the boundary separating the two liquids.

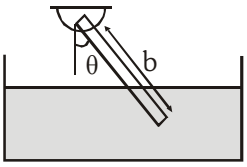
69. A cylindrical wooden float whose base area S = 4000 cm^2 & the altitude H = 50 cm drifts on the water surface. Specific weight of wood d = 0.8 gf/cm^3.
(i) What work must be performed to take the float out of the water?
(ii) Compute the work to be performed to submerged completely the float into the water.

70. A cylindrical rod of length ℓ = 2m & density $\frac{\rho}{2}$ floats vertically in a liquid of density ρ as shown in figure (a).



(i) Show that it performs SHM when pulled slightly up & released & find its time period. Neglect change in liquid level.
(ii) Find the time taken by the rod to completely immerse when released from position shown in (b). Assume that it remains vertical throughout its motion. (take $g=\pi^2$ m/s^2)

71. A uniform rod of length b capable of turning about its end which is out of water, rests inclined to the vertical. If its specific gravity is 5/9, find the length immersed in water.



72. On the opposite sides of a wide vertical vessel filled with water two identical holes are opened, each having the cross–sectional area S = 0.50 cm^2. The height difference between them is equal to Δh = 51 cm. Find the resultant force of reaction of the water flowing out of the vessel.

ANSWERS

- ***True and False***

1.	F	**2.**	F	**3.**	F	**4.**	F	**5.**	F

- ***Assertion–Reason***

6.	(C)	**7.**	(A)	**8.**	(A)	**9.**	(A)	**10.**	(A)
11.	(A)	**12.**	(B)	**13.**	(A)	**14.**	(A)	**15.**	(D)
16.	(A)	**17.**	(A)	**18.**	(A)	**19.**	(A)		

- ***Single Choice Correct***

20.	(D)	**21.**	(A)	**22.**	(A)	**23.**	(C)

- ***Multiple Choice Correct***

24.	(D)	**25.**	(D)	**26.**	(D)	**27.**	(C)	**28.**	(C)
29.	(B)	**30.**	(B)	**31.**	(A)	**32.**	(B)	**33.**	(B)
34.	(B)	**35.**	(A,B,C,D)	**36.**	(A,C,D)	**37.**	(B,D)	**38.**	(D)
39.	(A)	**40.**	(B)						

- ***Comprehension***

Comprehension-1 :	**41.**	(B)	**42.**	(C)	**43.**	(D)	**44.**	(A)	**45.**	(C)
Comprehension-2 :	**46.**	(B)	**47.**	(A)	**48.**	(B)	**49.**	(D)	**50.**	(D)

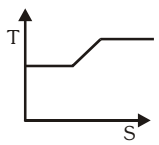
- ***Subjective Questions***

51. 248 kN/m^2

52. $P_P = 124.9$ kN/m^2, $P_Q = 89.5$ kN/m^2, $P_R = 89.5$ kN/m^2, $P_S = 46.4$ kN/m^2

53. $\theta = 30^0$ depth of water $\geq$ 2m

54.



55. 45^0

56. 2.78

57. +29625 J/m^3, – 30000 J/m^3

58. (i) 0.2 m/s^2 (ii) $\sqrt{2g\frac{m_0}{A\rho}}$

59. (i) $v = \left(\sqrt{2gh}\right)$ (ii) $a = \frac{2gA_1}{A_2}$

60. $\sqrt{3} : \sqrt{2}$

61. 5 cm

62. (i) $t_2 = t_1\left[\frac{d_L}{d_L - d}\right]$ (ii) No (iii) does not depend

63. (i) (a) $D=\frac{5}{4}d$ (b) $P=P_0 + \frac{1}{4}(6H+L)\,dg$

(ii) (a) $v = \sqrt{\frac{g}{2}(3H-4h)}$ (b) $x = \sqrt{h(3H-4h)}$ (c) $x_{max}=\frac{3}{4}H$

64. 6N

65. (i) $4 m/s^2$ (ii) 10% (iii) 0, 45 kPa

66. $\frac{Y}{Y-X+Z}$

67. $\rho = \frac{w}{\pi h^2 g\left(\frac{R}{\cos\alpha} - \frac{h}{3}\tan\alpha\right)}$

68. (i) 4 m/s (ii) F = 7.2 N (iii) $F_{min}=0$, $F_{max}=52.2$ N (iv) both 4×10^{-3} m/s

69. (i) $\frac{d^2H^2S}{2\rho g}$ = 32 kgf–m (ii) $\frac{1}{2}SH^2(1-d^2)$ = 2Kgf–m

70. (i) 2 sec (ii) 1 sec

71. $\frac{b}{3}$

72. 0.51 N

PROPERTIES OF MATTER

- ***True and False***

1. A big drop is formed by coalescing 1000 small droplets of water. The ratio of final surface energy to initial surface energy is 1/10.

2. Surface tension of antiseptics should be low.

3. If two row boats happen to sail parallel end close to each other, they experience a force which pulls then towards each other.

Fill in the blanks

4. Water is .....elastic than air.

5. Bulk modulus for an incompressible liquid is .....

6. A wire of length L and cross–sectional area A is made of a material of Young's modulus Y. If the wire is stretched by an amount x, the work done is .....

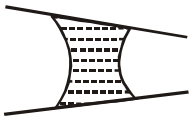
7. A solid sphere of radius R made of a material of bulk modulus K is surrounded by a liquid in a cylindrical container. A massless piston of area A floats on the surface of the liquid. When a mass M is placed on the piston to compress the liquid the fractional change in the radius of the sphere, $\frac{\delta R}{R}$, is .....

8. With increase in temperature, viscosity of a liquid .....

- ***Assertion–Reason***

(A) Statement–1 is true, Statement–2 is true ; Statement–2 is correct explanation for Statement–1.
(B) Statement–1 is true, Statement–2 is true ; Statement–2 is NOT a correct explanation for Statement–1
(C) Statement–1 is true, Statement–2 is false
(D) Statement–1 is false, Statement–2 is true

9. ***Statement–1*** : Two identical conical pipes shown in figure have a drop of water. The water drop tends to move towards tapered end.



and

Statement–2 : Excess pressure is directed towards centre of curvature and inversely proportional to radius of curvature. Net excess pressure is therefore, directed towards tapered end. So the water drop tends to move towards tapered end.

10. ***Statement–1*** : Elasticity restoring forces may be conservative.

and

Statement–2 : The value of strain for same stress are different while increasing the load and while decreasing the load.

11. ***Statement–1*** : The bridges are declared unsafe after a long use.

and

Statement–2 : Elastic strength of bridges losses with time.

12. ***Statement–1*** : Young's modulus for a perfectly plastic body is zero.
and
Statement–2 : For a perfectly plastic body, restoring force is zero.

13. ***Statement–1*** : Identical springs of steel and copper are equally stretched. More work will be done on the steel spring.
and
Statement–2 : Steel is more elastic than copper

14. ***Statement–1*** : The shape of an automobile is so designed that its front resembles the stream line pattern of the fluid through which it moves.
and
Statement–2 : The shape of the automobile is made stream lined in order to reduce resistance offered by the fluid.

15. ***Statement–1*** : Machine parts are jammed in winter.
and
Statement–2 : The viscosity of lubricant used in machine part decrease at low temperature.

16. ***Statement–1*** : The angle of contact of a liquid decrease with increase in temperature.
and
Statement–2 : With increase in temperature the surface tension of liquid increase.

17. ***Statement–1*** : In gravity free space, the liquid in a capillary tube will rise to infinite height.
and
Statement–2 : In the absence of gravity , there will be no force to prevent the rise of liquid due to surface tension.

18. ***Statement–1*** : It is better to wash the clothes in cold soap solution.
and
Statement–2 : The surface tension of cold solution is more than the surface tension of hot solution.***:***

19. ***Statement–1*** : A parachute descends slowly whereas a stone dropped from same height falls rapidly.
and
Statement–2 : The viscous force of air on parachute is larger than that of on a falling stone.

20. ***Statement–1*** : Hot soup tastes better than the cold soup.
and
Statement–2 : Hot soup spread properly on our tongue due to lower surface tension.

21. ***Statement–1*** : Leaves and small insects float on the surface of water buoyed up by Archimedes's principle.
and
Statement–2 : They are not partially submerged. The objects are kept afloat by surface tension.

22. ***Statement–1*** : The stretching of a coil is determined by its shear modulus.
and
Statement–2 : Shear modulus change only shape of a body keeping its dimensions unchanged

23. ***Statement–1*** : At critical temperature, surface tension of liquid becomes zero.
and
Statement–2 : At this temperature, intermolecular forces for liquids and gases become equal. Liquid can expand without any restriction.

24. ***Statement–1*** : When a large soap bubble and a small soap bubble are connected by a capillary tube, the large bubble expands and while the small bubble shrinks.
and
Statement–2 : The excess pressure inside a bubble is inversely proportional to radius.

25. ***Statement–1*** : Smaller drops of liquid resist deforming forces better than the larger drops.
and
Statement–2 : Excess pressure inside a drop is directly proportional to its surface area.

26. ***Statement–1*** : A thin stainless steel needle can lay floating on a still water surface.
and
Statement–2 : Any object floats when the buoyancy force balances the weight of the object.

- ***Single Choice Correct***

27. In a capillary tube experiment, a vertical 30 cm long capillary tube is dipped in water. The water rises up to a height of 10 cm due to capillary action. If this experiment is conducted in a freely falling elevator, the length of the water column becomes :–
(A) 10 cm (B) 20 cm (C) 30 cm (D) Zero

28. Water rises to a height of 16.3 cm in a capillary of height 18 cm above the water level. If the tube is cut at a height of 12 cm :–
(A) Water will come as a fountain from the capillary tube
(B) The height of the water in the capillary will be 12 cm
(C) The height of the water in the capillary will be 16.3 cm
(D) Water will flow down in it's arms

29. The height to which water rises in a capillary will be :–
(A) Maximum at 4° C (B) Maximum at 0° C (C) Minimum at 0° C (D) Minimum at 4° C

30. Water rises in a capillary upto a height h. If now this capillary is tilted by an angle of 45°, then the length of the water column in the capillary becomes :–
(A) 2h (B) $\frac{h}{2}$ (C) $\frac{h}{\sqrt{2}}$ (D) $h\sqrt{2}$

31. If a capillary of radius r is dipped in water, the height of water that rises in it is h and its mass is M. If the radius of the capillary is doubled the mass of water that rises in the capillary will be :–
(A) 4M (B) 2M (C) M (D) $\frac{M}{2}$

32. Calculate the force required to separate the glass plate of area 10^{-2} m^2 with a film of water 0.05 mm thick [surface tension of water is 70×10^{-3} N/m] :–
(A) 25 N (B) 20 N (C) 14 N (D) 28 N

33. A vessel, whose bottom has round holes with diameter of 0.1 mm, is filled with water. The maximum height to which the water can be filled without leakage is :– (S.T. of water = 75 dyne/cm, g = 1000 cm/s^2)
(A) 100 cm (B) 75 cm (C) 50 cm (D) 30 cm

34. More viscous oil is used in summer than in winter in motors due to :–
(A) Rise in temperature in summer, the viscosity of oil decreases
(B) Rise in temperature in summer, viscosity of oil increases
(C) Surface tension of oil increases
(D) Surface tension of oil decreases

35. With increase in temperature, the viscosity of :–
(A) Gases decreases and liquid increases (B) Gases increases and liquid decreases
(C) Both gases and liquid increases (D) Both gases and liquid decreases

36. A rain drop of radius 0.3 mm has a terminal velocity in air 1m/s. The viscosity of air is 18×10^{-5} poise. The viscous force on it is :–
(A) 101.73×10^{-4} dyne (B) 101.73×10^{-5} dyne
(C) 16.95×10^{-5} dyne (D) 16.95×10^{-4} dyne

37. Two liquids of densities d_1 and d_2 are flowing in identical capillaries under same pressure difference. If t_1 and t_2 are the time taken for the flow of equal quantities of liquids, then the ratio of coefficients of viscosities of liquids must be :–

(A) $\frac{d_1 d_2}{t_1 t_2}$ (B) $\frac{d_1 t_1}{d_2 t_2}$ (C) $\frac{d_1 t_2}{d_2 t_1}$ (D) $\sqrt{\left(\frac{d_1 t_1}{d_2 t_2}\right)}$

38. The velocity of falling rain drop attain limited value because of :–
(A) Surface tension (B) Upthrust due to air
(C) Viscous force exerted by air (D) Air current

39. The rate of flow of liquid through a capillary tube, in an experiment to determine the viscosity of the liquid, increases :–
(A) When the pressure of the tube is increased (B) When the length of the tube is increased
(C) When the radius of the tube is decreased (D) None of the above

40. A copper ball of radius 'r' travels with a uniform speed 'v' in a viscous fluid. If the ball is changed with another ball of radius '2r', then new uniform speed will be :–
(A) v (B) 2v (C) 4v (D) 8v

41. Two drops of equal radius are falling through air with a steady velocity of 5cm/sec. If the two drops coalesce, then its terminal velocity will be :–

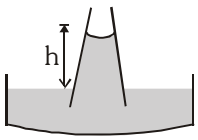
(A) $4^{\frac{1}{3}} \times 5$ cm/s (B) $4^{\frac{1}{3}}$ cm/s (C) $5^{\frac{1}{3}} \times 4$ cm/s (D) $4^{\frac{2}{3}} \times 5$ cm/s

- ***Multiple Choice Correct***

42. On dipping a capillary of radius 'r' in water, water rises upto a height H and potential energy of water is u_1. If a capillary of radius 2r is dipped in water, then the potential energy is u_2. The ratio $\frac{u_1}{u_2}$ is :–
(A) 2 : 1 (B) 1 : 2 (C) 4 : 1 (D) 1 : 1

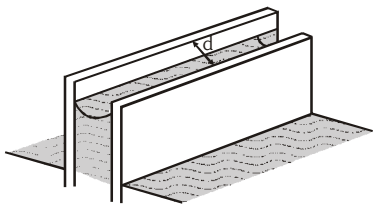
43. When a capillary tube is dipped in a liquid, the liquid rises to a height h in the tube. The free liquid surface inside the tube is hemispherical in shape. The tube is now pushed down so that the height of the tube outside the liquid is less than h:-
(A) The liquid will come out of the tube like in a small fountain.
(B) The liquid will ooze out of the tube slowly.
(C) The liquid will fill the tube but not come out of its upper end.
(D) The free liquid surface inside the tube will not be hemispherical.

