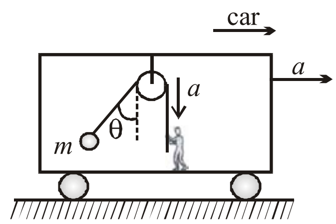
Chapter 3 LAWS OF MOTION

A SINGLE CORRECT CHOICE TYPE

Each of these questions has 4 choices (a), (b), (c) and (d) for its answer, out of which ONLY ONE is correct.

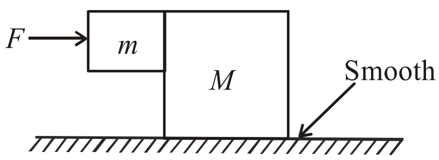
1. A bob is hanging over a pulley inside a car through a string. The second end of the string is in the hand of a person standing in the car. The car is moving with constant acceleration a directed horizontally as shown in figure. Other end of the string is pulled with constant acceleration a vertically.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



(a) $m\sqrt{g^2+a^2}$ (b) $m\sqrt{g^2+a^2}-ma$

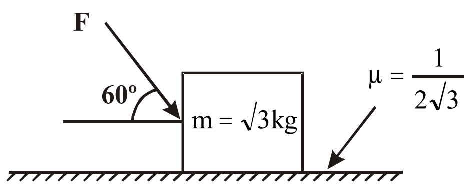
(c) $m\sqrt{g^2+a^2}+ma$ (d) $m(g+a)$

2. The two blocks, $m = 10$ kg and $M = 50$ kg are free to move as shown. The coefficient of static friction between the blocks is 0.5 and there is no friction between M and the ground. A minimum horizontal force F is applied to hold m against M that is equal to



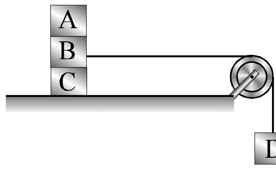
(a) 100 N (b) 50 N (c) 240 N (d) 180 N

3. What is the maximum value of the force F such that the block shown in the arrangement, does not move?



(a) 20N (b) 10N
(c) 12N (d) 15N

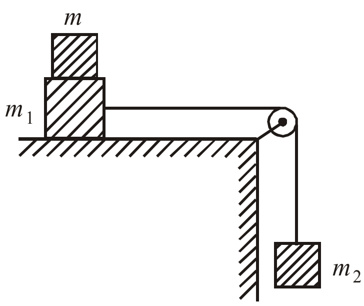
4. Three blocks A, B and C of equal mass m are placed one over the other on a smooth horizontal ground as shown in figure. Coefficient of friction between any two blocks of A, B and C is 1/2.



The maximum value of mass of block D so that the blocks A, B and C move without slipping over each other is

(a) 6m (b) 5m (c) 3m (d) 4m

5. Two blocks of masses $m_1 = 4$kg and $m_2 = 6$ kg are connected by a string of negligible mass passing over a frictionless pulley as shown in the figure below. The coefficient of friction between the block m_1 and the horizontal surface is 0.4. When the system is released, the masses m_1 and m_2 start accelerating. What additional mass m should be placed over mass m_1 so that the masses $(m_1 + m)$ slide with a uniform speed?



(a) 12 kg (b) 11kg
(c) 10 kg (d) 2 kg

MARK YOUR RESPONSE					
	1. ⓐⓑⓒⓓ	2. ⓐⓑⓒⓓ	3. ⓐⓑⓒⓓ	4. ⓐⓑⓒⓓ	5. ⓐⓑⓒⓓ

6. A ship of mass 3×10^7 kg initially at rest, is pulled by a force of 5×10^4 N through a distance of 3m. Assuming that the resistance due to water is negligible, the speed of the ship is

(a) 1.5 m/sec. (b) 60 m/sec.

(c) 0.1 m/sec. (d) 5 m/sec.

7. ϕ is the angle of the incline when a block of mass m just starts slipping down. The distance covered by the block if thrown up the incline with an initial speed u_0 is

(a) $u_0^2/4g\sin\phi$ (b) $4u_0^2/g\sin\phi$

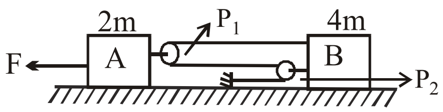
(c) $u_0^2/\sin\phi/4g$ (d) $4u_0^2\sin\phi/g$

8. A given object takes n times as much time to slide down a 45° rough incline as it takes to slide down a perfectly smooth 45° incline. The coefficient of friction between the object and the incline is

(a) $(1-1/n^2)$ (b) $1/(1-n^2)$

(c) $\sqrt{(1-1/n^2)}$ (d) $1/\sqrt{(1-n^2)}$

9. The acceleration of the block B in the above figure, assuming the surfaces and the pulleys P_1 and P_2 are all smooth.



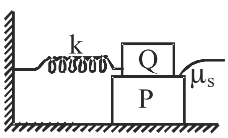
(a) $F/4$m

(b) $F/6$m

(c) $F/2$m

(d) $3F/17$m

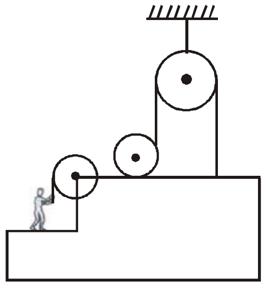
10. A block P of mass m is placed on a horizontal frictionless plane. A second block of same mass m is placed on it and is connected to a spring of spring constant k, the two blocks are pulled by distance A. Block Q oscillates without slipping. What is the maximum value of frictional force between the two blocks.



(a) $kA/2$ (b) kA

(c) μ_s mg (d) zero

11. A system is shown in the figure. A man standing on the block is pulling the rope. Velocity of the point of string in contact with the hand of the man is 2 m/s downwards.

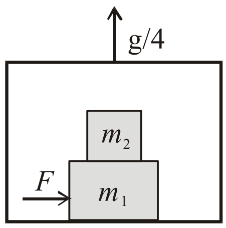


The velocity of the block will be [assume that the block does not rotate]

(a) 3 m/s (b) 2 m/s

(c) 1/2 m/s (d) 1 m/s

12. A plank of mass $M_1 = 8$ kg with a bar of mass $M_2 = 2$ kg placed on its rough surface, lie on a smooth floor of elevator ascending with an acceleration g/4. The coefficient of friction is $\mu = 1/5$ between m_1 and m_2.



A horizontal force $F = 30$ N is applied to the plank. Then the acceleration of bar and the plank in the reference frame of elevator are

(a) 3.5 m/s^2, 5 m/s^2

(b) 5 m/s^2, 50/8 m/s^2

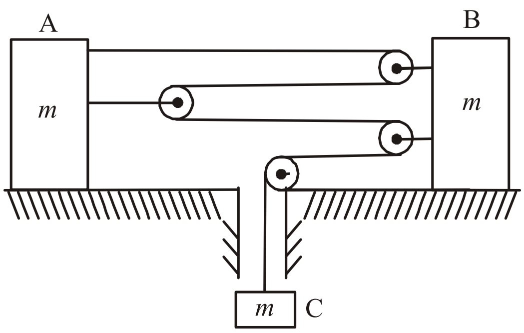
(c) 2.5 m/s^2, 25/8 m/s^2

(d) 4.5 m/s^2, 4.5 m/s^2

13. All the surfaces are frictionless then acceleration of the block B is

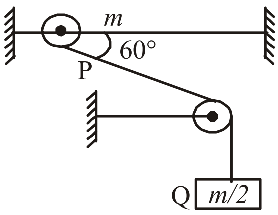
(a) 2g/13 (b) 3g/13

(c) 4g/13 (d) g/13



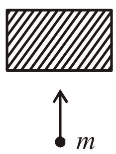
MARK YOUR RESPONSE					
	6. ⓐⓑⓒⓓ	7. ⓐⓑⓒⓓ	8. ⓐⓑⓒⓓ	9. ⓐⓑⓒⓓ	10. ⓐⓑⓒⓓ
	11. ⓐⓑⓒⓓ	12. ⓐⓑⓒⓓ	13. ⓐⓑⓒⓓ		

14. A smooth ring P of mass m can slide on a fixed horizontal rod. A string tied to the ring passes over a fixed pulley and carries a block Q of mass $(m/2)$ as shown in the figure. At an instant, the string between the ring and the pulley makes an angle 60° with the rod. The initial acceleration of the ring is



(a) $\frac{2g}{3}$ (b) $\frac{2g}{6}$ (c) $\frac{2g}{9}$ (d) $\frac{g}{3}$

15. A massive wooden plate of unknown mass M remains in equilibrium in vacuum when n bullets are fired per second on it. The mass of each bullet is m ($M >> m$) and it strikes the plate at the centre with speed v. If the coefficient of restitution is e, then M is equal to



(a) $\frac{mvn}{g}$ (b) $\frac{mevn}{g}$

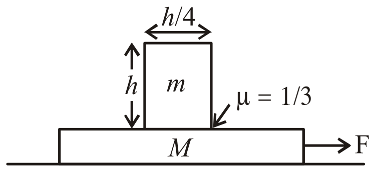
(c) $\frac{mv(1+e)n}{g}$ (d) nm

16. A block is resting on a horizontal plate in the xy plane and the coefficient of friction between block and plate is μ. The plate begins to move with velocity $u = bt^2$ in x direction. At what time will the block start sliding on the plate.

(a) $\frac{\mu b}{g}$ (b) $\frac{\mu bg}{2}$

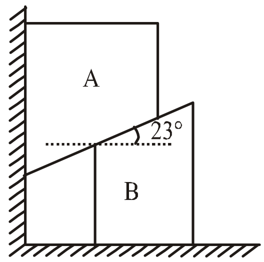
(c) $\frac{\mu g}{b}$ (d) $\frac{\mu g}{2b}$

17. A block of mass $m = 2$ kg is placed on a plank of mass $M = 10$ kg which is placed on a smooth horizontal plane. The coefficient of friction between the block and the plank is $\mu = \frac{1}{3}$. If a horizontal force F is applied on the plank, then find the maximum value of F for which the block and the plank move together. (Take $g = 10$ m/s^2)



(a) 30 N
(b) 40 N
(c) 120 N
(d) none of the above

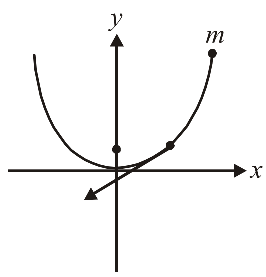
18. There are two blocks A and B in contact with vertical and horizontal smooth surfaces respectively, as shown in the figure. Acceleration of A and B are a_A and a_B respectively along their constrained direction of motions. Relation between a_A and a_B is (Assume sin 23° = 2/5).



(a) $2a_A = \sqrt{21}\,a_B$ (b) $2a_A = 5a_B$

(c) $5a_A = 2a_B$ (d) $\sqrt{21}\,a_A = 2a_B$

19. A bead of mass m is located on a parabolic wire with its axis vertical and vertex at the origin as shown in the figure and whose equation is $x^2 = 4ay$. The wire frame is fixed and the bead can slide on it without friction. The bead is released from point $y = 4a$ on the frame from rest. The tangential acceleration of the bead when it reaches the position given by $y = a$ is

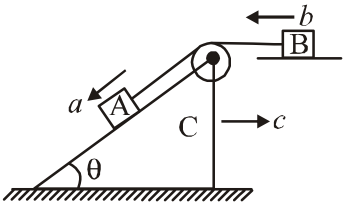


(a) $\frac{\sqrt{3}g}{2}$ (b) $\frac{g}{\sqrt{2}}$

(c) $\frac{g}{\sqrt{5}}$ (d) $\frac{g}{2}$

MARK YOUR RESPONSE					
	14. ⓐⓑⓒⓓ	15. ⓐⓑⓒⓓ	16. ⓐⓑⓒⓓ	17. ⓐⓑⓒⓓ	18. ⓐⓑⓒⓓ
	19. ⓐⓑⓒⓓ				

with directions. Values b and c are w.r.t. ground whereas a is acceleration of block A w.r.t. wedge C. Acceleration of block A w.r.t. ground is



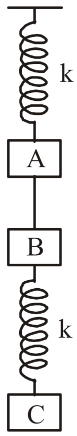
(a) $\sqrt{(b+c)^2 + a^2}$

(b) $c - (a + b) \cos \theta$

(c) $\sqrt{(b+c)^2 + c^2 - 2(b+c).c.\cos\theta}$

(d) $\sqrt{(b+c)^2 + c^2 + 2(b+c).c.\cos\theta}$

21. The system shown in the adjacent figure is in equilibrium. All the blocks are of the equal mass m and springs are ideal. When the string between A and B is cut then



(a) the acceleration of block A is 2g while the acceleration of block C is g

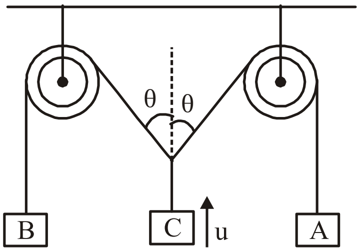
(b) the acceleration of block B is 2g while the acceleration of block C is zero

(c) the acceleration of block A is 2g while the acceleration of block B is g

(d) the acceleration of block B is g while the acceleration of block C is zero

22. In the arrangement shown in the adjacent figure, the two pulleys are fixed and the two blocks A and B are made to move downwards so that they decelerate at 10 m/s^2. The arrangement achieving the above is not shown in the diagram. The block C which is fixed to the middle of the string, moves upward with a constant velocity u. At a certain instant, θ (shown in the figure) = 30° and $\left(\frac{d\theta}{dt}\right) = +1$ radian/s.