44. A capillary of the shape as shown is dipped in a liquid. Contact angle between the liquid and the capillary is 0° and effect to liquid inside the meniscus is to be neglected. T is surface tension of the liquid, r is radius of the meniscus, g is acceleration due to gravity and ρ is density of the liquid then height h in equilibrium is:



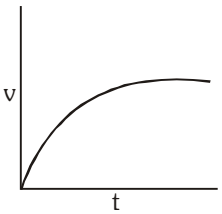
(A) Greater than $\frac{2T}{r\rho g}$ (B) Equal to $\frac{2T}{r\rho g}$
(C) Less than $\frac{2T}{r\rho g}$ (D) Of any value depending upon actual value

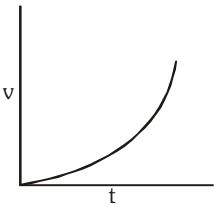
45. Two very wide parallel glass plates are held vertically at a small separation d, and dipped in water. Some water climbs up in the gap between the plates. Let S be the surface tension of water, P_0 = atmospheric pressure, P = pressure of water just below the water surface in the region between the plates–

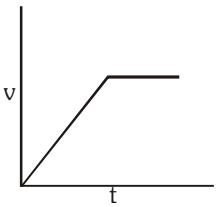


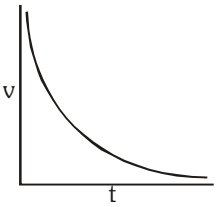
(A) $P=P_0-\frac{2S}{d}$ (B) $P=P_0+\frac{2S}{d}$
(C) $P=P_0-\frac{4S}{d}$ (D) $P=P_0+\frac{4S}{d}$

46. A piece of cork starts from rest at the bottom of a lake and floats up. Its velocity v is plotted against time t. Which of the following best represents the resulting curve–

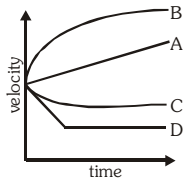
(A) 

(B) 

(C) 

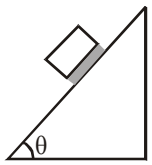
(D) 

47. A small ball is left in a viscous liquid form very much height. Correct graph of its velocity with time is :–



(A) A (B) B
(C) C (D) D

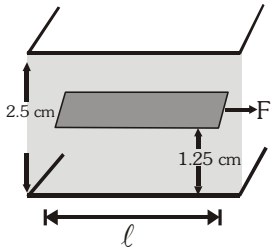
48. A cubical block of side 'a' and density 'ρ' slides over a fixed inclined plane with constant velocity 'v'. There is a thin film of viscous fluid of thickness 't' between the plane and the block. Then the coefficient of viscosity of the thin film will be:



(A) $\frac{\rho a g t \sin\theta}{v}$ (B) $\frac{\rho a g t \cos\theta}{v}$

(C) $\frac{v}{\rho a g t \sin\theta}$ (D) None of these

49. A space 2.5 cm wide between two large plane surfaces is filled with oil. Force required to drag a very thin plate of area 0.5 m^2 just midway the surfaces at a speed of 0.5 m/s is 1N. The coefficient of viscosity in kg–sec/m^2 is:

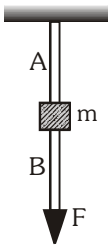


(A) 5×10^{-2} (B) 2.5×10^{-2}
(C) 1×10^{-2} (D) 7.5×10^{-2}

50. A large drop of oil, whose density is less than that of water, floats up through a column of water. Assume that the oil and the water do not mix. The coefficient of viscosity of the oil is η_o and that of water is η_W. The velocity of the drop will depend on–

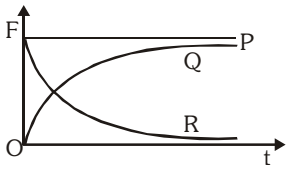
(A) both η_o and η_W (B) η_o only (C) η_W only (D) neither η_o nor η_W

51. The wires A and B shown in the figure are made of the same material, and have radii r_A and r_B respectively. The block between them has a mass m. When the force F is mg/3, one of the wires breaks–



(A) A will break before B if $r_A = r_B$
(B) A will break before B if $r_A < 2r_B$
(C) Either A or B may break if $r_A = 2r_B$
(D) The lengths of A and B must be known to predict which wire will break

52. A spherical ball is dropped in a long column of viscous liquid. Which of the following graphs represent the variation of :–



(i) Gravitational force with time
(ii) Viscous force with time
(iii) Net force acting on the ball with time

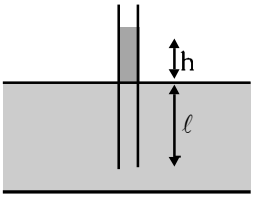
(A) Q, R, P (B) R, Q, P (C) P, Q, R (D) R, P, Q

53. A small sphere of mass m is dropped from a height. After it has fallen 100 m, it has attained its terminal velocity and continues to fall at that speed. The work done by air friction against the sphere during the first 100 m of fall is :–

(A) Greater than the work done by air friction in the second 100 m
(B) Less tan the work done by air friction in the second 100 m
(C) Equal to 100 mg
(D) Greater than 100 mg

- **Subjective Questions**

54. The capillary tube is dipped in water vertically. It is sufficiently long so that water rises to maximum height h in the tube. The length of the portion immersed in water is $\ell > h$. The lower end of the tube is closed, the tube is taken out and opened again. Then, find the length of the water column remaining in the tube.



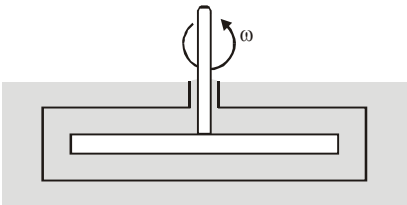
55. There is soap bubble of radius 2.4×10^{-4} m in air cylinder which is originally at the pressure of 10^5 N/m^2. The air in the cylinder is now compressed isothermally until the radius of the bubble is halved. Calculate now the pressure of air in the cylinder. The surface tension of the soap film is 0.08 Nm^{-1}.

56. A flask contains glycerine and the other contains water. Both are stirred vigorously and placed on the table. In which flask will the liquid come to rest earlier and why ?

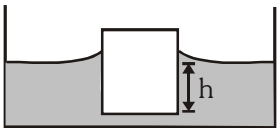
57. There is a 1mm thick layer of glycerine between a flat plate of area 100 cm^2 and a big plate. If the coefficient of viscosity of glycerine is 1.0 kg/m–sec, then how much force is required to move the plate with a velocity of 7 cm/sec.

58. A spherical ball of radius 3×10^{-4} m and density 10^4 kg/m^3 falls freely under gravity through a distance h before entering a tank of water. If after entering the water the velocity of the ball does not change, find h. The viscosity of water is 9.8×10^{-6} N–s/m^2.

59. A thin horizontal disc of radius R = 10 cm is located with in a cylindrical cavity filled with oil whose viscosity η = 0.08 P (figure). The distance between the disc and the horizontal planes of the cavity is equal to h = 1.0 mm. Find the power developed by the viscous forces acting on the disc when it rotates with the angular velocity ω=60 rad/s. The end effects are to be neglected.



60. A cube with a mass 'm' completely wettable by water floats on the surface of water. Each side of the cube is 'a'. What is the distance h between the lower face of cube and the surface of the water if surface tension is S. Take density of water as ρ_w. Take angle of contact is zero.



61. When a vertical capillary of length ℓ with the sealed upper end was brought in contact with the surface of a liquid, the level of this liquid rise to the height h. The liquid density is ρ, the inside diameter of the capillary is d, the contact angle is θ, the atmospheric pressure is P_0. Find the surface tension of the liquid.

62. The end of a capillary tube with a radius r is immersed into water. What amount of heat will be evolved when the water rises in the tube ? If surface tension of water 'T' density of water = ρ.

63. A soap bubble of radius 'r' and surface tension 'T' is given a potential of 'V' volt. Show that the new radius 'R' of the bubble is related to its initial radius by equation,

$$P_0 [R^3 - r^3] + 4T[R^2 - r^2] - \varepsilon_0 V^2 R/2 = 0,$$ where P_0 is the atmospheric pressure.

64. A glass rod of diameter d_1 = 1.5 mm is inserted symmetrically into a glass capillary with inside diameter d_2 = 2.0 mm. then the whole arrangement is vertically oriented and brought in contact with the surface water. To what height will the liquid rise in the capillary. Surface tension of water = 73×10^{-3} N/m. Angle of contact = 0°. (use g = 9.8 m/s^2)

65. Under isothermal condition two soap bubbles of radii a and b coalesce to form a single bubble of radius c. If the external pressure is p_0, show that the surface tension $T = p_0 (c^3 - a^3 - b^3)/4 (a^2 + b^2 - c^2)$.

ANSWERS

- ***True and False***

1. True **2.** True **3.** True

- ***Fill in the Blanks***

4. More **5.** Infinite **6.** $\frac{1}{2}\left(\frac{YA}{L}\right)x^2$ **7.** $\frac{Mg}{3AK}$ **8.** Decrease

- ***Assertion–Reason***

9.	A	**10.**	B	**11.**	A	**12.**	A	**13.**	A
14.	A	**15.**	C	**16.**	C	**17.**	A	**18.**	D
19.	A	**20.**	A	**21.**	D	**22.**	A	**23.**	A
24.	A	**25.**	C	**26.**	C				

- ***Single Choice Correct***

27.	C	**28.**	B	**29.**	D	**30.**	D	**31.**	B
32.	D	**33.**	D	**34.**	A	**35.**	B	**36.**	A
37.	B	**38.**	C	**39.**	A	**40.**	C	**41.**	A

- ***Multiple Choice Correct***

42.	D	**43.**	CD	**44.**	C	**45.**	A	**46.**	A
47.	B	**48.**	A	**49.**	B	**50.**	C	**51.**	ABC
52.	C	**53.**	B						

- ***Subjective Questions***

54. 2h

55. 8.08×10^5 N/m^2

56. Glycerine Flask

57. 0.7 N

58. 1.65×10^3 m

59. 9W

60. $h = \frac{mg + 4Sa}{\rho_w a^2 g}$

61. $\left[\rho gh + \frac{P_0 h}{\ell - h}\right]\frac{d}{4\cos\theta}$

62. $\frac{2\pi T^2}{\rho g}$

64. $h = \frac{4T}{\rho(d_2 - d_1)g} = 6\text{cm}$

True / False

1. Any physical system, when disturbed, will execute simple harmonic motion.

2. The motion of earth around the sun is periodic and oscillatory.

3. If the displacement, velocity and acceleration at a particular instant of particle describing SHM are respectively 1cm, 1cm/s and 1cm/s^2 respectively then period of oscillation is also 1sec.

4. A pendulum clock, in a lift that descends at a constant velocity shows correct time.

5. The velocity of a particle in S.H.M. increases as the particle moves towards mean position and decreases as it moves towards extreme positions.

6. The phase of an oscillator is determined by its displacement and velocity at time t =0.

7. The amplitude of a pendulum, oscillating in air, decreases with time.

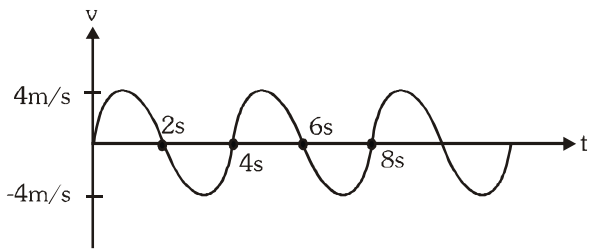
Fill in the blanks

8. An object of mass 0.2 kg executes simple harmonic oscillational along the x-axis with a frequency of $(25/\pi)$ Hz. At the position x = 0.04, the object has kinetic energy of 0.5 J and potential energy 0.4 J. The amplitude of oscillations is_____ m.

9. A second pendulum A (time period 2 second) and another simple pendulum B of slightly less length than A are made to oscillate at t = 0 in same phase. If they are again in the same phase first time, after 18 seconds, then the time period of B is_____

10. Suppose the mass m is attached to a long uniform spring of length L and observed to oscillate at a frequency f_o. Now the spring is cut into two pieces of lengths xL and (1-x)L. Mass m is divided into two pieces in this same ratio with m_1 = xm and m_2 = (1-x)m. The larger mass is attached to the shorter spring and the smaller mass to the larger spring. The frequency of oscillation for each of the two spring is _____

11. If velocity of a particle moving along a straight line changes sinusoidally with time as shown in the given graph,its average velocity over time interval t = 0 to t = 2(2n - 1) seconds, n being any +ve integer, will be_____



12. A block is kept on a platform which is oscillating simple harmonically along a horizontal line with angular frequency ω. If the coefficient of friction between the block and the plate form is μ then the maximum amplitude of SHM of the platform for which the block remains in constant with the platform is _____.

13. A particle performs SHM. If velocity at x_1 is v_1 and x_2 is v_2 then amplitude is _____and angular frequency is _____

14. Two particles perform SHM with the same amplitude and same frequency about the same mean position and along the same line. If the maximum distance between them during the motion is A (A is the amplitude of either) then the phase difference between their SHM is _____

Assertion & Reason

In each of the following questions, a statement of Assertion (A) is given followed by a corresponding statement of Reason (R) just below it . Of the statements mark the correct answer as

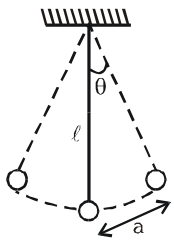
(A) Statement–1 is True, Statement–2 is True ; Statement–2 is a correct explanation for Statement–1

(B) Statement–1 is True, Statement–2 is True ; Statement–2 is NOT a correct explanation for Statement–1

(C) Statement–1 is True, Statement–2 is False.

(D) Statement–1 is False, Statement–2 is True.

15. ***Statement–1 :*** The motion of a simple pendulum is simple harmonic only for a $<< \ell$.



and

Statement–2 : Motion of a simple pendulum is SHM for small angular displacement.

16. ***Statement–1 :*** Pendulum clocks go slow in summer and fast in winter.

and

Statement–2 : The length of the pendulum used in clock increases in summer.

17. ***Statement–1 :*** SHM is not a periodic motion.

and

Statement–2 : Periodic motion repeat its position after certain interval of time.

18. ***Statement–1 :*** In compound pendulum, if suspension point and centre of oscillation are mutually interchange, then no change in time period is obtained.

and

Statement–2: Length of equivalent simple pendulum remains same in both the case.

19. ***Statement–1 :***Any oscillatory motion cannot be treated as simple harmonic.

and

Statement–2:Even under larger amplitude restoring force should be proportional to displacement for being classified as SHM.

20. ***Statement–1 :*** When a girl sitting on a swing stands up, the periodic time of the swing will increase.

and

Statement–2: In standing position of a girl, the length of the swing will decrease.

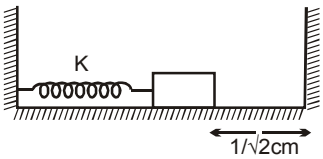
21. ***Statement–1:*** Mechanical energy of a particle executing SHM is E. Maximum KE of particle may be greater than E.

and

Statement–2 :Potential energy of a system may be negative.

Single Choice Correct

22. A block of mass 0.9 kg attached to a spring of force constant K is compressed by $\sqrt{2}$ cm and the block is at a distance $\frac{1}{\sqrt{2}}$ cm from the wall. When the block is released, it makes elastic collision with the wall and its period of motion is 0.2 s. The value of K is (take $\pi^2=10$)



(A) 100 Nm^{-1} (B) 10 Nm^{-1} (C) 0.1 Nm^{-1} (D) 1 Nm^{-1}

23. A system of two identical rods (L-shaped) of mass m and length ℓ are resting on a peg P as shown in the figure. If the system is displaced in its plane by a small angle θ, find the period of oscillations

(A) $2\pi\sqrt{\frac{\sqrt{2}\ell}{3g}}$ (B) $2\pi\sqrt{\frac{2\sqrt{2}\ell}{3g}}$ (C) $2\pi\sqrt{\frac{2\ell}{3g}}$ (D) $3\pi\sqrt{\frac{\ell}{3g}}$

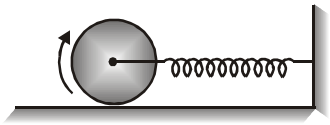
24. A heavy brass-sphere is hung from a spiral spring and it executes vertical vibrations with period T. The ball is now immersed in nonviscous liquid with a density one-tenth that of brass. When set into vertical vibrations with the sphere remaining inside the liquid all the time, the period will be-

(A) $\left[\frac{9}{10}\right]T$ (B) $T\sqrt{\left(\frac{10}{9}\right)}$ (C) Unchanged (D) $T\sqrt{\left(\frac{9}{10}\right)}$

25. An oscillation is described by the equation $x = A \sin 2\pi\gamma_1 t$ where A changes with time according to the law $A = A_0 (1+\cos 2\pi\gamma_2 t)$ where A_0 is constant. Find the ratio of frequencies of harmonic oscillations forming oscillation

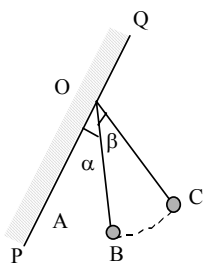
(A) $\gamma_1 : \gamma_2 : (\gamma_1 - \gamma_2)$ (B) $\gamma_1 : (\gamma_1 - \gamma_2) : (\gamma_1 + \gamma_2)$ (C) $\gamma_1 : \gamma_2 : (\gamma_2 - \gamma_1)$ (D) $\gamma_1 : \gamma_2 : (\gamma_1 + \gamma_2)$

26. A solid cylinder of mass M attached to a massless spring of force constant k is placed on a horizontal surface in such a way that cylinder can roll without slipping. If the system is released from the stretched position of the spring, then the period will be-



(A) $2\pi\sqrt{\frac{M}{k}}$ (B) $2\pi\sqrt{\frac{3M}{2k}}$ (C) $2\pi\sqrt{\frac{M}{2k}}$ (D) $2\pi\sqrt{\frac{2M}{3k}}$

27. A ball is suspended by a thread of length L at the point O on the wall PQ which is inclined to the vertical through an angle α. The thread with the ball is now displaced through a small angle β away from the vertical and the wall. If $\beta < \alpha$, then the time period of oscillation of the pendulum will be-

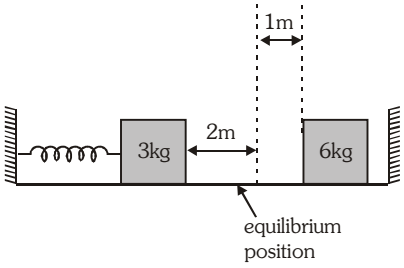


(A) $2\pi\sqrt{\frac{L}{g}}$ (B) $2\pi\sqrt{\frac{L}{g}\left[\pi + 2\sin^{-1}\left(\frac{\alpha}{\beta}\right)\right]}$

(C) $2\pi\sqrt{\frac{L}{g}\left[\frac{\pi}{2} + \sin^{-1}\left(\frac{\alpha}{\beta}\right)\right]}$ (D) None of the above

Multiple Choice Correct

28. Two blocks of masses 3 kg and 6 kg rest on a horizontal smooth surface. The 3 kg block is attached to a spring with a force constant k = 900 Nm^{-1} which is compressed 2 m from beyond the equilibrium position. The 6 kg block is at rest at 1 m from mean position. 3 kg mass strikes the 6 kg mass and the two stick together.



(A) velocity of the combined masses immediately after the collision is 10 ms^{-1}
(B) velocity of the combined masses immediately after the collision is 5 ms^{-1}
(C) amplitude of the resulting oscillation is $\sqrt{2}$ m
(D) amplitude of the resulting oscillation is $\sqrt{5}$ /2m.

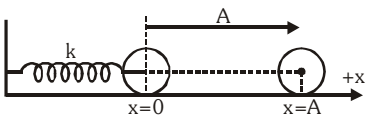
29. A disc of mass 3 m and a disc of mass m are connected by massless spring of stiffness k. The heavier disc is placed on the ground with the spring vertical and lighter disc on top. From its equilibrium position, the upper disc is pushed down by a distance δ and released. Then

(A) if δ >3mg/k, the lower disc will bounce up
(B) if δ =2 mg/k, maximum normal reaction from ground on lower disc = 6 mg
(C) if δ =2 mg/k, maximum normal reaction from ground on lower disc = 4 mg
(D) if δ >4mg/k, the lower disc will bounce up

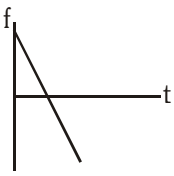
Comprehension

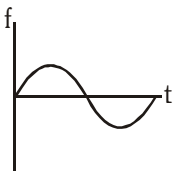
Comprehension-1

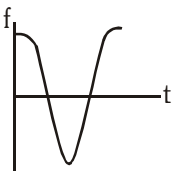
In case of pure rolling a = Rα, where a is the linear acceleration and α the angular acceleration. A disc of mass m and radius R is attached with a spring of force constant k at its centre as shown in figure. At x = 0, spring is unstretched. The disc is moved to x = A and then released. There is no slipping between disc and ground. Let f be the force of friction on the disc from the ground.

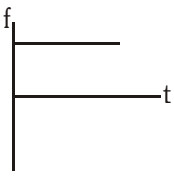


30. f versus t (time) graph will be as :

(A) 

(B) 

(C) 

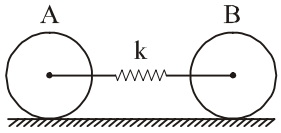
(D) 

31. In the problem if k = 10 N/m, m = 2 kg, R = 1 m and A = 2 m. Find linear speed of the disc at mean position:

(A) $\sqrt{\frac{40}{3}}$ m/s (B) $\sqrt{20}$ m/s (C) $\sqrt{\frac{10}{3}}$ m/s (D) $\sqrt{\frac{50}{3}}$ m/s

Comprehension-2

Two spheres A and B of the same mass m and the same radius are placed on a rough horizontal surface A is a uniform hollow sphere and B is uniform solid sphere. A and B can roll without sliding on the floor. they are also tied centrally to a light spring of spring constant k. A and B are released when the extension in the spring is x_0..



32. Find the amplitude of SHM of the sphere B

(A) $\frac{25x_0}{46}$ (B) $\frac{21x_0}{46}$ (C) $\frac{27x_0}{46}$ (D) $\frac{27x_0}{46}$

33. Find the frequency of oscillation of the spheres

(A) $\frac{1}{2\pi}\sqrt{\frac{35k}{46m}}$ (B) $\frac{1}{2\pi}\sqrt{\frac{46k}{35m}}$ (C) $\frac{1}{2\pi}\sqrt{\frac{25k}{46m}}$ (D) $\frac{1}{2\pi}\sqrt{\frac{21k}{46m}}$

Comprehension-3

Two particles A and B are performing SHM along x and y-axis respectively with equal amplitude and frequency of 2 cm and 1 Hz respectively. Equilibrium positions of the particles A and B are at the coordinates (3 cm, 0) and (0, 4 cm) respectively. At t = 0, B is at its equilibrium position and moving towards the origin, while A is nearest to the origin and moving away from the origin.

34. Equation of motion of particle A can be written as-

(A) $x = (2\text{ cm})\cos 2\pi t$ (B) $x = (3\text{ cm}) - (2\text{ cm})\cos 2\pi t$
(C) $x = (2\text{ cm})\sin 2\pi t$ (D) $x = (3\text{ cm}) - (2\text{ cm})\sin 2\pi t$

35. Equation of motion of particle B can be written as-

(A) $y = (2\text{ cm})\cos 2\pi t$ (B) $y = (4\text{ cm}) - (2\text{ cm})\cos 2\pi t$
(C) $y = (2\text{ cm})\sin 2\pi t$ (D) $y = (4\text{ cm}) - (2\text{ cm})\sin 2\pi t$

36. Minimum and maximum distance between A and B during the motion is

(A) $\sqrt{5}$ cm and $\sqrt{61}$ cm (B) 3 cm and 7 cm (C) 1 cm and 5 cm (D) 9 cm and 16 cm

Subjetive Questions

37. Find the resulting amplitude A' and the phase of the vibrations δ

$$S = A\cos(\omega t) + \frac{A}{2}\cos\left(\omega t + \frac{\pi}{2}\right) + \frac{A}{2}\cos(\omega t + \pi) + \frac{A}{8}\cos\left(\omega t + \frac{3\pi}{2}\right) = A'\cos(\omega t + \delta).$$

38. Two particles A and B execute SHM along the same line with the same amplitude a and same frequency about same equilibrium position O. If the phase difference between them is $\phi = 2\sin^{-1}(0.9)$, then find the maximum distance between the two.