It can be concluded that



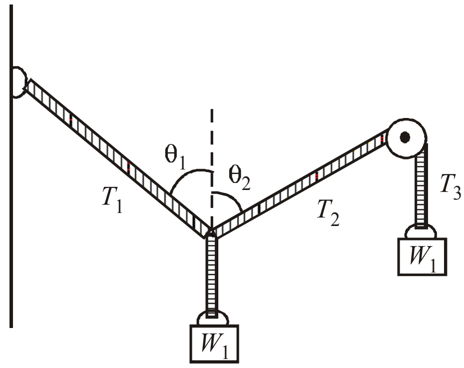
(a) $u = 5$m/s (b) $u = 10$ m/s

(c) $u = 20$ m/s (d) $u = 15$ m/s

23. If $\theta_1 = \theta_2$ in figure, (pulley is frictionless). Choose the correct option

(a) $T_1 = T_2 = T_3 = W_2 = \frac{W_1}{2\cos\theta_1}$

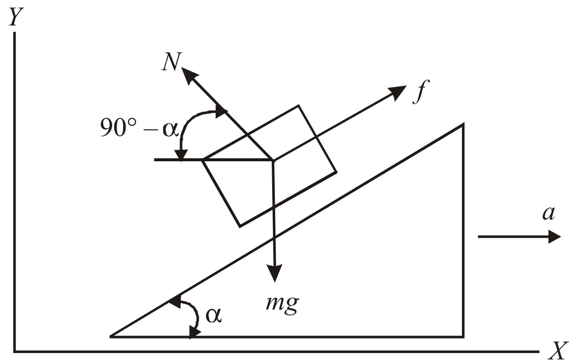
(b) $T_1 \neq T_2 = T_3 = W_2 = \frac{W_1}{2\cos\theta_1}$



(c) $T_1 = T_2 \neq T_3 = W_2 = \frac{W_1}{2\cos\theta_1}$

(d) $T_1 = T_2 = T_3 \neq W_2 \neq \frac{W_1}{2\cos\theta_1}$

24. The inclined plane shown in figure has an acceleration 'a' to the right. The block will side on the plane if ($\mu_s \equiv \tan\theta$ is the coefficient of static friction for the contacting surfaces)



(a) $a < g \tan(\theta - \alpha)$ (b) $a > g \tan(\theta + \alpha)$

(c) $a > g \tan(\theta - \alpha)$ (d) $a > g \cot(\theta - \alpha)$

MARK YOUR RESPONSE	20. ⓐⓑⓒⓓ	21. ⓐⓑⓒⓓ	22. ⓐⓑⓒⓓ	23. ⓐⓑⓒⓓ	24. ⓐⓑⓒⓓ

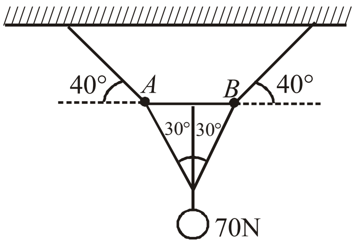
25. A student's life was saved in an automobile accident because an air bag expanded in front of his head. If the car had not been equipped with an air bag, the windshield would have stopped the motion of his head in a much shorter time. Compared to the windshield, the air bag

(a) exerts a much smaller impulse
(b) causes a much smaller change in kinetic energy
(c) exerts a much smaller force
(d) does much more work

26. Five persons A, B, C, D and 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 1 m/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 and 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) 30 m/s^2 (d) 25 m/s^2

27. What is the tension in cord AB ?

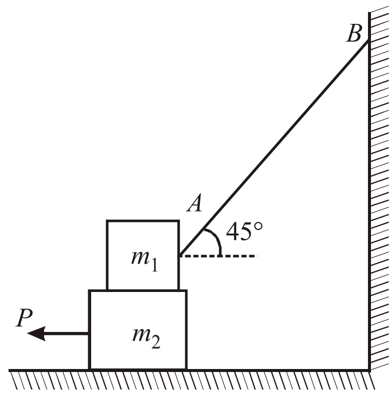


(a) 25.2 N (b) 18.3 N
(c) 15.5 N (d) 21.5 N

28. A box weighing 100N is at rest on a horizontal floor. The coefficient of static friction between the box and the floor is 0.4. What is the smallest force F exerted eastward and upward at an angle of 30° with the horizontal that can start the box in motion ?

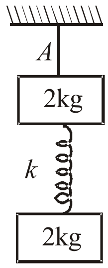
(a) 27.5 N (b) 37.5 N
(c) 14.2 N (d) 45.4 N

29. The block of mass m_1 = 20kg lies on the top of block of mass m_2 = 12 kg. A light inextensible string AB connects mass m_1 with vertical wall as shown. The coefficient of friction is μ = 0.25 for all surfaces in contact. A horizontal force P is applied to block of mass m_2 such that it just slides under block of mass m_1. Then the tension in the string AB is (Take g = 10 m/s^2)



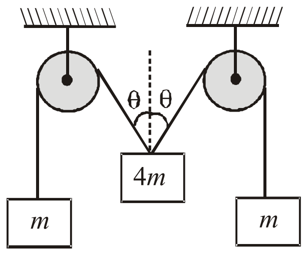
(a) $40\sqrt{2}$ N (b) 24 N
(c) 40 N (d) $24\sqrt{2}$ N

30. Two blocks of mass 2 kg are connected by a massless ideal spring of spring constant k = 10 N/m. The upper block is suspended from roof by a light inextensible string A. The system shown is in equilibrium. The string A is now cut, the acceleration of upper block just after the string A is cut will be (g = 10 m/s^2)



(a) 0 m/s^2 (b) 20 m/s^2
(c) 10 m/s^2 (d) 15 m/s^2

31. In the figure shown, the pulleys and strings are massless. The acceleration of the block of mass $4m$ just after the system is released from rest is ($\theta = \sin^{-1} 3/5$)

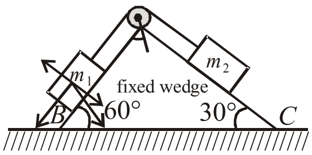


(a) $\frac{2g}{5}$ downwards (b) $\frac{2g}{5}$ upwards

(c) $\frac{5g}{11}$ downwards (d) $\frac{5g}{11}$ upwards

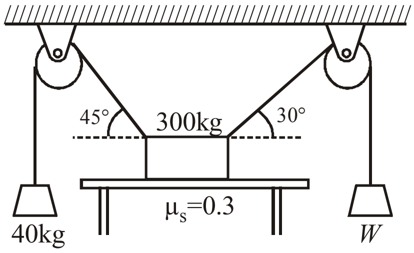
MARK YOUR RESPONSE					
	25. ⓐⓑⓒⓓ	26. ⓐⓑⓒⓓ	27. ⓐⓑⓒⓓ	28. ⓐⓑⓒⓓ	29. ⓐⓑⓒⓓ
	30. ⓐⓑⓒⓓ	31. ⓐⓑⓒⓓ			

32. Two small masses m_1 and m_2 are at rest on a frictionless, fixed triangular wedge of angles 30° and 60° as shown. They are connected by a light inextensible string. The side BC of wedge is horizontal and both the masses are 1 metre vertically above the horizontal side BC of wedge. There is no friction between the wedge and both the masses. If the string is cut, which mass reaches the bottom of the wedge first ? (Take $g = 10 \text{m/s}^2$)



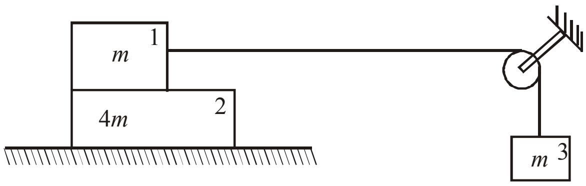
(a) Mass m_1 reaches the bottom of the wedge first.
(b) Mass m_2 reaches the bottom of the wedge first.
(c) Both reach the bottom of the wedge at the same time.
(d) It's impossible to determine from the given information.

33. Two weights are hung over two frictionless pulleys as shown in figure. What weight W will cause the 300kg block to just start moving to the right ?



(a) 108 kg (b) 115 kg
(c) 98 kg (d) 120 kg

34. In figure, block 1 is one-fourth the length of block 2 and weighs one-fourth as much. Assume that there is no friction between block 2 and the surface on which it moves and that the coefficient of sliding friction between blocks 1 and 2 is $\mu_k = 0.2$. After the system is released find the distance block 2 has moved when only one-fourth of block 1 still on block 2. Block 1 and block 3 have the same mass.

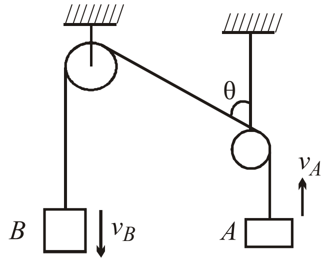


Configuration at $t = 0$

(a) 1/7.47 (b) 2/7.47
(c) 1/3.37 (d) 4/7.47

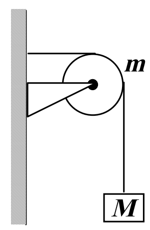
35. Two masses A and B are connected with two an inextensible string to write constraint relation between v_A and v_B.

Student A : $v_A \cos\theta = v_B$.
Student B : $v_B \cos\theta = v_A$.



(a) A is correct, B is wrong
(b) B is correct, A is wrong
(c) Both are correct
(D) Both are wrong

36. 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



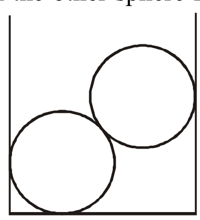
(a) $\sqrt{2}$ Mg (b) $\sqrt{2}$ mg
(c) $\sqrt{(M+m)^2+m^2}\ g$ (d) $\sqrt{(M+m)^2+M^2}\ g$

37. A small mass slides down a fixed inclined plane of inclination θ with the horizontal. The coefficient of friction is $\mu = \mu_0 x$ where x is the distance through which the mass slides down and μ_0 is a constant. Then the speed is maximum after the mass covers a distance of

(a) $\dfrac{\cos\theta}{\mu_0}$ (b) $\dfrac{\sin\theta}{\mu_0}$

(c) $\dfrac{\tan\theta}{\mu_0}$ (d) $\dfrac{2\tan\theta}{\mu_0}$

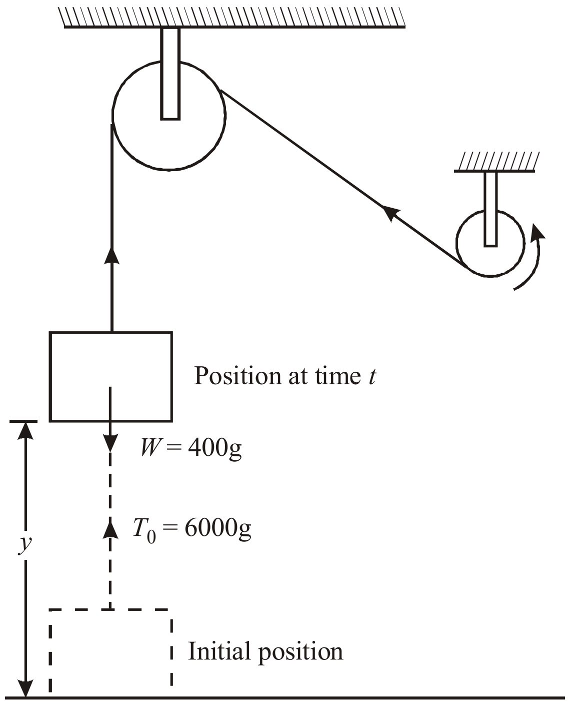
38. Two smooth spheres each of radius 5cm and mass 10kg rest one on the other inside a fixed smooth cylinder of radius 8cm. Then the magnitude of normal reaction exerted by one sphere on the other sphere is



(a) 125N (b) 225N (c) 150N (d) 100N

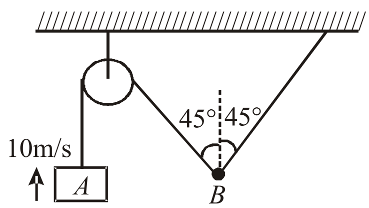
MARK YOUR RESPONSE					
	32. ⓐⓑⓒⓓ	33. ⓐⓑⓒⓓ	34. ⓐⓑⓒⓓ	35. ⓐⓑⓒⓓ	36. ⓐⓑⓒⓓ
	37. ⓐⓑⓒⓓ	38. ⓐⓑⓒⓓ			

39. A body of mass 400 kg is suspended at the lower end of a light vertical chain and is being pulled up vertically (see figure). Initially, the body is at rest and the pull on the chain is 6000g N. The pull gets smaller uniformly at the rate of 360g N per meter through which the body is raised. What is the velocity of the body when it has been raised 10m?