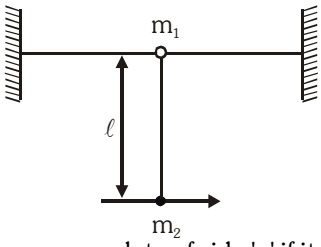
39. A point particle of mass 0.1 Kg is executing SHM with amplitude of 0.1m. When the particle passes through the mean position, its kinetic energy is 8×10^{-3} J. Obtain the equation of motion of this particle if the initial phase of oscillation is 45°.

40. Potential Energy (U) of a body of unit mass moving in a one-dimension conservative force field is given by, $U = (x^2 - 4x + 3)$. All units are in S.I.

(i) Find the equilibrium position of the body.
(ii) Show that oscillations of the body about this equilibrium position is simple harmonic motion & find it time period.
(iii) Find the amplitude of oscillations if speed of the body at equilibrium posiiton is $2\sqrt{6}$ m/s

41. A block of mass 1kg hangs without vibrating at the end of a spring with a force constant 1 N/m attached to the ceiling of an elevator. The elevator is rising with an upward acceleration of g/4. The acceleration of the elevator suddenly ceases. What is the amplitude of the resulting oscillations?

42. A small ring of mass m_1 is connected by a string of length ℓ to a small heavy bob of mass m_2. The ring is free to move (slide) along a fixed smooth horizontal wire . The bob is given a small displacement from its equilibrium position at right angles to string . Find period of small oscillations.

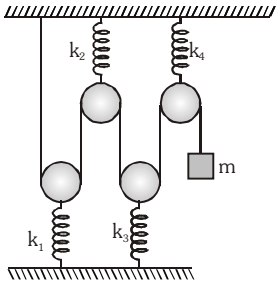


43. Calculate the time period of a uniform square plate of side 'a' if it is suspended through a corner.

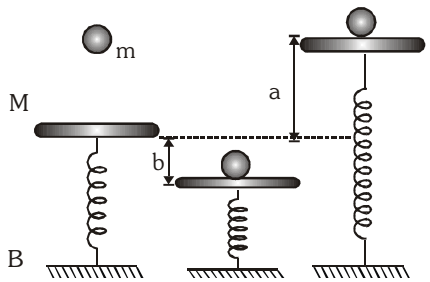
44. Two identical rods each of mass m and length L, are rigidly joined and then suspended in a vertical plane so as to oscillate freely about an axis normal to the plane of paper passing through 'S' (point of suspension). Find the time period of such small oscillations.

45. A half ring of mass m, radius R is hanged at its one end in verticle plane and is free to oscillate in its plane. Find oscillations frequency of the half ring.

46. In the arrangement as shown in fig., pulleys are small and springs are ideal. k_1, k_2, k_3 and k_4 are force constants of the springs. Calculate period of small vertical oscillations of block of mass m.

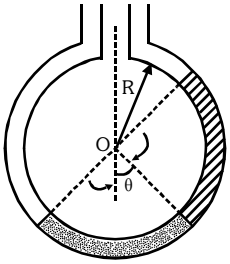


47. A mass M is in static equilibrium on a massless vertical spring as shown in the figure. A ball of mass m dropped from certain height sticks to the mass M after colliding with it. The oscillations they perform reach to height 'a' above the original level of scales & depth 'b' below it.



(i) find the constant of force of the spring
(ii) find the oscillation frequency.
(iii) what is the height above the initial level from which the mass m was dropped?

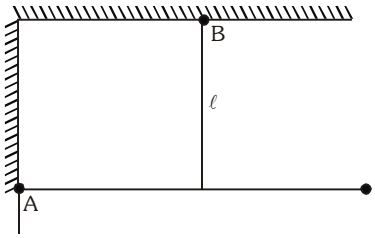
48. Two non-viscous, incompressible and immiscible liquids of densities ρ and 1.5ρ are poured into the two limbs of a circular tube of radius R and small cross-section kept fixed in a vertical plane as shown in figure. Each liquid occupies one-fourth the circumference of the tube.



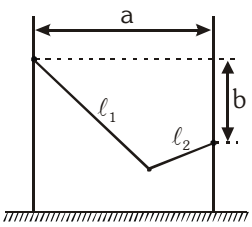
(i) Find the angle θ that the radius to the interface makes with the vertical in equilibrium position.

(ii) If the whole liquid column is given a small displacement from its equilibrium position, show that the resulting oscillations are simple harmonic. Find the time period of these oscillations.

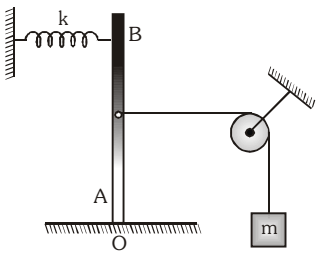
49. A weightless rigid rod with a load at the end is hinged at point A to the wall so that it can rotate in all directions. The rod is kept in the horizontal position by a vertical inextensible thread of length ℓ, fixed at its midpoint. The load receives a momentum in the direction perpendicular to the plane of the figure. Determine the period T of small oscillations of the system.



50. One rope of a swing is fixed above the other rope by b. The distance between the poles of the swing is a. The lengths ℓ_1 and ℓ_2 of the ropes are such that $\ell_1^2 + \ell_2^2 = a^2 + b^2$ (Fig.) Determine the period T of small oscillations of the swing, neglecting the height of the swining person in comparison with the above lengths.

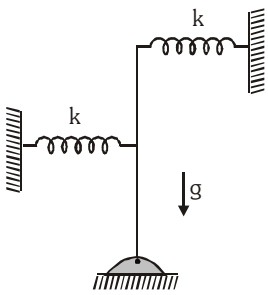


51. A massless rod rigidly fixed at O . A string carrying a mass m at one end is attached to point A on the rod so that OA = a. At another point B (OB = b) of the rod , a horizontal spring of force constant k is attached as shown . Find the period of small vertical oscillations of mass m around its equilibrium position



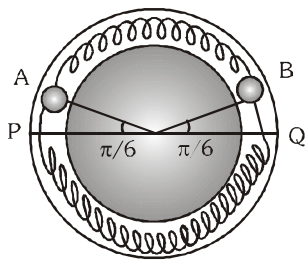
52. A lift operator hung an exact pendulum clock on the lift wall in a lift in a building to know the end of the working day. The lift moves with an upward & downward accelerations during the same time (according to a stationary clock), the magnitudes of the acceleration remaining unchanged. Will the operator work for more or less than required time .

53. In the figure shown, the spring are connected to the rod at one end and at the midpoint. The rod is hinged at its lower end.



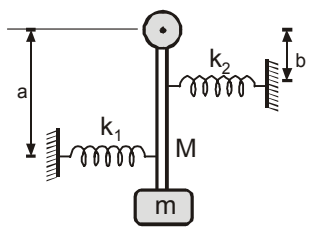
(i) Find the minimum value of k for rotational SHM of the rod (Mass m, length L)
(ii) If k = mg/L then find the angular frequency of oscillations of the rod.

54. Two identical balls A and B each of mass 0.1 kg are attached to two identical massless springs. The spring mass system is constrained to move inside a rigid smooth pipe in the form of a circle as in fig. The pipe is fixed in a horizontal plane. The centres of the ball can move in a circle of radius 0.06 m. Each spring has a natural length 0.06 πm and force constant 0.1 N/m. Initially both the balls are displaced by an angle of $\theta = \pi/6$ radian with respect to diameter PQ of the circle and released from rest.



(i) calculate the frequency of oscillation of the ball B. (ii) what is the total energy of the system
(iii) find the speed of the ball A when A and B are at the two ends of the diameter PQ.

55. A rod of mass M and length L is hinged at its one end and carries a block of mass m at its other end. A spring of force constant k_1 is installed at distance a from the hinge and another of force constant k_2 at a distance b as shown in the figure. If the whole arrangement rests on a smooth horizontal table top. Find the frequency of vibration.



ANSWERS

- ***True and False***

1. False **2.** False **3.** False **4.** True **5.** True
6. True **7.** True

- ***Fill in the Blanks***

8. 0.06 **9.** 1.8 s **10.** $\frac{f_0}{\sqrt{x(1-x)}}$ **11.** $\frac{8}{\pi(2n-1)}$ m/s

12. $\frac{\mu g}{\omega^2}$ **13.** $\frac{v_1^2x_2^2 - v_2^2x_1^2}{v_1^2 - v_2^2}$, $\sqrt{\frac{v_1^2 - v_2^2}{x_2^2 - x_1^2}}$ **14.** $\frac{\pi}{3}, \frac{5\pi}{3}$

- ***Assertion–Reason***

15. (A) **16.** (A) **17.** (D) **18.** (A) **19.** (B)
20. (D) **21.** (A)

- ***Single Choice Correct***

22. (A) **23.** (B) **24.** (B) **25.** (B) **26.** (B)
27. (A)

- ***Multiple Choice Correct***

28. (AC) **29.** (BD)

- ***Comprehension***

Comprehension-1 : **30.** (C) **31.** (A)
Comprehension-2 : **32.** (A) **33.** (C)
Comprehension-3 : **34.** (B) **35.** (D) **36.** (B)

- ***Subjective Questions***

37. $\frac{5a}{8}$, 37° **38.** 1.8 a **39.** $y = 0.1 \sin\left[4t + \frac{\pi}{4}\right]$

40. (i) 2m (ii) $\sqrt{2}\pi$ s (iii) $2\sqrt{3}$ m **41.** 2.45 m **42.** $2\pi\sqrt{\frac{m_1\ell}{(m_1+m_2)g}}$

43. $2\pi\sqrt{\frac{2\sqrt{2}a}{3g}}$ **44.** $2\pi\sqrt{\frac{17L}{18g}}$ **45.** $\frac{1}{2\pi}\sqrt{\frac{g\sqrt{1+\frac{4}{\pi^2}}}{2R}}$

46. $2\pi\sqrt{4\left(\frac{1}{k_1}+\frac{1}{k_2}+\frac{1}{k_3}+\frac{1}{k_4}\right)}$ **47.** (i) $\frac{2mg}{b-a}$ (ii) $\frac{1}{2\pi}\sqrt{\frac{2mg}{(b-a)(M+m)}}$ (iii) $\left(\frac{M+m}{m}\right)\left(\frac{ab}{b-a}\right)$

48. $\theta = \tan^{-1}\left(\frac{1}{5}\right)$, (ii) $2.47\sqrt{R}$ **49.** $2\pi\sqrt{\frac{2\ell}{g}}$ **50.** $2\pi\sqrt{\frac{\ell_1+\ell_2}{g}}$ **51.** $2\pi\frac{a}{b}\sqrt{\frac{m}{k}}$

52. $\sqrt{\frac{4x}{a}}\left[\sqrt{\frac{g}{g-a}} - \sqrt{\frac{g}{g+a}}\right]$
where x is the total distance travelled

53. (i) $k = \frac{2mg}{5L}$ (ii) $\frac{3}{2}\sqrt{\frac{k}{m}}$

54. (i) $\frac{1}{\pi}$ Hz, (ii) $4\pi^2 \times 10^{-5}$ J (iii) $2\pi \times 10^{-2}$ ms^{-1} **55.** $\frac{1}{2\pi}\sqrt{\frac{k_1a^2+k_2b^2}{L^2(m+\frac{M}{3})}}$

STRING WAVES AND SOUND WAVES

Assertion & Reason

These questions contains, Statement 1 (assertion) and Statement 2 (reason).

(A) Statement–1 is true, Statement–2 is true ; Statement–2 is correct explanation for Statement–1.
(B) Statement–1 is true, Statement–2 is true ; Statement–2 is NOT a correct explanation for Statement–1
(C) Statement–1 is true, Statement–2 is false
(D) Statement–1 is false, Statement–2 is true

1. ***Statement–1 :*** Sound travels faster in moist air.
and
Statement–2 :The density of moist air is less then density of dry air.

2. ***Statement–1 :*** The fundamental frequency of an organ pipe increases as the temperature increases.
and
Statement–2 : As the temperature increases, the velocity of sound increases more rapidly than length of the pipe.

3. ***Statement–1 :*** Explosions on other planets are not heard on earth.
and
Statement–2 : To hear distinct beats, difference in frequencies of two sources should be less than 10.

4. ***Statement–1 :*** Vacuum is densest for sound and rarest for light.
and
Statement–2 : A medium is said to be denser, when velocity of waves through this medium is smaller.

5. ***Statement–1 :*** Ultrasonics is the acoustic analogue of ultraviolet radiation.
and
Statement–2 : Ultraviolet rays do not produce visual sensations while ultrasonic waves are not heards by the human ear.

6. ***Statement–1 :*** The flash of lightening is seen before the sound of thunder is heard.
and
Statement–2 : The sound of thunder is produced after the flash of lightening.

7. ***Statement–1 :*** Earthquakes cause vast devastation. Sometimes short and tall structures remain unaffected while the medium height structures fall.
and
Statement–2 : The natural frequency of the medium structures coincides with the frequency of the seismic wave.

8. ***Statement–1 :*** Shock waves produced by supersonic aircraft may be visible.
and
Statement–2 : The sudden decrease in air pressure in the shock waves caused water molecules in the air to condense, forming a fog.

9. ***Statement–1 :*** In the case of a stationary wave, a person hear a loud sound at the nodes as compared to the antinodes.
and
Statement–2 : In a stationary wave all the particles of the medium vibrate in phase.

10. ***Statement–1 :*** Waves generated in a metal piece can be transverse or longitudinal.
and
Statement–2 : Waves generated depend upon the method of creating waves in the metal.

11. ***Statement–1 :*** A balloon filled with CO_2 gas acts as a converging lens for a sound wave.
and
Statement–2 : Sound waves travel faster in air than in CO_2.

12. ***Statement–1 :*** Node of pressure wave is formed at the open end of an organ pipe.
and
Statement–2 : Due to huge volume of the atmosphere outside the tube, deformation in its volume is negligible.

13. ***Statement–1 :*** If transverse waves are produced in a very long string fixed at one end. Near the free end only progressive wave is observed, in practice.
and
Statement–2 : Energy of reflected wave does not reach the free end.

14. ***Statement–1 :*** When two vibrating tuning forks have $f_1 = 300$ Hz and $f_2 = 350$ Hz and held close to each other; beats cannot be heard.
and
Statement–2 : The principle of superposition is valid only when $f_1 - f_2 < 10$ Hz

15. ***Statement–1 :*** During thunderstorm, light is seen much earlier than the sound is heard
and
Statement–2 : Light travels faster than sound.

16. ***Statement–1 :*** Infrasonic waves are generally produced by large vibrating bodies.
and
Statement–2 : Infrasonic waves have frequency range lies below 20 Hz.

17. ***Statement–1 :*** Partially transverse waves are possible on a liquid surface.
and
Statement–2 : Surface tension provide some rigidity on a liquid surface.

18. ***Statement–1 :*** The superposition of the waves $y_1 = A \sin(kx - \omega t)$ and $y_2 = 3A \sin(kx + \omega t)$ is a pure standing wave plus a travelling wave moving in the negative direction along X–axis.
and
Statement–2 : The resultant of y_1 & y_2 is $y = y_1 + y_2 = 2A \sin kx \cos \omega t + 2A \sin(kx + \omega t)$

19. ***Statement–1 :*** Mechanical transverse waves cannot be generated in gaseous medium.
and
Statement–2 : Mechanical transverse waves can be produced only in such medium which have shearing property.

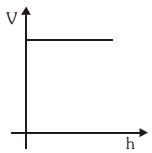
20. ***Statement–1 :*** Description of sound as pressure wave is preferred over displacement wave.
and
Statement–2 : Sound sensors (ear or mike) detect pressure changes.

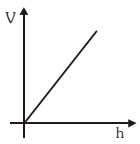
- ***Single Choice Correct***

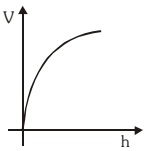
21. A wire of length 'ℓ' having tension T and radius 'r' vibrates with fundamental frequency 'f'. Another wire of the same metal with length '2ℓ' having tension 2T and radius 2r will vibrate with fundamental frequency:

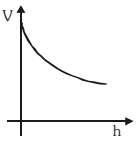
(A) f (B) 2f (C) $\frac{f}{2\sqrt{2}}$ (D) $\frac{f}{2}\sqrt{2}$

22. A uniform rope having some mass hinges vertically from a rigid support. A transverse wave pulse is produced at the lower end. The speed (v) of the wave pulse varies with height (h) from the lower end as:–

(A) 

(B) 

(C) 

(D) 

23. An open pipe is suddenly closed at one end with the result that the frequency of third harmonic of the closed pipe is found to be higher by 100 Hz than the fundamental frequency of the open pipe. The fundamental frequency of the open pipe is:–
(A) 200 Hz (B) 300 Hz (C) 240 Hz (D) 480 Hz

24. A cylindrical tube (L = 120 cm.) is in resonance with a tuning fork of frequency 330 Hz. If it is filling by water then to get resonance again, minimum length of water column is (v_{air} = 330 m/s):–
(A) 45 cm (B) 60 cm (C) 25 cm (D) 20 cm

25. 16 tuning forks are arranged in increasing order of frequency. Any two consecutive tuning forks when sounded together produce 8 beats per second. If the frequency of last tuning fork is twice that of first, the frequency of first tuning fork is:–

(A) 60 (B) 80 (C) 100 (D) 120

26. Two open pipes of length L are vibrated simultaneously. If length of one of the pipes is reduced by y, then the number of beats heard per second will be if the velocity of sound is v and y << L:–

(A) $\frac{vy}{2L^2}$ (B) $\frac{vy}{L^2}$ (C) $\frac{vy}{2L}$ (D) $\frac{2L^2}{vy}$

27. The power of sound from the speaker of a radio is 20MW by turning the knob of the volume control the power of the sound is increased to 400 MW. The power increase in describe as compared to the original power is :–

(A) 13 dB (B) 10 dB (C) 20 dB (D) 800 dB

28. A sound absorber attenuates the sound level by 20 dB. The intensity decreases by a factor of:–

(A) 1000 (B) 10000 (C) 10 (D) 100

29. A whistle giving out 450 Hz approaches a stationary observer at a speed of 33 m/s. The frequency heard by the observer (in Hz) is : (speed of sound 333 m/s)

(A) 409 (B) 429 (C) 517 (D) 500

30. A person observes a change of 2.5% in frequency of sound of horn of a car. If the car is approaching forward the person & sound velocity is 320 m/s, then velocity of car in m/s will be approximately:–

(A) 8 (B) 800 (C)7 (D) 6

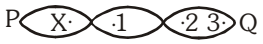
31. A sinusoidal progressive wave is generated in a string. It's equation is given by

$$y=(2mm)\sin(2\pi x-100\pi t+\pi/3)$$

The time when particle at x = 4 m first passes through mean position, will be:–

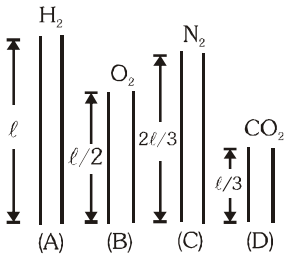
(A) $\frac{1}{150}$s (B) $\frac{1}{12}$s (C) $\frac{1}{300}$s (D) $\frac{1}{100}$s

32. Figure, shows a stationary wave between two fixed points P and Q. Which point (s) of 1, 2 and 3 are in phase with the point X ?



(A) 1, 2 and 3 (B) 1 and 2 only (C) 2 and 3 only (D) 3 only

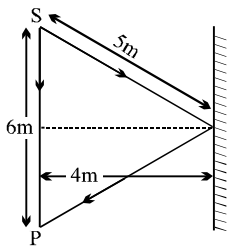
33*. Four open organ pipes of different length and different gases at same temperature as shown in figure. Let f_A, f_B, f_C and f_D be their fundamental frequencies then:– [Take $\gamma_{CO_2}=7/5$]



(A) $f_A/f_B = \sqrt{2}$ (B) $f_B/f_C = \sqrt{72/28}$

(C) $f_C/f_D = \sqrt{11/28}$ (D) $f_D/f_A = \sqrt{76/11}$

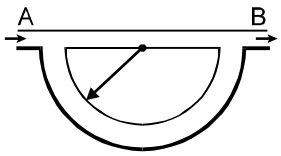
34. A person standing at a distance of 6 m from a source of sound receives sound wave in two ways, one directly from the source and other after reflection from a rigid boundary as shown in the figure. The maximum wavelength for which, the person will receive maximum sound intensity, is



(A) 4 m (B) $\frac{16}{3}$ m

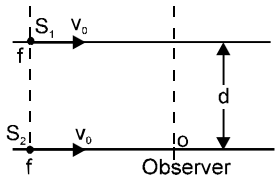
(C) 2 m (D) $\frac{8}{3}$ m

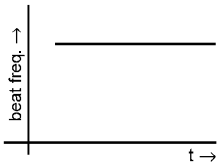
35*. Sound signal is sent through a composite tube as shown in the figure. The radius of the semicircular portion of the tube is r. Speed of sound in air is v. The source of sound is capable of giving varied frequencies in the range of ν_1 and ν_2 (where $\nu_2 > \nu_1$). If n is an integer then frequency for maximum intensity is given by :

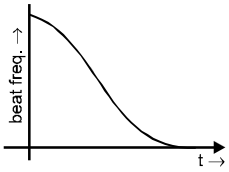


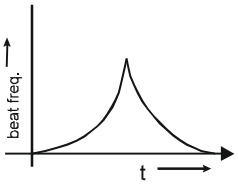
(A) $\frac{nv}{r}$ (B) $\frac{nv}{r(\pi-2)}$ (C) $\frac{nv}{\pi r}$ (D) $\frac{nv}{(r-2)\pi}$

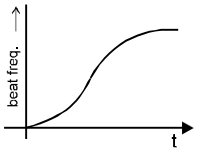
36. Two identical sources moving parallel to each other at separation 'd' are producing sounds of frequency 'f' and are moving with constant velocity v_0. A stationary observer 'O' is on the line of motion of one of the sources. Then the variation of beat frequency heard by O with time is best represented by: (as they come from large distance and go to a large distance)



(A) 

(B) 

(C) 

(D) 

37. A source which is emitting sound of frequency f is initially at (– r, 0) and an observer is situated initially at (2r, 0). If observer and source both are moving with velocities $\vec{v}_{observer} = -\sqrt{2}V\hat{i} - \sqrt{2}V\hat{j}$ and $\vec{v}_{source} = \frac{V}{\sqrt{2}}\hat{i} + \frac{V}{\sqrt{2}}\hat{j}$, then which of the following is correct option ?

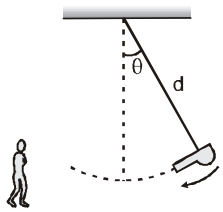
(A) Apparent frequency first increases, then decreases and observer observes the original frequency once during the motion.

(B) Apparent frequency first increases, then decreases and observer observes the original frequency twice during the motion.

(C) Apparent frequency first increases, then decreases during the motion and observer never observes the initial frequency.

(D) Apparent frequency continuously decreases and once during the motion, observer hears the original frequency.

38*. A source on a swing which is covering an angle θ from the vertical is producing a frequency ν. The source is distant d from the place of support of swing. If velocity of sound is c, acceleration due to gravity is g, then the maximum and minimum frequency heard by a listener in front of swing is



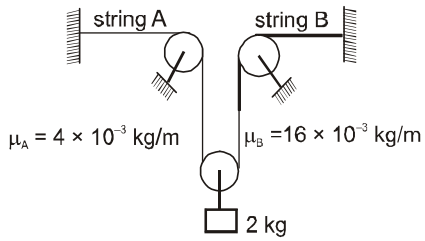
(A) $\frac{c\nu}{\sqrt{2\ gd}-c}$, $\frac{c\nu}{\sqrt{2gd}+c}$

(B) $\frac{c\nu}{\sqrt{2gd\ (1-\cos\theta)}-c}$, $\frac{c\nu}{\sqrt{2gd\ (1-\cos\theta)}+c}$

(C) $\frac{c\nu}{c-\sqrt{2gd\ (1-\cos\theta)}}$, $\frac{c\nu}{c+\sqrt{2gd\ (1-\cos\theta)}}$

(D) $\frac{c\nu}{c-\sqrt{2gd\ (1-\sin\theta)}}$, $\frac{c\nu}{c+\sqrt{2gd\ (1-\sin\theta)}}$

39. The velocity of wave in strings A & B is respectively.



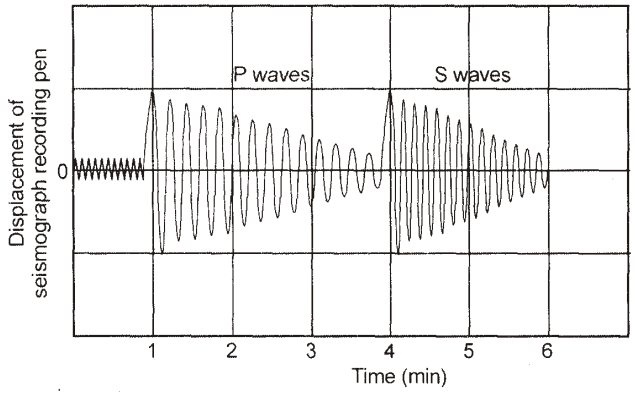
(A) 50 m/sec, 20 m/sec

(B) 40 m/sec, 25 m/sec

(C) 50 m/sec, 25 m/sec

(D) 40 m/sec, 20 m/sec

40*. Earthquakes generate sound waves inside Earth. Unlike a gas, Earth can experience both transverse (S) and longitudinal (P) sound waves. Typically, the speed of S waves is about 4 km/s. A seismograph records P and S waves P and S waves from an earthquake. The first P waves arrive 3.0 min before the first S wave (figure). Assuming the waves travel in a straight line, how far away does the earthquake occur?
($Y_{earth} = 12.8 \times 10^{10}$pa, $\rho_{earth} = 2000$kg/m^3)