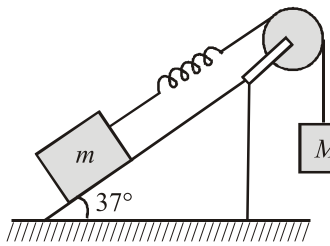
(a) 44.1 m/s (b) 43.2 m/s
(c) 54.1 m/s (d) 33.3 m/s

40. A system is shown in the figure. Block *A* moves vertically upwards with velocity 10 m/s. The speed of the mass *B* at the shown instant will be



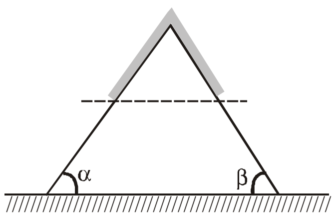
(a) $10\sqrt{2}$ m/s (b) 10 m/s
(c) $5\sqrt{3}$ m/s (d) $\frac{20}{\sqrt{3}}$ m/s

41. A block of mass *m* is attached with massless spring of force constant *k*. The block is placed over a fixed rough inclined surface for which the coefficient of friction is $\mu = 3/4$. The block of mass *m* is initially at rest. The block of mass *M* is released from rest with spring in unstretched state. The minimum value of M required to move the block up the plane is (neglect mass of string and pulley and friction in pulley.)



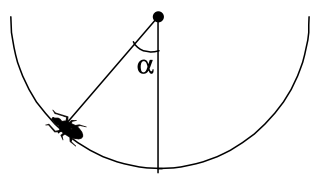
(a) $\frac{3}{5}$m (b) $\frac{4}{5}$m
(c) $\frac{6}{5}$m (d) $\frac{3}{2}$m

42. 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) $M(\cos\alpha - \cos\beta)g$ (b) zero
(c) $M(\tan\alpha - \tan\beta)g$ (d) None of these

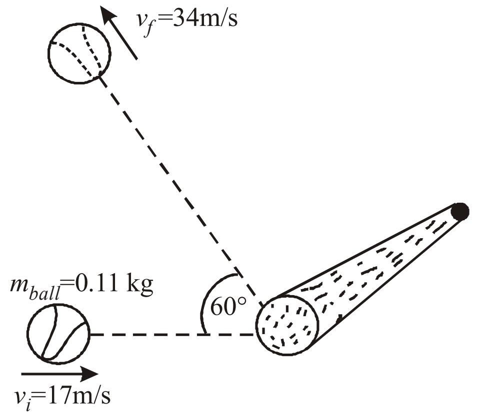
43. An insect crawls up a hemispherical surface very slowly (see fig.). The coefficient of friction between the insect and the surface is 1/3. If the line joining the center of the hemispherical surface to the insect makes an angle α with the vertical, the maximum possible value of α is given by



(a) $\cot\alpha = 3$ (b) $\tan\alpha = 3$
(c) $\sec\alpha = 3$ (d) $\text{cosec}\,\alpha = 3$

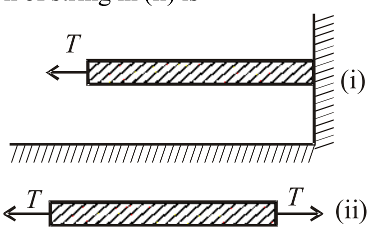
MARK YOUR RESPONSE	39. ⓐⓑⓒⓓ	40. ⓐⓑⓒⓓ	41. ⓐⓑⓒⓓ	42. ⓐⓑⓒⓓ	43. ⓐⓑⓒⓓ

44. A 0.11 kg baseball is thrown with a speed of 17 m/s towards a batsman. After the ball is stuck by the bat, it has a speed of 34 m/s in the direction shown in figure. If the ball and bat are in contact for 0.025s, find the magnitude of the average force exerted on the ball by the bat.



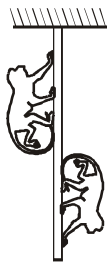
(a) 167.90 N (b) 171.90 N
(c) 197.90 N (D) 122.20 N

45. In the figure (i) an extensible string is fixed at one end and the other end is pulled by a tension T. In figure (ii) another identical string is pulled by tension T at both the ends. The ratio of elongation in equilibrium of string in (i) to the elongation of string in (ii) is



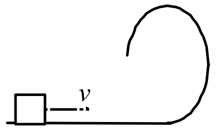
(a) 1 : 1 (b) 1 : 2 (c) 2 : 1 (d) 0

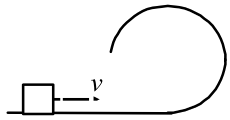
46. Two monkeys of masses 10 kg and 8 kg are moving along a vertical rope which is light and inextensible, the former climbing up with an acceleration of 2m/s^2 while the latter coming down with a uniform velocity of 2m/s. Find the tension (in newtons).

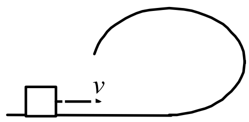


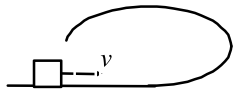
(a) 200 N (b) 150 N (c) 300 N (d) 100 N

47. 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 in

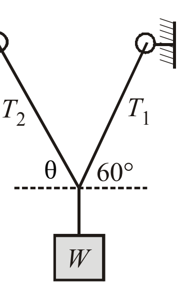
(a) 

(b) 

(c) 

(d) 

48. A weight W is supported by two cables as shown. The tension in the cable making angle θ with horizontal will be the minimum when the value of θ is

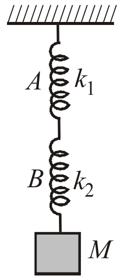


(a) 0 (b) 30°
(c) 60° (d) None of these

49. An object of mass M is moving on a conveyor belt. The object and the belt move together at a constant velocity $\vec{v}$. The coefficient of static friction is μ_s, the coefficient of kinetic friction is μ_k, and the acceleration due to gravity is g. What is the magnitude of the force of friction on the object ?

(a) $(\mu_s - \mu_k)\,Mg$ (b) $\mu_s\,Mg$
(c) $\mu_k Mg$ (d) zero

50. A mass M is suspended by two springs A and B of force constants k_1 and k_2 respectively as shown in the diagram. The total stretch of springs in equilibrium is

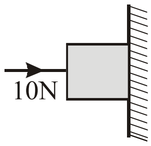


(a) $\dfrac{Mg}{k_1 + k_2}$ (b) $\dfrac{2Mg}{k_1 + k_2}$

(c) $\dfrac{Mg}{2\,(k_1 + k_2)}$ (d) $\dfrac{Mg\,(k_1 + k_2)}{k_1 k_2}$

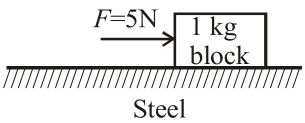
MARK YOUR RESPONSE					
	44. ⓐⓑⓒⓓ	45. ⓐⓑⓒⓓ	46. ⓐⓑⓒⓓ	47. ⓐⓑⓒⓓ	48. ⓐⓑⓒⓓ
	49. ⓐⓑⓒⓓ	50. ⓐⓑⓒⓓ			

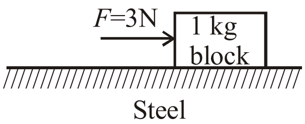
51. A minimum horizontal force of 10N is necessary to just hold a block stationary against a wall. The coefficient of friction between the block and the wall is 0.2. The weight of the block is

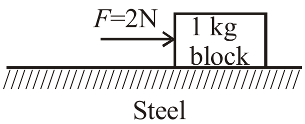


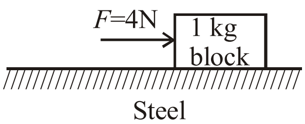
(a) 100 N (b) 50N (c) 20N (d) 2N

52. A different forces is applied to each of four 1 kg blocks to slide them across a uniform steel surface at constant speed as shown. In which diagram is the coefficient of friction between the block and the steel smallest ?

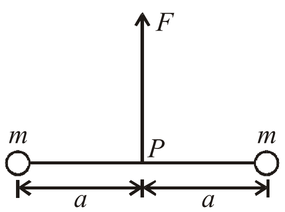
(a)


(b)


(c)


(d)


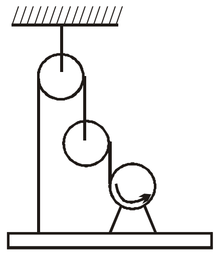
53. Two particles of mass m each are tied at the ends of a light string of length $2a$. The whole system is kept on a frictionless horizontal surface with the string held tight so that each mass is at a distance 'a' from the centre P (as shown in the figure). Now, the mid-point of the string is pulled vertically upwards with a small but constant force F. As a result, the particles move towards each other on the surface. The magnitude of acceleration, when the separation between them becomes $2x$, is



(a) $\frac{F}{2m}\frac{a}{\sqrt{a^2-x^2}}$ (b) $\frac{F}{2m}\frac{x}{\sqrt{a^2-x^2}}$

(c) $\frac{F}{2m}\frac{x}{a}$ (d) $\frac{F}{2m}\frac{\sqrt{a^2-x^2}}{x}$

54. If in the arrangement shown, motor runs winding rope at a rate of v m/s the upward speed of platform will be

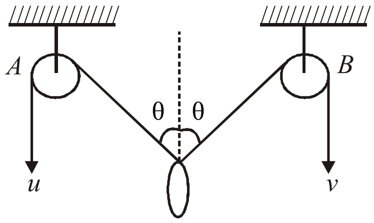


(a) $\frac{v}{3}$ (b) $\frac{v}{4}$

(c) $\frac{v}{7}$ (d) None of these

55. A and B are two smooth pegs on the same horizontal line. An inextensible light string carrying a heavy smooth ring (which can freely slide on the string) passes over the pegs as shown in the figure.

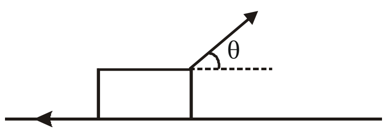
The free ends of the string are pulled down vertically with speed u and v respectively. The speed with which the ring goes up at any instant is



(a) $(u+v)\cos\theta$ (b) $\frac{(u+v)}{2}\cos\theta$

(c) $\frac{u+v}{2\cos\theta}$ (d) $\frac{u+v}{\cos\theta}$

56. A block of mass m is pulled in the direction shown in the figure on a rough horizontal ground with a constant acceleration of magnitude 'a'. The magnitude of the frictional force is –

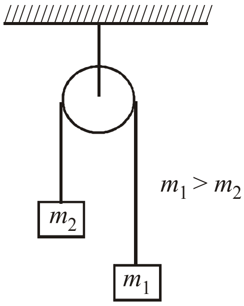


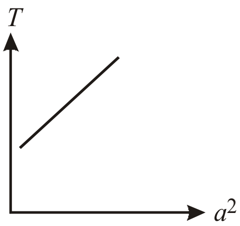
(a) $T\cos\theta - ma$ (b) $\mu_k mg$

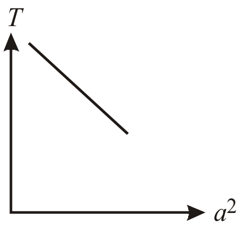
(c) $\mu_k(T-mg)$ (d) $\mu_k T\sin\theta$

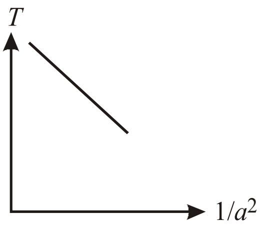
MARK YOUR RESPONSE					
	51. ⓐⓑⓒⓓ	52. ⓐⓑⓒⓓ	53. ⓐⓑⓒⓓ	54. ⓐⓑⓒⓓ	55. ⓐⓑⓒⓓ
	56. ⓐⓑⓒⓓ				

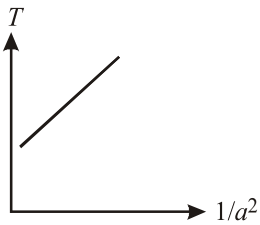
57. For the arrangement shown in the figure let 'a' and T be the acceleration of the blocks and tension in the string respectively. The string and the pulley are frictionless and massless. Which of the graphs show the correct relationship between 'a' and T for the system in which sum of the two masses m_1 and m_2 is constant.