(A) 1900 km (B) 1440 km (C) 1800 km (D) 1200 km

41. A string of length 0.4 m and mass 10^{-2} kg is tightly clamped at its ends. The tension in the string is 1.6 N. Identicals wave pulses are produced at one end at equal intervals of time Δt. The minimum value of Δt, which allows constructive interference between successive pulses, is :– ***[IIT-JEE 1998]***
(A) 0.05 s (B) 0.10 s (C) 0.20 s (D) 0.40 s

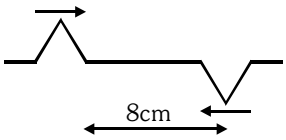
42. A train moves towards a stationary observer with speed 34 m/s. The train sounds a whistle and its frequency registered by the observer is f_1. If the train's speed is reduced to 17 m/s, the frequency registered is f_2. If the speed of sound is 340 m/s then the ratio $\frac{f_1}{f_2}$ is :– ***[IIT-JEE 2000]***
(A) $\frac{18}{19}$ (B) $\frac{1}{2}$ (C) 2 (D) $\frac{19}{18}$

43. Two vibrating strings of the same material but of lengths L and 2L have radii 2r and r respectively. They are stretched under the same tension. Both the strings vibrate in their fundamental modes, the one of length L with frequency f_1 and the other with frequency f_2. The ratio $\frac{f_1}{f_2}$ is given by :– ***[IIT-JEE 2000]***
(A) 2 (B) 4 (C) 8 (D) 1

44. The ends of a stretched wire of length L are fixed at x=0 and x = L. In one experiment the displacement of the wire is $y_1 = A\sin\left(\frac{\pi x}{L}\right)\sin\omega t$ and energy is E_1 and in other experiment its displacement is $y_2 = A\sin\left(\frac{2\pi x}{L}\right)\sin 2\omega t$ and energy is E_2. Then :– ***[IIT-JEE 2001]***
(A) $E_2 = E_1$ (B) $E_2 = 2E_1$ (C) $E_2 = 4E_1$ (D) $E_2 = 16E_1$

45. Two pulses in a stretched string, whose centres are initially 8 cm apart, are moving towards each other as shown in the figure. The speed of each pulse is 2 cm/s. After 2 s the total energy of the pulses will be : ***[IIT-JEE 2001]***

(A) Zero
(B) Purely kinetic
(C) Purely potential
(D) Partialy kinetic and partialy potential

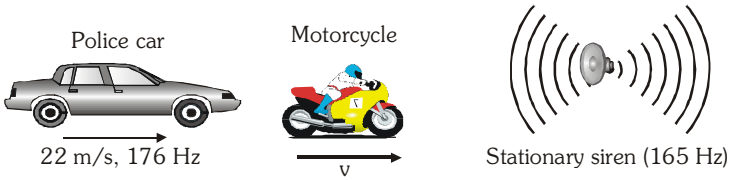


46. A siren placed at a railway platform is emitting sound of frequency 5 kHz. A passenger sitting in a moving train A records a frequency of 5.5 kHz, while the train approaches the siren. During his return journey in a different train B he records a frequency of 6.0 kHz while approaching the same siren. The ratio of the velocity of train B to that train A is :– ***[IIT-JEE 2002]***
(A) $\frac{242}{252}$ (B) 2 (C) $\frac{5}{6}$ (D) $\frac{11}{6}$

47. A sonometer wire resonates with a given tuning fork forming standing waves with five antinodes between the two bridges when a mass of 9 kg is suspended from the wire. When this mass is replaced by mass M. The wire resonates with the same tuning fork forming three antinodes for the same positions of the bridges. The value of M is :– ***[IIT-JEE 2002]***

(A) 25 kg (B) 5 kg (C) 12.5 kg (D) $\frac{1}{25}$ kg

48. A police car moving at 22 m/s chases a motocyclist. The police man sounds his horn at 176 Hz, while both of them move towards a stationary siren of frequency 165 Hz. Calculate the speed of the motorcycle. If it is given that the motorcyclist does not observe any beats :– ***[IIT-JEE 2003]***



(A) 33 m/s (B) 22 m/s (C) zero (D) 11 m/s

49. In the experiment for the determination of the speed of sound in air using the resonance column method, the length of the air column that resonates in the fundamental mode, with a tuning fork is 0.1 m. When this length is changed to 0.35 m, the same tuning fork resonates with the first overtone. Calculate the end correction :– ***[IIT-JEE 2003]***

(A) 0.012 m (B) 0.025 m (C) 0.05 m (D) 0.024 m

50. A source of sound of frequency 600 Hz is placed inside water. The speed of sound in water is 1500 m/s and in air it is 300 m/s. The frequency of sound recorded by an observer who is standing in air is :–

(A) 200 Hz (B) 3000 Hz (C) 120 Hz (D) 600 Hz ***[IIT-JEE 2004]***

51. A closed organ pipe of length L and an open organ pipe contain gases of densities ρ_1 and ρ_2 respectively. The compressibility of gases are equal in both the pipes. Both the pipes are vibrating in their first overtone with same frequency. The length of the open organ pipe is :– ***[IIT-JEE 2004]***

(A) $\frac{L}{3}$ (B) $\frac{4L}{3}$ (C) $\frac{4L}{3}\sqrt{\frac{\rho_1}{\rho_2}}$ (D) $\frac{4L}{3}\sqrt{\frac{\rho_2}{\rho_1}}$

52. A source emits sound of frequency 600 Hz inside water. The frequency heard in air will be equal to (velocity of sound in water = 1500 m/s, velocity of sound in air = 300 m/s) :– ***[IIT-JEE 2004]***

(A) 3000 Hz (B) 120 Hz (C) 600 Hz (D) 6000 Hz

53. An open pipe is in resonance in 2nd harmonic with frequency f_1. Now one end of the tube is closed and frequency is increased to f_2 such that the resonance again occurs in nth harmonic. Choose the correct option :– ***[IIT-JEE 2005]***

(A) $n = 3,\ f_2 = \frac{3}{4}f_1$ (B) $n = 3,\ f_2 = \frac{5}{4}f_1$ (C) $n = 5,\ f_2 = \frac{5}{4}f_1$ (D) $n = 5,\ f_2 = \frac{3}{4}f_1$

54. A tuning fork of 512 Hz is used to produce resonance in a resonance tube experiment. The level of water at first resonance is 30.7 cm and at second resonance is 63.2 cm. The error in calculating velocity of sound is :– ***[IIT-JEE 2005]***

(A) 204.1 cm/s (B) 110 cm/s (C) 58 cm/s (D) 280 cm/s

- **Multiple Choice Correct**

55*. The (x, y) coordinates of the corners of a square plate are (0, 0), (L, 0), (L, L) and (0, L). The edges of the plate are clamped and transverse standing waves are set–up in it. If u(x, y) denotes the displacement of the plate at the point (x, y) at some instant of time, the possible expression (s) for u is (are) (a = positive constant) :– **[IIT-JEE 1998]**

(A) $a\cos\left(\frac{\pi x}{2L}\right)\cos\left(\frac{\pi y}{2L}\right)$ (B) $a\sin\left(\frac{\pi x}{L}\right)\sin\left(\frac{\pi y}{L}\right)$ (C) $a\sin\left(\frac{\pi x}{L}\right)\sin\left(\frac{2\pi y}{L}\right)$ (D) $a\cos\left(\frac{2\pi x}{L}\right)\sin\left(\frac{\pi y}{L}\right)$

56. A transverse sinusoidal wave of amplitude a, wavelength λ and frequency f is travelling on a stretched string. The maximum speed of any point on the string is $\frac{v}{10}$, where v is the speed of propagation of the wave. If a = 10^{-3} m and v = 10 m/s, then λ and f are given by :– **[IIT-JEE 1998]**

(A) $\lambda = 2\pi \times 10^{-2}$ m (B) $\lambda = 10^{-3}$ m (C) $f = \frac{10^3}{2\pi}$ Hz (D) $f = 10^4$ Hz

57. As a wave propagates :– **[IIT-JEE 1999]**
(A) The wave intensity remains constant for a plane wave
(B) The wave intensity decreases as the inverse of the distance from the source for a spherical wave
(C) The wave intensity decreases as the inverse square of the distance from the source for a spherical wave
(D) Total intensity of the spherical wave over the spherical surface centred at the source remains constant at all time

58*. $y(x,t)=\frac{0.8}{[(4x+5t)^2+5]}$ represents a moving pulse where x and y are in metres and t in second. Then:
(A) pulse is moving in positive x–direction (B) in 2 s it will travel a distance of 2.5 m
(C) its maximum displacement is 0.16 m (D) it is a symmetric pulse **[IIT-JEE 1999]**

59. In a wave motion y=asin(kx–ωt), y can represent : **[IIT-JEE 1999]**
(A) electric field (B) magnetic field (C) displacement (D) pressure

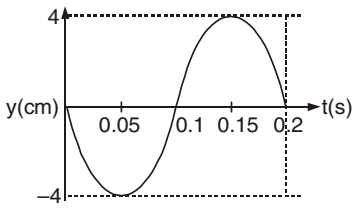
60. Standing wave can be produced : **[IIT-JEE 1999]**
(A) on a string clamped at both ends
(B) on a string clamped at one end and free at the other
(C) when incident wave gets reflected from a wall
(D) when two identical waves with a phase difference of π are moving in the same direction

61. Sounds from two identical sources S_1 and S_2 reach a point P. When the sounds reach directly, and in the same phase, the intensity at P is I_0. The power of S_1 is now reduced by 64% and the phase difference between S_1 and S_2 is varied continuously. The maximum and minimum intensities recorded at P are now I_{max} and I_{min}:

(A) $I_{max} = 0.64I_0$ (B) $I_{min} = 0.36\ I_0$ (C) $\frac{I_{max}}{I_{min}} = 16$ (D) $\frac{I_{max}}{I_{min}} = \frac{1.64}{0.36}$

62. In a standing wave on a string :
(A) In one time period all the particles are simultaneously at rest twice.
(B) All the particles must be at their positve extremes simultaneously once in one time period.
(C) All the particles may be at their positive extremes simultaneously once in a time period.
(D) All the particles are never at rest simultaneously.

63*. For a certain transverse standing wave on a long string, an antinode is formed at x = 0 and next to it, a node is formed at x = 0.10 m. The displacement y(t) of the string particle at x = 0 is shown in figure.



(A) Transverse displacement of the particle at x = 0.05m and t =0.05 s is $-2\sqrt{2}$ cm.

(B) Transverse displacement of the particle at x = 0.04 m and t =0.025 s is $-2\sqrt{2}$ cm.

(C) Speed of the travelling waves that interfere to produce this standing wave is 2 m/s.

(D) The transverse velocity of the string particle at x = $\frac{1}{15}$ m and t= 0.1 s is 20 π cm/s

64*. In standing wave experiment, a 1.2 kg horizontal rope is fixed in place at its two ends (x = 0 and x = 2.0 m) and made to oscillate up and down in the fundamental mode, at frequency 5.0 Hz. At t = 0, the point at x = 1.0 m has zero displacement and is moving upward in the positive direction of y axis with a transverse velocity 3.14 m/s.

(A) Tension in the rope is 240 N

(B) Tension in the rope is 120 N

(C) The correct expression of the standing wave equation is $(0.1)\sin(\pi/2)x\sin(10\pi)t$

(D) The correct expression of the standing wave equation is $(0.1)\sin(\pi)x\sin(10\pi)t$

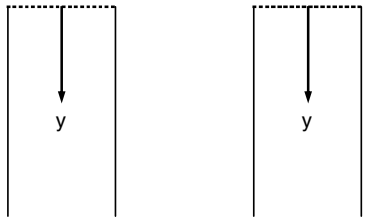
65. Two identical stretched wires are vibrated together.,They produce 8 beats/s. When tension in one wire is changed then also the beat frequency is increased. If T_1 and T_2 denote the tensions in the two wires at any instant and $T_1 > T_2$(initially) Then how the change may be performed.

(A) T_1 decreased (B) T_1 increased (C) T_2 decreased (D) T_2 increased

66. In an organ pipe (may be closed or open) of 99 cm length standing wave is setup, whose equation is given by longitudinal displacement

$$\xi = (0.1\text{ mm})\cos\frac{2\pi}{0.8}(y+1\text{cm})\cos 2\pi(400)t$$

where y is measured from the top of the tube in meters and t in second. Here 1 cm is the end correction.



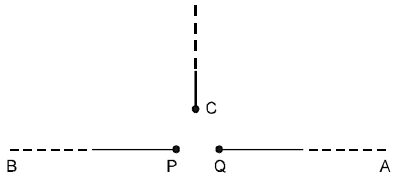
(A) The upper end and the lower end of the tube are respectively open – closed

(B) The upper end and the lower end of the tube are respectively open – open

(C) The air column is vibration in Second overtone

(D) The air column is vibration in Third harmonic

67. Two monochromatic sources of electromagnetic wave, P and Q emit waves of wavelength λ = 20 m and separated by 5m as shown. A,B and C are three points where interference of these waves is observed. If phase of a wave generated by P is ahead of wave generated by Q by $\pi/2$ then (given intensity of both waves is I) :



(A) phase difference of these waves at B is 180°

(B) intensities at A,B and C are in the ratio 2 : 0 : 1 respectively.

(C) intensities at A,B and C are in the ratio 1 : 2 : 0 respectively.

(D) phase difference at A is 0°.

68. A cylindrical tube, open at one end and closed at the other, is in acoustic unison (resonance) with an external source of sound of single frequency held at the open end of the tube, in its fundamental note. Then:

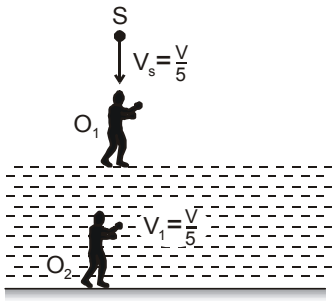
(A) the displacement wave from the source gets reflected with a phase change of π at the closed end

(B) the pressure wave from the source get reflected without a phase change at the closed end

(C) the wave reflected from the closed end again gets reflected at the open end

(D) the wave reflected from the closed end does not suffer reflection at the open end

69*. In the figure shown an observer O_1 floats (static) on water surface with ears in air while another observer O_2 is moving upwards with constant velocity V_1 = V/5 in water. The source moves down with constant velocity V_s = V/5 and emits sound of frequency 'f'. The velocity of sound in air is V and that in water is 4V. For the situation shown in figure :



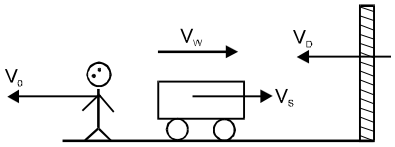
(A) The wavelength of the sound received by O_1 is $\frac{4V}{5f}$

(B) The wavelength of the sound received by O_1 is V/f

(C) The frequency of the sound received by O_2 is $\frac{21f}{16}$

(D) The wavelength of the sound received by O_2 is $\frac{16V}{5f}$

70*. S, O & W represent source of sound (of frequency f), observer & wall respectively. V_O , V_S, V_D, V are velocity of observer, source, wall & sound (in still air) respectively. V_W is the velocity of wind. They are moving as shown. then match the following : where $f_r = \frac{V + V_w + V_D}{V + V_w - V_S} f$



(A) The wavelength of the waves coming towards the observer from source is $(V - V_W + V_S)/f$
(B) The wavelength of the waves incident on the wall is $(V + V_W - V_S)/f$
(C) The wavelength of the waves coming towards observer from the wall is $(V - V_W - V_D)/f_r$
(D) Frequency of the waves (as detected by O) coming from wall after reflection is $(V - V_W - V_O)f_r/(V - V_W - V_D)$

- ***Match the Column***

71.

Column I	***Column II***
(A) Pitch	(p) Number of overtones
(B) Quality	(q) Intensity
(C) Loudness	(r) Frequency
(D) Musical interval	(s) Difference of the frequencies of two notes
	(t) Ratio of the frequencies of two notes

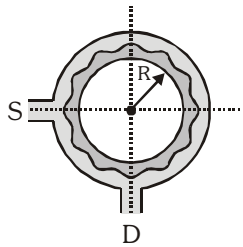
72.

Column I	***Column II***
(A) Infrasonic	(p) Speed is greater than speed of sound
(B) Ultrasonic	(q) Frequency < 20 Hz
(C) Audible (sonic)	(r) Frequency > 20 kHz
(D) Supersonic	(s) 20 Hz < frequency < 20 kHz

- ***Comprehension***

Comprehension-2*

A narrow tube is bent in the form of a circle of radius R, as shown in the figure. Two small holes S and D are made in the tube at the positions right angle to each other. A source placed at S generated a wave of intensity I_0 which is equally divided into two parts : One part travels along the longer path, while the other travels along the shorter path. Both the parts waves meet at the point D where a detector is placed.



73. If a maxima is formed at the detector then, the magnitude of wavelength λ of the wave produced is given by :–

(A) πR (B) $\frac{\pi R}{2}$ (C) $\frac{\pi R}{4}$ (D) $\frac{\pi R}{3}$

74. If the minima is formed at the detector then, the magnitude of wavelength λ of the wave produced is given by:–

(A) πR (B) $\frac{3\pi R}{2}$ (C) $\frac{2\pi R}{3}$ (D) $\frac{2\pi R}{5}$

75. The maximum intensity produced at D is given by :–

(A) $4I_0$ (B) $2 I_0$ (C) I_0 (D) $3I_0$

76. The maximum value of λ to produce a maxima at D is given by :–

(A) πR (B) $2\pi R$ (C) $\frac{\pi R}{2}$ (D) $\frac{3\pi R}{2}$

77. The maximum value of λ to produce a minima at D is given by :–

(A) πR (B) $2\pi R$ (C) $\frac{\pi R}{2}$ (D) $\frac{3\pi R}{2}$

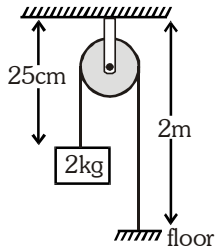
- ***Subjective Questions***

78. Two audio speakers are kept some distance apart and are driven by the same amplifier system. A person is sitting at a place 6.0 m from one of the speakers and 6.4 m from the other. If the sound signal is continuously varied from 500 Hz to 5000 Hz, what are the frequencies for which there is a destructive interference at the place of the listener? Speed of sound in air = 320 m/s.

79*. One end of a long string of linear mass density 8.0×10^{-3} kg m^{-1} is connected to an electrically driven tuning fork of frequency 256 Hz. The other end passes over a pulley and is tied to a pan containing a mass of 90 kg. The pulley end absorbs all the incoming energy so that reflected waves at this end have negligible amplitude. At t = 0, the left end (fork end) of the string x = 0 has zero transverse displacement (y = 0) and is moving along positive y–direction. The amplitude of the wave is 5.0 cm. Write down the transverse displacement y as function of x and t that describes the wave on the string.

80. A steel wire of length 1m, mass 0.1 kg and uniform cross–sectional area 10^{-6} m^2 is rigidly fixed at both ends. The temperature of the wire is lowered by 20°C. If transverse waves are set up by plucking the string in the middle calculate the frequency of the fundamental mode of vibration.
[Given: $Y_{stell} = 2 \times 10^{11}$ N/m^2, $\alpha_{stell} = 1.21 \times 10^{-5}$/°C]

81*. In the given figure the string has mass 4.5 g. Find the time taken by a transverse pulse produced at the floor to reach the pulley. (g = 10 ms^{-2}).



82*. A uniform rope of length 12 m and mass 6 kg hangs vertically from a rigid support. A block of mass 2 kg is attached to the free end of the rope. A transverse pulse of wavelength 0.06 m is produced at the lower end of the rope. What is the wavelength of the pulse when it reaches the top of the rope ?

83. A string vibrate according to the equation $y = 5 \sin\left(\frac{\pi x}{3}\right) \cos(40\pi t)$ where x and y are in cm's and t is in second.
(i) What is the equation of incident and reflected wave ? (ii) What is the distance between the adjacent nodes?
(iii) What is the velocity of the particle of the string at the position x = 1.5 cm when $t = \frac{9}{8}$ sec ?

84*. The vibrations of a string of length 60 cm fixed at both ends are represented by the equation :

$y = 4 \sin\left(\frac{\pi x}{15}\right) \cos(96\pi t)$ where x and y are in cm and t in seconds.

(i) What is the maximum displacement of a point at x = 5 cm ?
(ii) Where are the nodes located along the string ?
(iii) What is the velocity of the particle at x = 7.5 cm at t = 0.25 s ?
(iv) Write down the equations of the component waves whose superposition gives the above wave

85. Given below are some functions of x and t to represent the displacement (transverse or longitudinal) of an elastic wave. State which of these represent (a) a travelling wave, (b) a stationary wave or (c) none at all :

(i) $y = \cos(3x) \sin(10t)$
(ii) $y = 2\sqrt{x - vt}$
(iii) $y = 3 \sin(5x - 0.5t) + 4 \cos(5x - 0.5t)$
(iv) $y = \cos x \sin t + \cos 2x \sin 2t$

86. A flute which we treat as a pipe open at both ends is 60 cm long. How far from the mouth piece should a hole be uncovered for the fundamental frequency to be 330 Hz ? Take the speed of sound in air as 340 m/sec. And also calculate fundamental frequency when all the holes are covered ?

87. Two sitar strings A and B playing the note 'Dha' are slightly out of tune and produce beats of frequency 5 Hz. The tension of the string B is slightly increased and the beat frequency is found to decrease to 3 Hz. What is the original frequency of B if the frequency of A is 427 Hz ?

88*. A car has two horns having a difference in frequency of 180 Hz. The car is approaching a stationary observer with a speed of 60 ms^{-1}. Calculate the difference in frequencies of the notes as heard by the observer, if velocity of sound in air is 330 ms^{-1}.

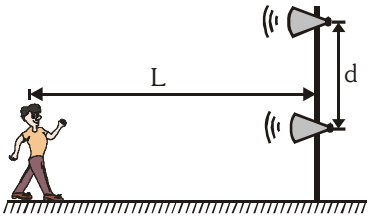
89. Two tuning forks with natural frequencies of 340 Hz each move relative to a stationary observer. One fork moves away from the observer, While the other moves towards him at the same speed. The observer hears beats of frequency 3 Hz. Find the speed of the tuning fork. [Speed of sound = 330m/s]

90*. A train approaching a hill at a speed of 40 km/h sounds a whistle of frequency 580 Hz when it is at a distance of 1 km from a hill. A wind with a speed of 40 km/h is blowing in the direction of motion of the train. Find
(i) The frequency of the whistle as heard by an observer on the hill.
(ii) The distance from the hill at which the echo from the hill is heard by the driver and its frequency.
(Velocity of sound in air = 1200 km/h)

91. Two radio stations broadcast their programmes at the same amplitude A and at slightly different frequencies ω_1 and ω_2 respectively, where $\omega_1 - \omega_2 = 10^3$ Hz. A detector receives the signals from the two stations simultaneously. It can only detect signals of intensity $\geq 2A^2$.
(i) Find the time interval between successive maximum of the intensity of the signal received by the detector.
(ii) Find the time for which the detector remains idle in each cycle of the intensity of the signal

92*. The harmonic wave $y_i = (2.0 \times 10^{-3}) \cos\pi\ (2.0\,x - 50t)$ travels along a string toward a boundary at x=0 with a second string. The wave speed on the second string is 50 m/s. Write expressions for reflected and transmitted waves. Assume SI units.

93*. Two speakers are driven by the same oscillator with frequency of 200 Hz. They are located 4 m apart on a vertical pole. A man walks straight towards the lower speaker in a direction perpendicular to the pole, as shown in figure. (i) How many times will he hear a minimum in sound intensity, and (ii) how far is he from the pole at these moments? Take the speed of sound to be 330 m/s, and ignore any sound reflections coming off the ground.

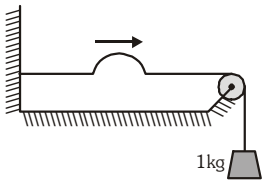


94. The displacement of the medium in a sound wave is given by the equation $y_1 = A\cos(ax + bt)$ where A, a and b are positive constants. The wave is reflected by an obstacle situated a x = 0. The intensity of the reflected wave is 0.64 times that of the incident wave.
(i) What are the wavelength and frequency of incident wave ?
(ii) Write the equation for the reflected wave.
(iii) In the resultant wave formed after reflection, find the maximum and minimum values of the particle speeds in the medium.
(iv) Express the resultant wave as a superposition of a standing wave and a travelling wave.
What are the positions of the antinodes of the standing wave ?
What is the direction of propagation of travelling wave?

95. The air column in a pipe closed at one end is made to vibrate in its second overtone by tuning fork of frequency 440 Hz. The speed of sound in air is 330 m/s. End corrections may be neglected. Let P_0 denote the mean pressure at any point in the pipe and ΔP_0 the maximum amplitude of pressure variation. ***[IIT-JEE 1998]***
(i) Find the length L of the air column.
(ii) What is the amplitude of pressure variation at the middle of the column ?
(iii) What are the maximum and minimum pressures at the open end of the pipe ?
(iv) What are the maximum and minimum pressures at the closed end of the pipe ?