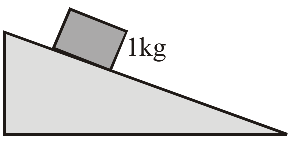
(a)


(b)


(c)


(d)


58. The force exerted by the rough incline on stationary block of mass 1 kg is closest to

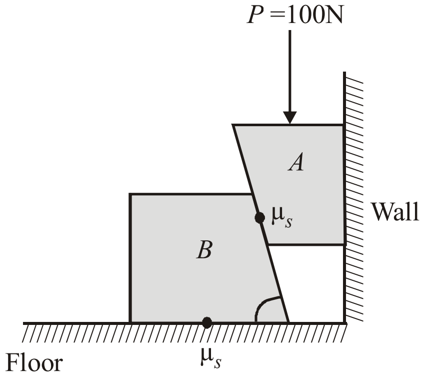


(a) 1N (b) 10N
(c) Impossible to determine without the coefficient of static friction
(d) Impossible to determine without the angle of the incline

59. A particle moves in the X-Y plane under the influence of a force such that its linear momentum is $\vec{p}(t) = A\,[\hat{i}\cos(kt) - \hat{j}\sin(kt)]$, where A and k are constants. The angle between the force and the momentum is

(a) 0° (b) 30°
(c) 45° (d) 90°

60. A 10 kg block A resting against 50 kg block B is shown in figure. The coefficient of static friction between block A and the wall is negligible. If $P = 100$N, determine the value of μ_s (as shown) for which motion is impending.



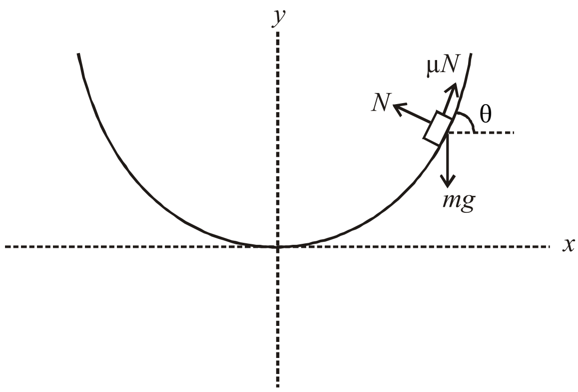
(a) 0.962 (b) 0.162
(c) 0.362 (d) 0.562

61. An overweight acrobat, "weighing" in at 115 kg, wants to perform a single hand stand. He tries to cheat by resting one foot against a smooth frictionless vertical wall. The horizontal force there is 130 N. What is the magnitude of the force exerted by the floor on his hand? Answer in N.

(a) 1134 (b) 1257
(c) 997 (d) 1119

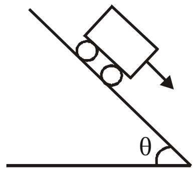
62. A parabolic bowl with its bottom at origin has the shape $y = \dfrac{x^2}{20}$. Here x and y are in meter. The maximum height at which a small mass m can remain on the bowl without slipping (coefficient of static friction is 0.5) is

(a) 2.5m (b) 1.25m
(c) 1.0m (d) 4.0m



MARK YOUR RESPONSE	57. ⓐⓑⓒⓓ	58. ⓐⓑⓒⓓ	59. ⓐⓑⓒⓓ	60. ⓐⓑⓒⓓ	61. ⓐⓑⓒⓓ
	62. ⓐⓑⓒⓓ				

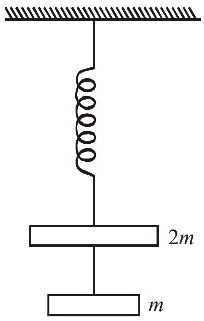
63. A car is coming down hill with constant velocity. A bob is hung from its ceiling. Choose correct statement



(a) The string joining bob to ceiling is vertical
(b) The string is perpendicular to the inclined plane
(c) The string is parallel to the inclined plane
(d) None of these

64. A cart initially moving on a frictionless track filled with sand has a hole at its bottom from where sand leaks out –
Student-*A* says : The velocity of cart remains constant although mass of sand in cart decrease.
Student- *B* say : Since mass is decreasing, the velocity of cart must increase.
(a) Student-*A* is correct, Student-*B* is wrong
(b) Student-*A* is wrong, Student-*B* is correct
(c) Both are correct (d) Both are wrong

65. The string between blocks of mass m and 2m is massless and inextensible. The system is suspended by a massless spring as shown. If the string is cut find the magnitudes of accelerations of mass $2m$ and m (immediately after cutting)

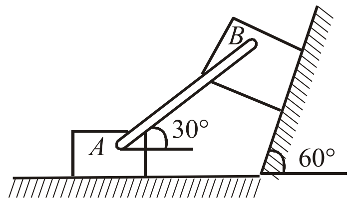


(a) g, g (b) $g, \frac{g}{2}$
(c) $\frac{g}{2}$, g (d) $\frac{g}{2}, \frac{g}{2}$

66. A bowling ball is tied to a rope such that the rope lifts the ball straight up at a constant velocity. The magnitude of the tension in the rope is
(a) greater than the force of gravity on the ball
(b) equal to the net force acting on the ball
(c) less than the force of gravity on the ball
(d) equal to the force of gravity on the ball

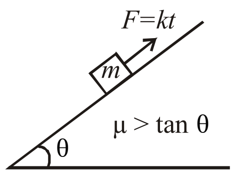
67. A shopper pushes a shopping cart of a store with a constant force of 75 N [forward]. The shopping cart exerts a force of 75 N [backward] on the shopper
(a) only if the velocity of the cart is constant.
(b) only if there is no friction between the cart and the floor.
(c) only if the velocity of the cart is increasing.
(d) under all circumstances assuming the system to be the shopper and cart.

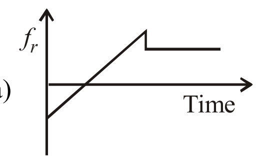
68. In figure, two blocks are separated by a uniform strut attached to each block with frictionless pins. Block *A* weighs 400N, block *B* weighs 300N, and the strut *AB* weigh 200N. If $\mu = 0.25$ under *B*, determine the minimum coefficient of friction under *A* to prevent motion.

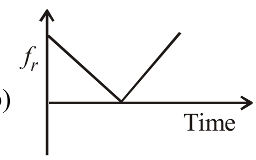


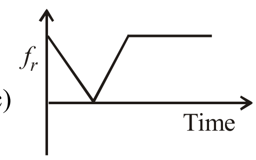
(a) 0.4 (b) 0.2
(c) 0.8 (d) 0.1

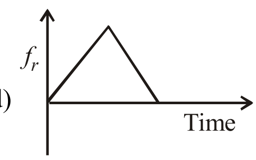
69. A block of mass m is placed on an inclined surface. Coefficient of friction between plane and block is $\mu > \tan\theta$. A force $F = kt$ is applied on block at $t = 0$, then which of the following represents variation of magnitude of frictional force with time ?



(a)


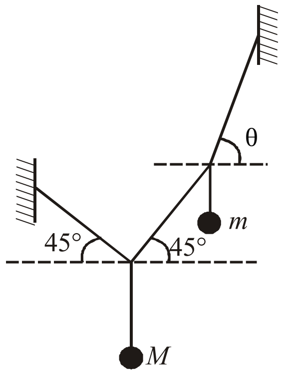
(b)


(c)


(d)


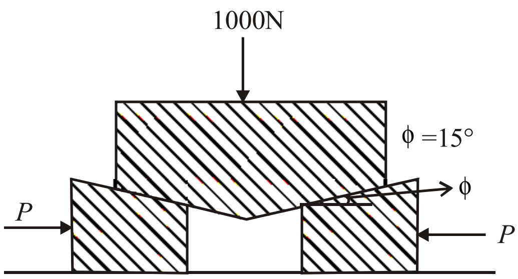
MARK YOUR RESPONSE					
	63. ⓐⓑⓒⓓ	64. ⓐⓑⓒⓓ	65. ⓐⓑⓒⓓ	66. ⓐⓑⓒⓓ	67. ⓐⓑⓒⓓ
	68. ⓐⓑⓒⓓ	69. ⓐⓑⓒⓓ			

70. Two masses m and M are attached to strings as shown in the figure. In equilibrium, $\tan\theta$ is



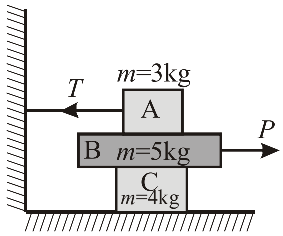
(a) $1 + (2M/m)$ (b) $(1 + 2m/M)$
(c) $1 + (M/2m)$ (d) None of these

71. What force P must be applied to the weightless wedges shown to start them under the 1000N block ? The angle of friction at all contact surfaces is 10°.



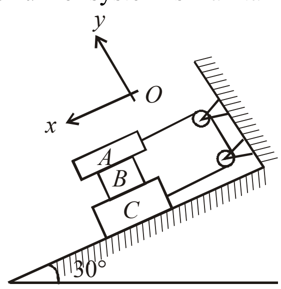
(a) 221.32 N (b) 121.32 N
(c) 421.32 N (d) 321.32 N

72. Determine the force P required to impend the motion of the block B shown in figure. Take coefficient of friction = 0.3 for all surfaces in contact.



(a) 12.34 N (b) 32.34 N
(c) 62.12 N (d) 6.34 N

73. Three blocks A, B, C of weights 40N, 30N, 80N respectively are at rest on an inclined plane as shown in figure. Determine the smallest value of coefficient of limiting friction (μ_s) for which equilibrium of system is maintained.



(a) 0.1757 (b) 0.2757
(c) 0.5757 (d) 0.8757

74. A pail filled with sand has a total mass of 60 kg. A crane is lowering it such that it has an initial downward acceleration of 1.5 m/s^2. A hole in the pail allows sand to leak out. If the force exerted by the crane on the pail does not change, what mass of sand must leak out before the downward acceleration decreases to zero?

(a) 9.2 kg (b) 20 kg
(c) 40 kg (d) 51 kg

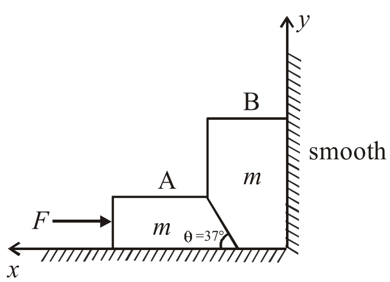
MARK YOUR RESPONSE	70. ⓐⓑⓒⓓ	71. ⓐⓑⓒⓓ	72. ⓐⓑⓒⓓ	73. ⓐⓑⓒⓓ	74. ⓐⓑⓒⓓ

B COMPREHENSION TYPE

This section contains groups of questions. Each group is followed by some multiple choice questions based on a paragraph. Each question has 4 choices (a), (b), (c) and (d) for its answer, out of which ONLY ONE is correct.

PASSAGE-1

Two smooth blocks are placed at a smooth corner as shown. Both the blocks are having mass m. We apply a force F on the small block m.



Block A presses the block B in the normal direction, due to which pressing force on vertical wall will increase and pressing force on the horizontal wall decrease, as we increase F. ($\theta = 37°$ with horizontal).

As soon as the pressing force on the horizontal wall by block B becomes zero, it will loose the contact with the ground. If the value of F is further increased, the block B will accelerate in upward direction and simultaneously the block A will move toward right.

1. What is minimum value of F, to lift block B from ground ?

(a) $\frac{25}{12}mg$ (b) $\frac{5}{4}mg$ (c) $\frac{3}{4}mg$ (d) $\frac{4}{3}mg$

2. If both the blocks are stationary, the force exerted by ground on block A is

(a) $mg+\frac{3F}{4}$ (b) $mg-\frac{3F}{4}$

(c) $mg+\frac{4F}{3}$ (d) $mg-\frac{4F}{3}$

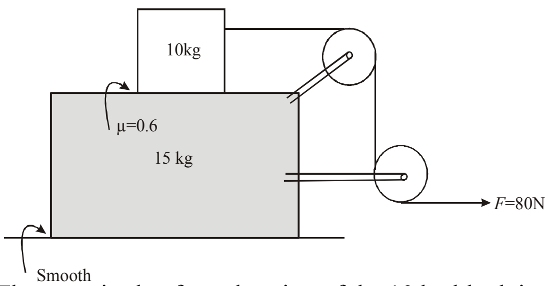
3. If acceleration of block A is a rightward, then acceleration of block B will be

(a) $\frac{3a}{4}$ upwards (b) $\frac{4a}{3}$ upwards

(c) $\frac{3a}{5}$ upwards (d) $\frac{4a}{5}$ upwards

PASSAGE-2

A block of mass 15 kg is placed over a frictionless horizontal surface. Another block of mass 10 kg is placed over it, that is connected with a light string passing over two pulleys fastened to the 15 kg block. A force F = 80N is applied horizontally to the free end of the string. Friction coefficient between two blocks is 0.6. The portion of the string between 10 kg block and the upper pulley is horizontal. Pulley, string and connecting rods are massless. (Take g = 10 m/s²)



4. The magnitude of acceleration of the 10 kg block is

(a) 3.2 m/s² (b) 2.0 m/s²
(c) 1.6 m/s² (d) 0.8 m/s²

5. The magnitude of acceleration of the 15 kg block is

(a) 4.2 m/s² (b) 3.2 m/s²
(c) 16/3 m/s² (d) 2.0 m/s²

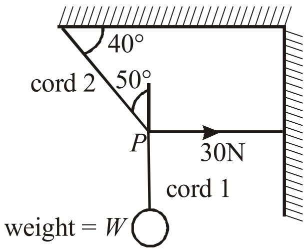
6. If applied force F = 120 N, then magnitude of acceleration of 15 kg block will be

(a) 8 m/s² (b) 4 m/s²
(c) 3.2 m/s² (d) 4.8 m/s²

PASSAGE-3

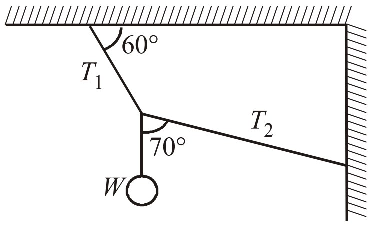
For the object to be in equilibrium
$\Sigma F_x = 0, \Sigma F_y = 0, \Sigma \quad = 0$ and $\Sigma \tau = 0$

7. As shown in figure, the tension in the horizontal cord is 30N. The weight of the object is



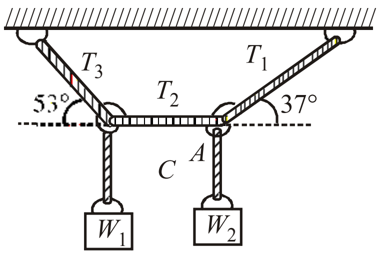
(a) 25.2N (b) 22.2 N
(c) 39.2 N (d) 42.5 N

8. If W = 40N in the equilibrium situation shown in figure, find T_1 and T_2.



(a) $T_1 = 48.3$ N, $T_2 = 25$ N
(b) $T_1 = 58.3$ N, $T_2 = 31$ N
(c) $T_1 = 65.3$ N, $T_2 = 15$ N
(d) $T_1 = 54.4$ N, $T_2 = 21$ N

9. The weight W_1 in figure is 300N. Find T_1, T_2, T_3, and W_2.

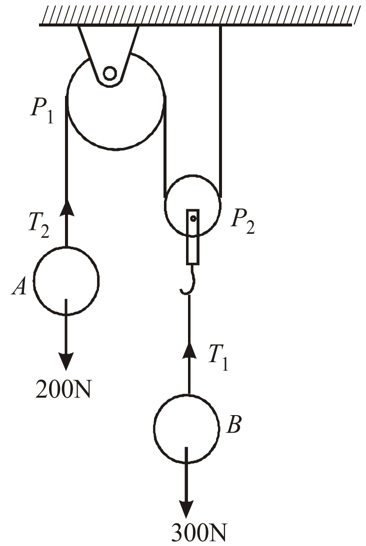


(A) $T_1 = 500$ N, $T_2 = 400$ N, $T_3 = 670$ N, $W_2 = 530$ N
(B) $T_1 = 500$ N, $T_2 = 300$ N, $T_3 = 670$ N, $W_2 = 530$ N
(C) $T_1 = 400$ N, $T_2 = 400$ N, $T_3 = 670$ N, $W_2 = 530$ N
(D) $T_1 = 500$ N, $T_2 = 400$ N, $T_3 = 300$ N, $W_2 = 530$ N

MARK YOUR RESPONSE					
	1. ⓐⓑⓒⓓ	2. ⓐⓑⓒⓓ	3. ⓐⓑⓒⓓ	4. ⓐⓑⓒⓓ	5. ⓐⓑⓒⓓ
	6. ⓐⓑⓒⓓ	7. ⓐⓑⓒⓓ	8. ⓐⓑⓒⓓ	9. ⓐⓑⓒⓓ	

PASSAGE-4

In figure, the weights of the objects are 200 N and 300 N. The pulleys are essentially frictionless and massless. Pulley P_1 has a stationary axle but pulley P_2 is free to move up and down.



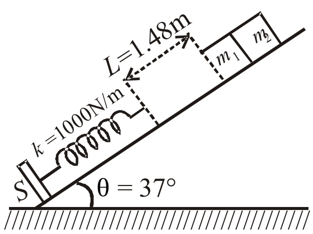
10. Tension T_1 is
(a) 327 N (b) 164 N (c) 315 N (d) 300 N

11. Tension T_2 is
(a) 327 N (b) 164 N (c) 315 N (d) 300 N

12. Acceleration of A is
(a) $1.78\ m/s^2$ (b) $0.39\ m/s^2$
(c) $3.56\ m/s^2$ (d) $2.72\ m/s^2$

PASSAGE-5

Two blocks of mass $m_1 = 10$ kg and $m_2 = 20$ kg are placed on a fixed inclined surface making an angle $\theta = 37°$ with horizontal. One end of a light spring of spring constant $k = 100$ N/m is free and other end is connected to a support S rigidly fixed to inclined surface. The coefficient of friction between block of mass m_1 and inclined plane is $\mu_1 = 0.5$ and that between block of mass m_2 and inclined plane is $\mu_2 = 1$. At time $t = 0$ both blocks are released at rest from shown position. (Take $g = 10\ m/s^2$)



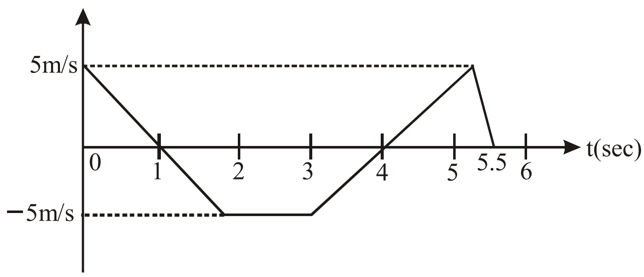
13. At the instant the speed of block of mass m_1 is maximum, the compression in the spring is
(a) 5 cm (b) 10 cm
(c) 20 cm (d) 60 cm

14. At the instant speed of block of mass m_1 is maximum, the speed of block of mass m_2 is
(a) zero (b) 2 m/s
(c) $\frac{2}{3}$ m/s (d) $\frac{4}{3}$ m/s

15. The maximum force exerted by block of mass m_1 on block of mass m_2 is
(a) zero (b) $\frac{40}{3}$ N
(c) $\frac{80}{3}$ N (d) 40N

PASSAGE-6

An elevator is moving in vertical direction such that its velocity varies with time as shown in figure. Their upward direction is taken as positive. A man of mass 60 kg is standing in the elevator on a weighing machine. When the lift is accelerated up, the reading of the weighing machine increases and when the lift is accelerating down, the reading decreases.



16. The man will not be in contact with weighing machine at time
(a) t = 1s (b) t = 5.1s
(c) t = 2.4s (d) t = 4.2s

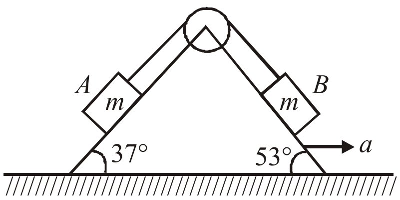
17. What will be the maximum reading of the weighing machine?
(a) 90 kg (b) 100 kg
(c) 6 kg (d) None of these

18. If the total mass of (elevator + man) system is 150 kg, the maximum tension in the cable supporting the lift will be
(a) 1500 N (b) 3000 N
(c) 2250 N (d) None of these

MARK YOUR RESPONSE					
	10. ⓐⓑⓒⓓ	11. ⓐⓑⓒⓓ	12. ⓐⓑⓒⓓ	13. ⓐⓑⓒⓓ	14. ⓐⓑⓒⓓ
	15. ⓐⓑⓒⓓ	16. ⓐⓑⓒⓓ	17. ⓐⓑⓒⓓ	18. ⓐⓑⓒⓓ	

PASSAGE-7

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)



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

(a) $\frac{m}{5}(3g-4a)$ (b) $\frac{m}{5}(4g+3a)$

(c) $\frac{m}{5}(3g+4a)$ (d) $\frac{m}{5}(4g-3a)$

20. Normal reaction (in N) acting on block A is

(a) $\frac{m}{5}(3g+4a)$ (b) $\frac{m}{5}(4g-3a)$

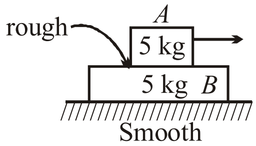
(c) $\frac{m}{5}(3g-4a)$ (d) $\frac{m}{5}(4g+3a)$

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

(a) $\frac{3}{4}g$ (b) $\frac{3}{5}g$ (c) $\frac{5}{3}g$ (d) $\frac{4}{3}g$

PASSAGE-8

Block A of 5 kg is placed on long block B also having 5 kg. The coefficient of friction between two block is 0.4. There is no friction between the ground and lower block. The upper block is given a sudden velocity of 10 m/s. The upper block slides toward right, so friction force acting on it will be toward left. Its reaction will act on the lower block, which will act forward. The friction force absorb x mechanical energy from upper block but supply only y mechanical energy to lower block. Due to friction the velocity of upper block reduces and velocity of lower block increases. This will continue till velocity of both the block get equal.

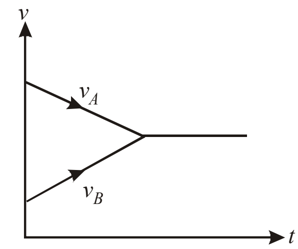


22. The net energy loss due to friction in the entire process is

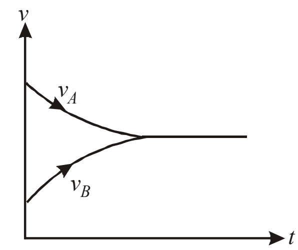
(a) $x+y$ (b) $x-y$ (c) x (d) y

23. Which curve shows the correct variation of velocity of each block v/s time ?

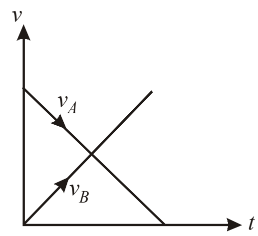
(a)



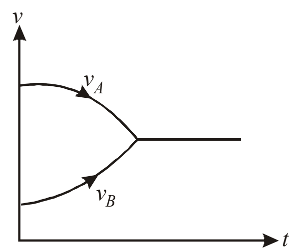
(b)



(c)



(d)



24. After what time, both the blocks start moving together ?

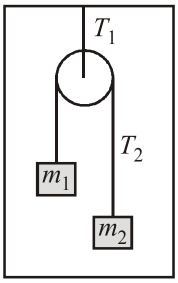
(a) 1 sec. (b) 2.25 sec.