96. A long wire PQR is made by joining two wires PQ and QR of equal radii. PQ has length 4.8 m and mass 0.06 kg. QR has length 2.56 m and mass 0.2 kg. The wire PQR is under a tension of 80 N. A sinusoidal wave pulse of amplitude 3.5 cm is sent along the wire PQ from the end P. No power is dissipated during the propagation of the wave pulse. Calculate : (i) The time taken by the wave pulse to reach the other end R and (ii) The amplitude of the reflected and transmitted wave pulse after the incident wave pulse crosses the joint Q. ***[IIT-JEE 1999]***

97*. Figure shows a string of linear mass density 1.0 g/cm on which a wave pulse is travelling. Find the time taken by the pulse in travelling through a distance of 50 cm on the string. ($g = 10\ m/s^2$).

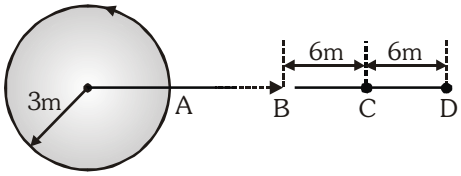


98*. Two successive resonant frequencies in an open organ pipe are 1944 and 2592 Hz. If the speed of sound in air 324 ms^{-1}, then find the length of tube.

99*. A string 25 cm long and having a mass of 2.5 g is under tension. A pipe closed at one end is 40 cm long. When the string is set vibrating in its first overtone and the air in the pipe in its fundamental frequency. 8 beats/s are heard. It is observed that decreasing the tension in the string decreases the beat frequency. If the speed of sound in air is 320 m/s find the tension in the string.

100*. A SONAR system fixed in a submarine operates at a frequency 40.0 kHz. An enemy submarine moves towards the SONAR with a speed of 360 km h^{-1}. What is the frequency of sound reflected by the submarine ? Take the speed of sound in water to be 1450 ms^{-1}.

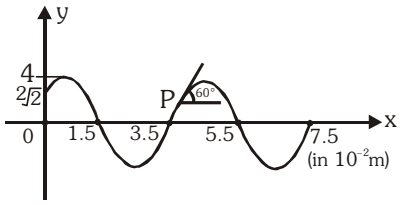
101*. A source of sound is moving along a circular orbit of radius 3m with an angular velocity of 10 rad/s. A sound detector located far away from the source is executing linear simple harmonic motion along the line BD (see figure) with an amplitude BC = CD = 6 m. The frequency of oscillation of the detector is $\frac{5}{\pi}$ per second.



The source is at the point A when the detector is at the point B. If the source emits a continuous sound wave of frequency 340 Hz, find the maximum and the minimum frequencies recorded by the detector. (Speed of sound = 340 m/s)

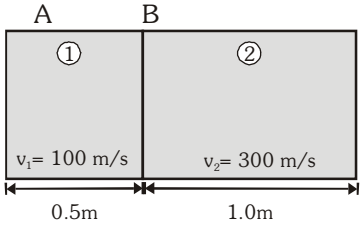
102*. A band playing music at a frequency f is moving towards a wall at a speed v_b. A motorist is following the band with a speed v_m. If v is the speed of sound. Obtain an expression for the beat frequency heard by the motorist.

103*. The figure shows a snap photograph of a vibrating string at t=0. The particle P is observed moving up with velocity $20\sqrt{3}$ cm/s. The tangent at P makes an angle 60^0 with x–axis (i) Find the direction in which the wave is moving (ii) the equation of the wave (iii) the total energy carried by the wave per cycle of the string. [Assuming that μ, the mass per unit length of the string = 50 gm/m]



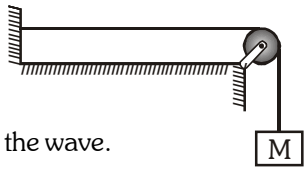
104*. An open organ pipe filled with air has a fundamental frequency 500 Hz. The first harmonic of another organ pipe closed at one end and filled with carbon dioxide has the same frequency as that of the first harmonic of the open organ pipe. Calculate the length of each pipe. Assume that the velocity of sound in air and in carbondioxide to be 330 and 264 m/s respectively.

105*. A cylinder ABC consists of two chambers 1 and 2 which contains two different gases. The wall C is rigid but the walls A and B are thin diaphragms. A vibrating tuning fork approaches the wall A with velocity u = 30 m/s and air columns in chamber 1 and 2 vibrates with minimum frequency such that there is node (displacement) at B and antinode (displacement) at A. Find :



(i) the fundamental frequency of air column
(ii) find the frequency of tuning fork.
Assume velocity of sound in the first and second chamber be 1100 m/s and 300 m/s respectively. Velocity of sound in air 330 m/s.

106. A string of length 1 m fixed at one end and on the other end a block of mass M = 4 kg is suspended. The string is set into vibration and represented by equation $y = 6\sin\left(\frac{\pi x}{10}\right)\cos(100\pi t)$ where x and y are in cm and t is in seconds.



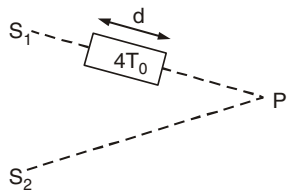
(i) Find the number of loops formed in the string .
(ii) Find the maximum displacement of a point at x=5/3 cm
(iii) Calculate the maximum kinetic energy of the string
(iv) Write down the equations of the component waves whose superposition gives the wave.

107*. The following equation represent transverse wave; $z_1 = A\cos(kx - \omega t)$, $z_2 = A\cos(kx + \omega t)$, $z_3 = A\cos(ky - \omega t)$ Identify the combination (s) of the waves which will produce. (i) standing wave (s) (ii) a wave travelling in the direction making an angle of 45° with the positive x and positive y–axis. In each case, find the position at which the resultant intensity is always zero.

108*. A metallic rod of length 1m is rigidly clamped at its mid point. Longitudinal stationary waves are setup in the rod in such a way that there are two nodes on either side of the midpoint. The amplitude of an antinode is 2×10^{-6}m. Write the equation of motion at a point 2 cm from the midpoint and those of the constituent waves in the rod. (Young's modulus of the material of the rod = 2×10^{11} Nm^{-2}; density = 8000 $kg\text{–}m^{-3}$). Both ends are free.

109*. A parabolic pulse given by equation y (in cm) = $0.3 - 0.1\,(x - 5t)^2$ $(y \geq 0)$ travelling in a uniform string. The pulse passes through a boundary beyond which its velocity becomes 2.5 m/s. What will be the amplitude of pulse in this medium after transmission?

110. Sound from two coherent sources S_1 and S_2 are sent in phase, and detected at point p, equidistant from both the sources. Speed of sound in normal air is V_0, but in some part in path S_1, there is a zone of Hot air having temperature 4 times, the normal temperature, and width d. What would be minimum frequency of sound, so that minima can be found at P?



111. A sonometer wire under tension of 64 N vibrating in its fundamental mode is in resonance with a vibrating tuning fork. The vibrating portion of the sonometer wire has a length of 10 cm and mass of 1g. The vibrating tuning fork is now moved away from the vibrating wire with a constant speed and an observer standing near the sonometer hears one beat per second. Calculate the speed with which the tuning fork is moved, if the speed of sound in air is 300 m/s.

112. A train of length ℓ is moving with a constant speed v along a circular track of radius R, the engine of the train emits a whistle of frequency f. Find the frequency heard by a guard at the rear end of the train.

ANSWERS

- ***Assertion–Reason***

1.	(A)	**2.**	(A)	**3.**	(B)	**4.**	(A)	**5.**	(A)
6.	(C)	**7.**	(A)	**8.**	(A)	**9.**	(C)	**10.**	(A)
11.	(A)	**12.**	(A)	**13.**	(A)	**14.**	(C)	**15.**	(A)
16.	(A)	**17.**	(A)	**18.**	(A)	**19.**	(A)	**20.**	(A)

- ***Single Choice Correct***

21.	(C)	**22.**	(C)	**23.**	(A)	**24.**	(A)	**25.**	(D)
26.	(A)	**27.**	(A)	**28.**	(D)	**29.**	(D)	**30.**	(A)
31.	(C)	**32.**	(C)	**33.**	(C)	**34.**	(A)	**35.**	(B)
36.	(C)	**37.**	(D)	**38.**	(C)	**39.**	(C)	**40.**	(B)
41.	(B)	**42.**	(D)	**43.**	(D)	**44.**	(C)	**45.**	(B)
46.	(B)	**47.**	(A)	**48.**	(B)	**49.**	(B)	**50.**	(D)
51.	(C)	**52.**	(C)	**53.**	(C)	**54.**	(D)		

- ***Multiple Choice Correct***

55.	(B,C)	**56.**	(A,C)	**57.**	(A,C,D)	**58.**	(B,C,D)	**59.**	(A,B,C)
60.	(A,B,C)	**61.**	(A,C)	**62.**	(A,C)	**63.**	(A,C,D)	**64.**	(A,C)
65.	(B,C)	**66.**	(A,C)	**67.**	(A,B,D)	**68.**	(A,B,C)	**69.**	(A,C,D)
70.	(A,B,C,D)								

- ***Match the Column***

71. (A) r, (B) p (C) q (D) t **72.** (A) q, (B) r (C) s (D) p

- ***Comprehension***

73.	(ABCD)	**74.**	(CD)	**75.**	(B)	**76.**	(A)	**77.**	(B)

- ***Subjective Questions***

78. 1200 Hz, 2000 Hz, 2800 Hz, 3600Hz, 4400 Hz

79. y = 0.05 sin (1609 t – 4.84 x) (where x and y in m)

80. 11 Hz **81.** 0.02 s **82.** 10.12 m

83. (i) $y_{incident} = 2.5 \sin\left(40\pi t + \frac{\pi}{3}x\right)$ and $y_{reflected} = -2.5 \sin\left(40\pi t - \frac{\pi}{3}x\right)$ (ii) 3 cm (iii) 0

84. (i) $2\sqrt{3}$ cm (ii) x = 0, 15 cm, 30 cm .. etc.

(iii) 0 (iv) $y_1 = 2 \sin\left(\frac{\pi x}{15} - 96\pi t\right)$ and $y_2 = 2 \sin\left(\frac{\pi x}{15} + 96\pi t\right)$

85. (i) Stationary wave (ii) Unacceptable function for any travelling wave
(iii) Travelling harmonic wave (iv) Superposition of two stationary waves.

86. 283.33 Hz

87. 422 Hz

88. 220 Hz

89. 1.5 m/s

90. (i) 599.33 Hz (ii) 0.935 km, 621.43 Hz

91. (i) 6.28×10^{-3} S, (ii) 1.57×10^{-3} S

92. (i) $6.67 \times 10^{-4}\ \pi(2.0x + 50t)$ (ii) $2.67 \times 10^{-3}\ \cos\pi(1.0x - 50t)$

93. (i) 2 (ii) 9.28 m and 1.99 m

94. (i) $\frac{2\pi}{a}, \frac{b}{2\pi}$ (ii) $y_r = -0.8\ A \cos(ax - bt)$ (iii) 1.8 Ab, 0

(iv) $y = -1.6\ A \sin ax \sin bt + 0.2\ A \cos(ax + bt)$

Antinodes are at $x = \left[n + \frac{(-1)^n}{2}\right]\frac{\pi}{a}$. Travelling wave is propagating in negative x–direction

95. (i) $\frac{15}{16}$ m (ii) $\frac{\Delta P_0}{\sqrt{2}}$ (iii) $P_{max} = P_{min} = P_0$, (iv) $P_{max} = P_0 + \Delta P_0, P_{min} = P_0 - \Delta P_0$

96. (i) 140 ms (ii) $A_r = \left(\frac{v_2 - v_1}{v_2 + v_1}\right)A_i = 1.5\text{cm}$, $A_t = \left(\frac{2v_2}{v_2 + v_1}\right)A_i = 2$ cm

97. 0.05 s

98. 0.25 m

99. 27.04 N

100. 45.93 kHz

101. 438.7Hz, 257.3Hz

102. $\frac{2f\,v_b(v + v_m)}{(v^2 - v_b^2)}$

103. (i) Negative x, (ii) $y = 0.4 \sin\left(10\pi t + \frac{\pi}{2}x + \frac{\pi}{4}\right)$ (x, y are in cm) (iii) 1.6×10^{-5} J

104. 33 cm and 13.2 cm

105. (i) 1650 Hz (ii) 1500 Hz

106. (i) 10 (ii) 3cm (iii) 36 J (iv) $y_1 = 3\sin\left(\frac{\pi x}{10} - 100\pi t\right)$, $y_2 = 3\sin\left(\frac{\pi x}{10} + 100\pi t\right)$

107. (i) z_1 and z_2 : $x = (2n + 1)\frac{\pi}{2k} \Rightarrow (2n+1)\ \lambda/4$ where n = 0, ± 1, ± 2 ..... etc.

(ii) z_1 and z_3 : $x - y = (2n + 1)\frac{\pi}{k}$ where n = 0, ± 1, ± 2 .....etc.

108. $y = 10^{-6} \sin(0.1\pi) \sin(25000\ \pi t)$, $y_1 = 10^{-6} \sin(25000\ \pi t - 5\pi x)$, $y_2 = 10^{-6} \sin(25000\ \pi t + 5\pi x)$

109. 0.2 cm

110. $\frac{V}{d}$

111. 0.073 m/s

112. f

Important Notes

Important Notes

Important Notes