(c) 1.25 sec. (d) None of these

MARK YOUR RESPONSE					
	19. ⓐⓑⓒⓓ	20. ⓐⓑⓒⓓ	21. ⓐⓑⓒⓓ	22. ⓐⓑⓒⓓ	23. ⓐⓑⓒⓓ
	24. ⓐⓑⓒⓓ				

PASSAGE-9

A lift can move upward or downward. A light inextensible string fixed from ceiling of lift with a frictionless pulley and tension in string T_1. Two masses of m_1 and m_2 are connected with inextensible light string and tension in this string T_2 as shown in the figure.



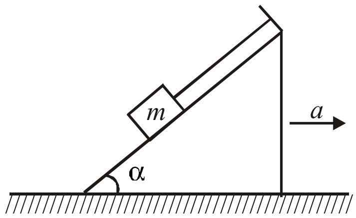
25. If $m_1 + m_2 = m$ and lift is moving with constant velocity then value of T_1
(a) $\geq mg$ (b) $= mg$ (c) $\leq mg$ (d) $> mg$

26. If m_1 is very small as compared to m_2 and lift is moving with constant velocity then value of T_2 is nearly
(a) $m_2 g$ (b) $2m_1 g$
(c) $(m_1 + m_2)\, g$ (d) zero

27. If $m_1 = m_2$ and m_1 is moving at a certain instant with velocity v upward with respect to lift and the lift is moving in upward direction with constant acceleration ($a < g$) then speed of m_1 with respect to lift
(a) increases
(b) decreases
(c) remains constant
(d) depend upon acceleration of lift

PASSAGE-10

A body of mass $m = 1.8$ kg is placed on an inclined plane, the angle of inclination is $\alpha = 37°$, and is attached to the top end of the slope with a thread which is parallel to the slope. Then the slope is moved with a horizontal acceleration of a. Friction is negligible.



28. The acceleration if the body pushes the slope with a force of $\frac{3}{4}mg$ is
(a) $\frac{5}{3}\text{m/s}^2$ (b) 0.5 m/s^2
(c) 0.75 m/s^2 (d) $\frac{5}{6}\text{m/s}^2$

29. The tension in thread is
(a) 12 N (b) 10 N
(c) 8 N (d) 4 N

30. At what acceleration will the body lose contact with plane?
(a) $\frac{40}{3}$ m/s^2 (b) 7.5 m/s^2
(c) 10 m/s^2 (d) 5 m/s^2

MARK YOUR RESPONSE	25. ⓐⓑⓒⓓ	26. ⓐⓑⓒⓓ	27. ⓐⓑⓒⓓ	28. ⓐⓑⓒⓓ	29. ⓐⓑⓒⓓ
	30. ⓐⓑⓒⓓ				

C REASONING TYPE

In the following questions two Statements (1 and 2) are provided. Each question has 4 choices (a), (b), (c) and (d) for its answer, out of which ONLY ONE is correct. Mark your responses from the following options :

(a) Both Statement-1 and Statement-2 are true and Statement-2 is the correct explanation of Statement-1.
(b) Both Statement-1 and Statement-2 are true and Statement-2 is not the correct explanation of Statement-1.
(c) Statement-1 is true but Statement-2 is false.
(d) Statement-1 is false but Statement-2 is true.

1. **Statement - 1 :** On a rainy day it is difficult to drive a car or bus at high speed.
Statement - 2 : The value of coefficient of friction is lowered due to wetting of the surface.

2. **Statement - 1 :** A rocket moves forward by pushing the surrounding air backwards.
Statement - 2 : It derives the necessary thrust to move forward according to Newton's third law of motion.

MARK YOUR RESPONSE	1. ⓐⓑⓒⓓ	2. ⓐⓑⓒⓓ			

3. **Statement - 1** : The driver in a vehicle moving with a constant speed on a straight road is an inertial frame of reference.

Statement - 2 : A reference frame in which Newton's laws of motion are applicable is non-inertial.

4. **Statement - 1** : Use of ball bearings between two moving parts of a machine is a common practice.

Statement - 2 : Ball bearings reduce vibrations and provide good stability.

5. **Statement - 1** : A man in a closed cabin falling freely does not experience gravity.

Statement - 2 : Inertial and gravitational mass have equivalence.

6. **Statement - 1** : A cloth covers a table. Some dishes are kept on it. The cloth can be pulled out without dislodging the dishes from the table.

because

Statement - 2 : For every action there is an equal and opposite reaction.

7. A solid sphere and a hollow sphere of same mass M and same radius R are released from the top of a rough inclined plane. Friction coefficient is same for both the bodies. If both bodies perform imperfect rolling, then

Statement - 1 : Work done by friction for the motion of bodies from top of incline to the bottom will be same for both the bodies.

Statement - 2 : Force of friction will be same for both the bodies.

8. **Statement - 1** : Maximum value of friction force between two surfaces is $\mu \times$ normal reaction. where μ = coefficient of friction between surfaces.

Statement - 2 : Friction force between surface of a body is always less than or equal to externally applied force.

9. **Statement - 1** : If we assume that there are only two bodies, earth and sun, in the universe. Their size, shape and motion remains same. A frame placed on sun is an inertial frame.

Statement - 2 : Inertial frame is non-accelerating in nature.

10. A man of mass 80 kg pushes a box of mass 20 kg horizontally. The man moves the box with a constant acceleration of $2 m/s^2$ but his foot does not slip on the ground. There is no friction between the box and the ground, whereas there is sufficient friction between the man's foot and ground to prevent him from slipping.

Statement - 1 : The force applied by the man on the box is equal and opposite to the force applied by the box on the man.

Statement - 2 : Friction force applied by the ground on the man is 200 N.

11. **Statement - 1 :** A uniform elastic rod lying on smooth horizontal surface is pulled by constant horizontal force of magnitude F as shown in figure (i). Another identical elastic rod is pulled vertically upwards by a constant vertical force of magnitude F (figure ii). The extension in both rods will be same.

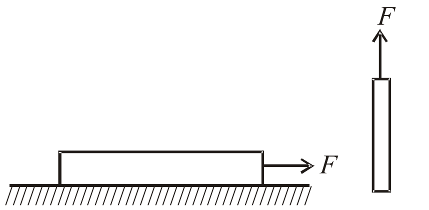
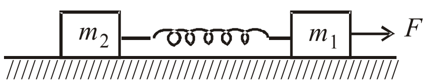


Fig. (i) Fig. (ii)

Statement - 2 : In a uniform elastic rod, the extension depends only on forces acting at the ends of rod.

12. **Statement - 1** : Two blocks of mass m_1 and m_2 connected by a massless spring are lying on smooth horizontal surface as shown. The block of mass m_1 is pulled to right by a horizontal force of magnitude F. When the spring is compressed state, the acceleration of block of mass m_2 is towards left even if its velocity is towards right.



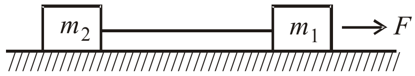
smooth horizontal surface

Statement - 2 : A massless spring exerts force on a block fixed at one end of spring in direction opposite to that of velocity of block as a consequence of Newton's third law.

MARK YOUR RESPONSE					
	3. ⓐⓑⓒⓓ	4. ⓐⓑⓒⓓ	5. ⓐⓑⓒⓓ	6. ⓐⓑⓒⓓ	7. ⓐⓑⓒⓓ
	8. ⓐⓑⓒⓓ	9. ⓐⓑⓒⓓ	10. ⓐⓑⓒⓓ	11. ⓐⓑⓒⓓ	12. ⓐⓑⓒⓓ

13. Statement - 1 : Two blocks of masses m_1 and m_2 are connected by a light extensible string (having non zero tension) and this system lies on smooth horizontal surface. The block of mass m_1 is pulled to right by horizontal force of magnitude F as shown. Then the value of $m_1a_1 + m_2a_2$ does not depend on tension in the string connecting both the blocks, where a_1 and a_2 are the magnitudes of acceleration of blocks of masses m_1 and m_2 respectively.

Statement - 2 : Internal forces with in a system does not depend on net force on the system because sum of all internal forces within a system is zero.



smooth horizontal surface

14. Statement - 1 : Newton's first law of motion can be derived using Newton's second law.

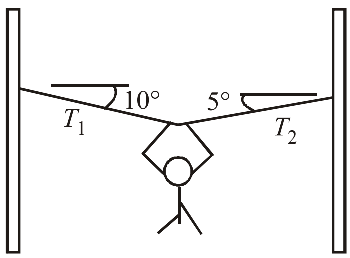
Statement - 2 : In inertial frame $a = F/m$ hence $a = 0$ when $F = 0$. (Symbols have usual meanings)

MARK YOUR RESPONSE	13. ⓐⓑⓒⓓ	14. ⓐⓑⓒⓓ			

D MULTIPLE CORRECT CHOICE TYPE

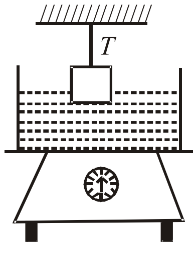
Each of these questions has 4 choices (a), (b), (c) and (d) for its answer, out of which ONE OR MORE is/are correct.

1. A rope extends between two poles. A 90N boy hangs from it, as shown in figure. Choose the correct option(s)



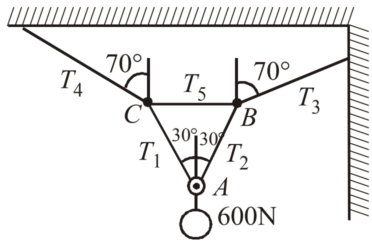
(a) $T_1 = 346$ N (b) $T_2 = 342$ N
(c) $T_2 = 322$ N (d) $T_1 = 342$ N

2. The mass of block is m_1 and that of liquid with the vessel is m_2. The block is suspended by a string (tension T) partially in the liquid. The reading of the weighing machine placed below the vessel



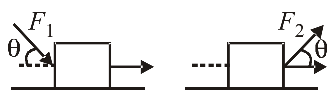
(a) can be $(m_1 + m_2)g$
(b) can be greater than $(m_1 + m_2)g$
(c) is equal to $(m_1g + m_2g - T)$
(d) can be less than $(m_1 + m_2)g$

3. Choose the correct option(s) for the figure shown.



(a) $T_1 = 346$ N (b) $T_2 = 346$ N
(c) $T_3 = 877$ N (d) $T_4 = 877$ N & $T_5 = 651$ N

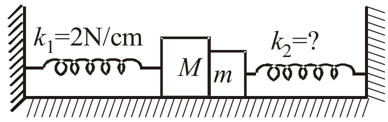
4. In the two cases shown, the coefficient of kinetic friction between the block and the surface is the same, and both the identical blocks are moving with the same uniform speed. If $\sin\theta = mg/4F_2$, then



(a) $F_1 = F_2$ (b) $F_1 < F_2$
(c) $F_1 > F_2$ (d) $F_1 = 2F_2$

MARK YOUR RESPONSE	1. ⓐⓑⓒⓓ	2. ⓐⓑⓒⓓ	3. ⓐⓑⓒⓓ	4. ⓐⓑⓒⓓ	

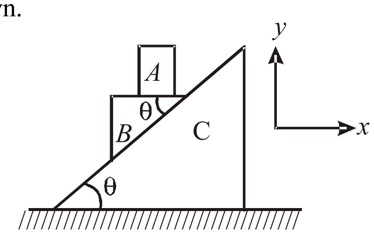
5. Two blocks of mass M and m, are used to compress two different massless springs as shown. The left spring is compressed by 3cm, while the right spring is compressed by an unknown amount. The system is at rest, and all surfaces are fixed and smooth. Which of the following statements is/are true ?



(a) The force exerted on block of mass m by the right spring is 6N to the left
(b) The net force on block of mass m is zero
(c) The force exerted on block of mass m by the right spring is impossible to determine
(d) The normal force exerted by block of mass m on block of mass M is 6N

6. A block of mass m is lying at rest on a rough horizontal surface having coefficient of kinetic and static friction μ_k and μ_s respectively. Now a constant horizontal force is applied on the block in the horizontal direction. Choose the correct alternative(s).
(a) If $F > \mu_s mg$, block will start moving and a constant friction force of magnitude μ_s mg will act on the block
(b) If $\mu_k mg < F < \mu_s mg$, block will start moving and a constant friction force of magnitude $\mu_k\, mg$ will act on the block
(c) If $F < \mu_s mg$, block will not start moving
(d) If $F > \mu_s mg$, block will move with a constant acceleration given by $\dfrac{F - \mu_k mg}{m}$

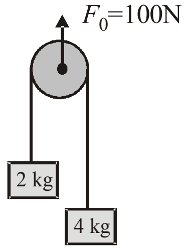
7. In the figure shown all the surface are smooth. All the blocks A, B and C are movable, x-axis is horizontal and y-axis vertical as shown. Just after the system is released from the position as shown.



Horizontal surface

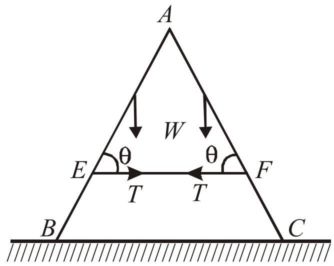
(a) acceleration of A relative to ground is in negative y-direction.
(b) acceleration of A relative to B is in positive x-direction.
(c) the horizontal acceleration of B relative to ground is in negative x-direction
(d) the acceleration of B relative to ground directed along the inclined surface of C is greater than $g \sin \theta$.

8. Two blocks of masses m_1 = 2 kg and m_2 = 4 kg over a massless pulley as shown in the figure. The string connecting both the blocks is light and inextensible. A force F_0 = 100N acting at the axis of the pulley accelerates the system upwards. Then (Take $g = 10\text{m/s}^2$)



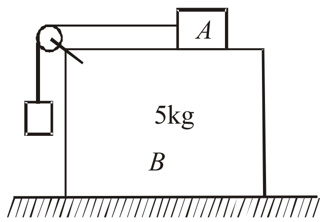
(a) acceleration of both the masses is same
(b) magnitude of acceleration of 2 kg mass is 15 m/sec^2
(c) magnitude of acceleration of 4 kg mass is 2.5 m/sec^2
(d) acceleration of both the masses is upward

9. Two uniform and equal ladders AB and AC, each of weight W lean against each other and a string is tied between E and F. They stand on a smooth horizontal surface. Then



(a) the force exerted by one ladder on the other at A is equal in magnitude to the tension T in the string
(b) tension $T = (W/2) \cot \theta$
(c) the normal reaction at B and C are equal
(d) the normal reaction at B or C is greater than W

10. All the blocks shown in the figure are at rest. The pulley is smooth and the strings are light. Coefficient of friction at all contacts is 0.2. A frictional force of 10N acts between A and B. The block A is about to slide on block B. The normal reaction and frictional force exerted by the ground on the block B is



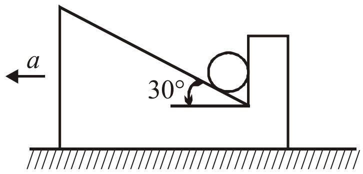
(a) the normal reaction exerted by the ground on the block B is 110N
(b) the normal reaction exerted by the ground on the block B is 50N
(c) the frictional force exerted by the ground on the block B is 20N
(d) the frictional force exerted by the ground on the block B is zero

MARK YOUR RESPONSE					
	5. ⓐⓑⓒⓓ	6. ⓐⓑⓒⓓ	7. ⓐⓑⓒⓓ	8. ⓐⓑⓒⓓ	9. ⓐⓑⓒⓓ
	10. ⓐⓑⓒⓓ				

slide it up a 30° incline. The friction force retarding the motion is 80N. Choose the correct option(s)

(a) If the acceleration of the moving box is to be zero then P is 223N
(b) If the acceleration of the moving box is to be 0.75 m/s^2 then P is 206 N
(c) If the acceleration of the moving box is to be zero then P is 206 N
(d) If the acceleration of the moving box is to be 0.75 m/s^2 then P is 223 N

12. The system in figure is given an acceleration. Weight of the ball is W.



(a) The force on the ball from vertical surface is 1.15 W
(b) The force on the ball from inclined surface is

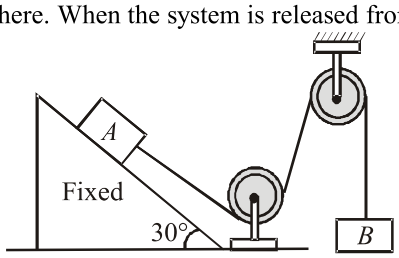
$$W\left(0.58+\frac{a}{g}\right)$$

(c) The force on the ball from vertical surface is

$$W\left(0.58+\frac{a}{g}\right)$$

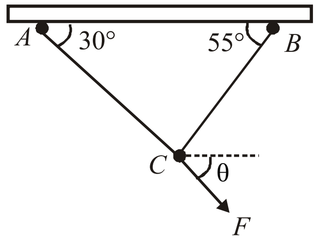
(d) The forces on the ball from inclined surface is 1.15 W

13. Two blocks A and B of equal mass m are connected through a massless string and arranged as shown in figure. The wedge is fixed on horizontal surface. Friction is absent everywhere. When the system is released from rest



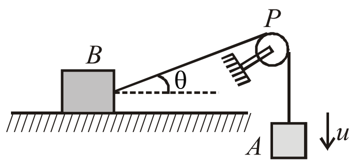
(a) tension in string is $mg/2$
(b) tension in string is $mg/4$
(c) acceleration of A is $g/2$
(d) acceleration of A is $3g/4$

14. Two cables tied together at C are loaded as shown. Knowing that the maximum allowable tension is 1400N in cable AC and 700N in cable BC, choose the correct options



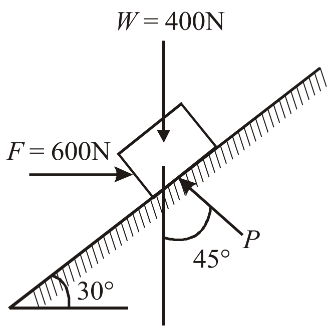
(a) the magnitude of the largest force F which may be applied at C is 1210 N
(b) the value of θ is 57.5°
(c) the magnitude of the largest force F which may be applied at C is 1510 N
(b) the value of θ is 37.5°

15. In the figure, the blocks are of equal masses. The pulley is fixed. In the position shown, A moves down with a speed u, and v_B = the speed of B.



(a) B will never lose contact with the ground
(b) The downward acceleration of A is equal in magnitude to the horizontal acceleration of B.
(c) $v_B = u \cos\theta$
(d) $v_B = u/\cos\theta$

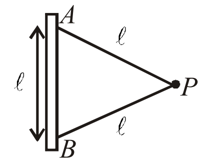
16. The block shown is acted on by its weight W = 400N, a horizontal force F = 600N and the pressure P exerted by the inclined plane. The resultant R of these forces is parallel to the incline. Choose the correct option(s).



(a) P = 670 N
(b) R = 146.2 N
(c) Block is moving upwards
(d) Block is moving downwards

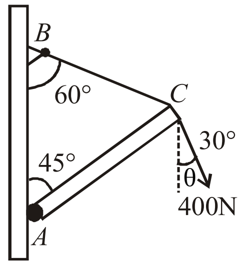
MARK YOUR RESPONSE	11. ⓐⓑⓒⓓ	12. ⓐⓑⓒⓓ	13. ⓐⓑⓒⓓ	14. ⓐⓑⓒⓓ	15. ⓐⓑⓒⓓ
	16. ⓐⓑⓒⓓ				

17. A particle P of mass m is attached to a vertical axis by two strings AP and BP of length ℓ each. The separation $AB = \ell$. P rotates around the axis with an angular velocity ω. The tensions in the two strings are T_1 and T_2. Then



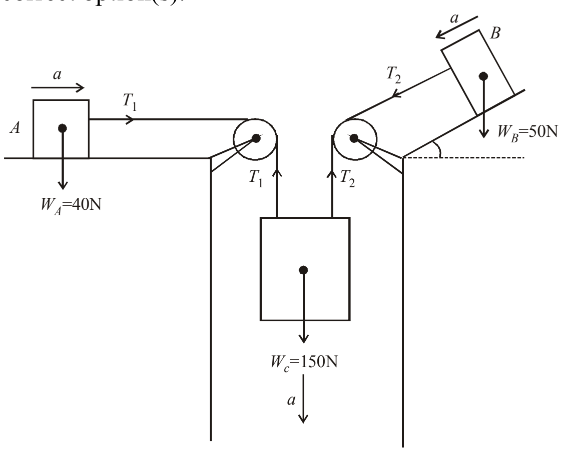
(a) $T_1 = T_2$
(b) $T_1 + T_2 = m\omega^2\ell$
(c) $T_1 - T_2 = 2mg$
(d) BP will remain taut only if $\omega \geq \sqrt{2g/\ell}$

18. Figure shows a beam AC supported by cable BC. Force at C is 400N. Choose the correct option(s).



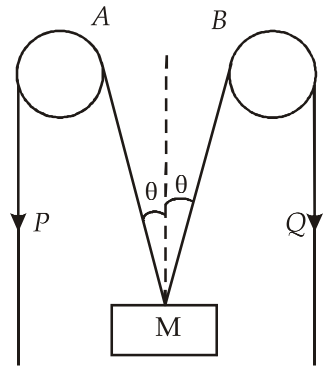
(a) magnitude of force along AC is 107 N
(b) the tension in cable BC is 200 N
(c) magnitude of force along AC is 207 N
(d) the tension in cable BC is 400 N

19. Three bodies A, B and C are connected by inextensible light strings as shown. The weights of these bodies are 40N, 50N and 150N respectively. The pulleys are frictionless. A is placed on a horizontal plane while B is placed on an inclined plane which is at an inclination of $\tan^{-1}(3/4)$ with the horizontal. The coefficient of kinetic friction between bodies A and B and the planes are same equal to 0.25. Choose the correct option(s).



(a) The acceleration of the system is 6.53 m/s^2
(b) The tension in the two strings are 36.65 N and 13.32 N
(c) The acceleration of the system is 3.53 m/s^2
(d) The tension in the two strings are 16.65 N and 18.32 N

20. In the arrangement shown in the Fig, the ends P and Q of an unstretchable string move downwards with uniform speed U. Pulleys A and B are fixed.



Mass M moves upwards with a speed

(a) $2U\cos\theta$ (b) $U/\cos\theta$
(c) $2U/\cos\theta$ (d) $U\cos\theta$

21. A reference frame attached to the earth

(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 are applicable in this frame.
(d) cannot be an inertial frame because the earth is rotating about its own axis.

22. A simple pendulum of length L and mass (bob) M is oscillating in a plane about a vertical line between angular limit $-\phi$ and $+\phi$. For an angular displacement $\theta\ (|\theta| < \phi)$, the tension in the string and the velocity of the bob are T and V respectively. The following relations hold good under the above conditions :

(a) $T\cos\theta = Mg$

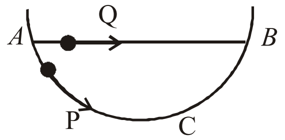
(b) $T - Mg\cos\theta = \dfrac{Mv^2}{L}$

(c) The magnitude of the tangenial acceleration of the bob $|a_T| = g\sin\theta$

(d) $T = Mg\cos\theta$

MARK YOUR RESPONSE	17. ⓐⓑⓒⓓ	18. ⓐⓑⓒⓓ	19. ⓐⓑⓒⓓ	20. ⓐⓑⓒⓓ	21. ⓐⓑⓒⓓ
	22. ⓐⓑⓒⓓ				

23. 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 :



(a) $t_P < t_Q$

(b) $t_P = t_Q$

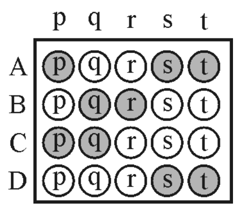
(c) $t_P > t_Q$

(d) $\dfrac{t_P}{t_Q} = \dfrac{\text{length of arc } ACB}{\text{length of arc } AB}$

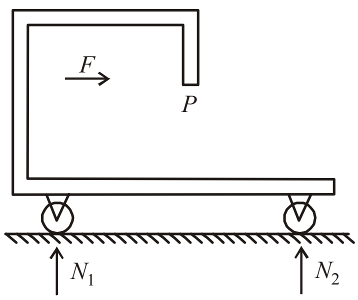
MARK YOUR RESPONSE	23. ⓐⓑⓒⓓ				

E MATRIX-MATCH TYPE

Each question contains statements given in two columns, which have to be matched. The statements in Column-I are labeled A, B, C and D, while the statements in Column-II are labelled p, q, r, s and t. Any given statement in Column -I can have correct matching with ONE OR MORE statement(s) in Column-II. The appropriate bubbles corresponding to the answers to these questions have to be darkened as illustrated in the following example:
If the correct matches are A–p, s and t; B–q and r; C–p and q; and D–s and t; then the correct darkening of bubbles will look like the given.

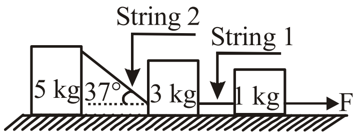


1. In the shown assembly on wheels, a force F is applied at point P as shown in the figure. If C denotes the centre of mass of the whole assembly and N_1 & N_2 are the normal reaction as shown. Consider the following two cases.
Case I : Wheels are frictionless.
Case II : Wheels are jammed such that the van doesn't move.
When $F = 0$, $N_1 = N_1^0$ and $N_2 = N_2^0$



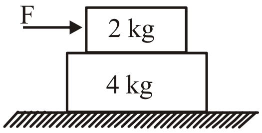
Column-I	**Column-II**
(A) Case I, C lies above P	(p) $N_1 > N_1^0$
(B) Case II, C lies above P	(q) $N_1 < N_1^0$
(C) Case I, C lies below P	(r) $N_2 > N_2^0$
(D) Case II, C lies below P	(s) $N_2 < N_2^0$

2. System of blocks are placed on a smooth horizontal system as shown. For a particular value of F, 3 kg block is just about to leave ground. ($\tan 37° = 3/4$)



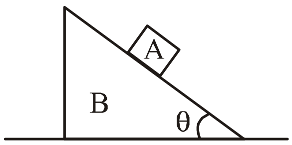
	Column I		Column II
(A)	Tension in string 1	(p)	80 N
(B)	Tension in string 2	(q)	64 N
(C)	Net force by ground on 5 kg block	(r)	50 N
(D)	Net force on 3 kg block	(s)	24 N

3. A block of mass 2 kg is placed on 4 kg block and force F is applied on the block of mass 2 kg as shown in the figure. Coefficient of friction between any two surfaces is $\mu = 0.2$, choose the correct choice if it is true for any block

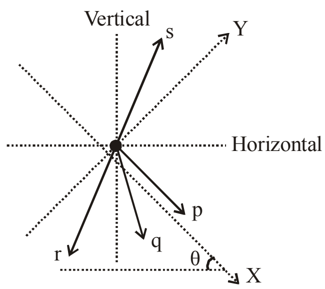


	Column I		Column II
(A)	Limiting friction force on block of 2 kg or 4 kg or ground is	(p)	12 N
(B)	Net friction exerted by 4 kg block on ground when F = 3 N	(q)	Zero
(C)	Net friction force on a block, when F = 10 N can have the values (s)	(r)	3 N
(D)	Net friction exerted on a block, if F = 3 N can have the value(s)	(s)	4 N

4. A block A is placed on wedge B, which is placed on horizontal surface. All the contact surfaces are rough but friction is not sufficient to prevent sliding at any surface. Match Column I and II. Column II indicates possible direction(s) of the physical quantities mentioned under Column I. X and Y axes are along the incline and perpendicular to the incline.



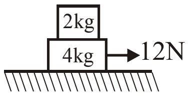
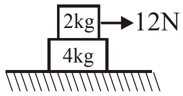
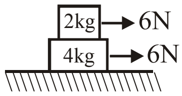
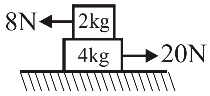
	Column I		Column II
(A)	Acceleration of A	(p)	
(B)	Net force applied by A on B	(q)	
(C)	Acceleration of A relative to B	(r)	
(D)	Net force applied by ground on B	(s)	



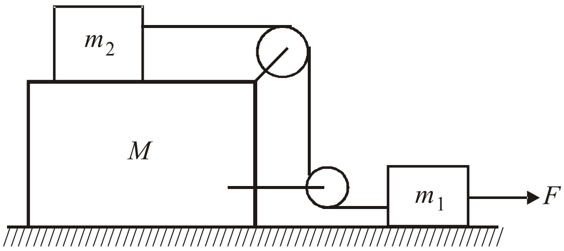
MARK YOUR RESPONSE

1. A ⓟⓠⓡⓢ B ⓟⓠⓡⓢ C ⓟⓠⓡⓢ D ⓟⓠⓡⓢ
2. A ⓟⓠⓡⓢ B ⓟⓠⓡⓢ C ⓟⓠⓡⓢ D ⓟⓠⓡⓢ
3. A ⓟⓠⓡⓢ B ⓟⓠⓡⓢ C ⓟⓠⓡⓢ D ⓟⓠⓡⓢ
4. A ⓟⓠⓡⓢ B ⓟⓠⓡⓢ C ⓟⓠⓡⓢ D ⓟⓠⓡⓢ

5. Column II gives certain situations involving two blocks of mass 2 kg and 4 kg. The 4 kg block lies on a smooth horizontal table. There is sufficient friction between both the blocks and there is no relative motion between both the blocks in all situations. Horizontal forces act on one or both blocks are shown. Column I gives certain statement related to figures given in column II. Match the statements in column I with the figure in column II.

Column I	Column II
(A) Magnitude of frictional force is maximum	(p) 
(B) Magnitude of frictional force is least	(q) 
(C) Frictional force on 2 kg block is towards right	(r) 
	(s) 

6. Three blocks of masses m_1, m_2 and M are arranged as shown in figure. All the surfaces are frictionless and string is inextensible. A constant horizontal force of magnitude F is applied on block of mass m_1 as shown. Pulleys and string are light. Part of the string connecting both pulleys is vertical and part of the strings connecting pulleys with masses m_1 and m_2 are horizontal.



smooth horizontal surface

Column I	Column II
(A) Acceleration of mass m_1	(p) $\frac{F}{m_1}$
(B) Acceleration of mass m_2	(q) $\frac{F}{m_1 + m_2}$
(C) Acceleration of mass M	(r) zero
(D) Tension in the string	(s) $\frac{m_2 F}{m_1 + m_2}$

MARK YOUR RESPONSE

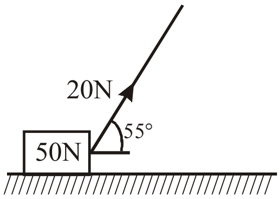
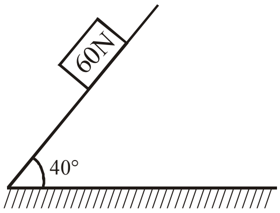
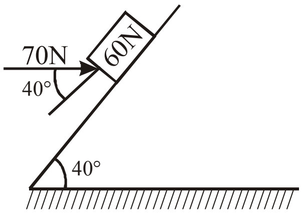
5.

	p	q	r	s
A	(p)	(q)	(r)	(s)
B	(p)	(q)	(r)	(s)
C	(p)	(q)	(r)	(s)
D	(p)	(q)	(r)	(s)

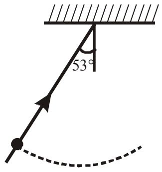
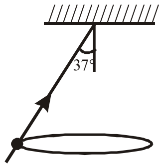
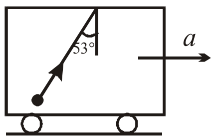
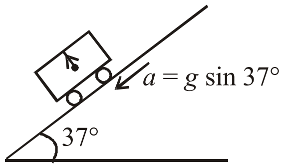
6.

	p	q	r	s
A	(p)	(q)	(r)	(s)
B	(p)	(q)	(r)	(s)
C	(p)	(q)	(r)	(s)
D	(p)	(q)	(r)	(s)

7. Column II shows normal force acting on the block in each of the equilibrium situations shown in column I.

Column I	**Column II**
(A) 	(p) 46 N
(B) 	(q) 33.6 N
(C) 	(r) 91 N

8. Match the column to value of tension assuming mass of particle equal to m :

Column I	**Column II**
(A)  Extreme position in simple pendulum	(p) $\frac{4mg}{5}$
(B)  Conical pendulum	(q) $\frac{5mg}{4}$
(C)  Cart is accelerated such that particle remains at rest as shown w.r.t. cart	(r) $\frac{3mg}{5}$
(D)  Cart is accelerating freely on the incline. Particle remains at rest w.r.t. cart as shown.	(s) $\frac{5mg}{3}$

MARK YOUR RESPONSE

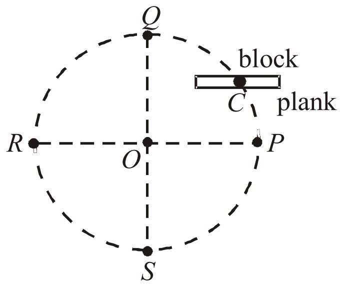
7.

	p	q	r	s
A	(p)	(q)	(r)	(s)
B	(p)	(q)	(r)	(s)
C	(p)	(q)	(r)	(s)
D	(p)	(q)	(r)	(s)

8.

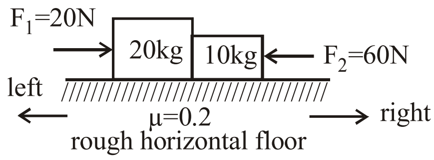
	p	q	r	s
A	(p)	(q)	(r)	(s)
B	(p)	(q)	(r)	(s)
C	(p)	(q)	(r)	(s)
D	(p)	(q)	(r)	(s)

9. A small block lies on a rough horizontal platform above its centre C as shown in 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 towards the centre	(s) when block is at position S

10. Two blocks of masses 20kg and 10kg are kept on a rough horizontal floor. The coefficient of friction between both blocks and floor is $\mu = 0.2$. The surface of contact of both blocks are smooth. Horizontal forces of magnitude 20N and 60N are applied on both the blocks as shown in figure. Match the statements in column I with the statements in column II.



Column I	Column II
(A) Frictional forces acting on block of mass 10 kg	(p) has magnitude 20N
(B) Frictional forces acting on block of mass 20 kg	(q) has magnitude 40N
(C) Normal reaction exerted by 20kg block on 10 kg block	(r) is zero
(D) Net force on system consisting of 10kg block and 20kg block	(s) is towards right (in horizontal direction)

11. Match the columns – ($g = 10$ m/s^2)

Column I	Column II
(A) Block of mass 2 kg on a rough horizontal surface pulled by a horizontal force of 20N, $\mu_s = 0.5$	(p) Tension at the mid point of block is 10N
(B) Block of mass 2 kg pulled with constant speed up an incline of inclination 30° and coefficient of friction $1/\sqrt{3}$	(q) Acceleration of block is 5 m/s^2
(C) Block of mass 0.75kg pulled by a constant force of 7.5N upon incline of inclination 30° and coefficient of friction $1/\sqrt{3}$	(r) Force of friction acting is 5N
(D) Block of mass 2 kg pulled vertically by a force 20N	(s) Resultant force on the block is zero
	(t) Force of friction is 10 N

MARK YOUR RESPONSE

9.

	p	q	r	s
A	ⓟ	ⓠ	ⓡ	ⓢ
B	ⓟ	ⓠ	ⓡ	ⓢ
C	ⓟ	ⓠ	ⓡ	ⓢ
D	ⓟ	ⓠ	ⓡ	ⓢ

10.

	p	q	r	s
A	ⓟ	ⓠ	ⓡ	ⓢ
B	ⓟ	ⓠ	ⓡ	ⓢ
C	ⓟ	ⓠ	ⓡ	ⓢ
D	ⓟ	ⓠ	ⓡ	ⓢ

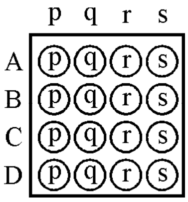
11.

	p	q	r	s
A	ⓟ	ⓠ	ⓡ	ⓢ
B	ⓟ	ⓠ	ⓡ	ⓢ
C	ⓟ	ⓠ	ⓡ	ⓢ
D	ⓟ	ⓠ	ⓡ	ⓢ

12. A bicycle moves forward and assume that the rider is not braking and pedaling at the same time. Match the columns regarding friction on the wheels of bicycle.

Column I	**Column II**
(A) When rear brakes are applied on a bicycle and it does not slide	(p) Friction force will be forward on both wheels
(B) When front brakes are applied on a bicycle and it does not slide	(q) Friction force will be backward on both wheels
(C) When front and rear brakes are applied simultaneously so hard that both wheels stop rotating	(r) Friction force will be forward on rear wheel and backward on front wheel
(D) When force on pedals is applied to accelerate bicycle without sliding	(s) Friction force will be backward on rear wheel and forward on front wheel

MARK YOUR RESPONSE

12.


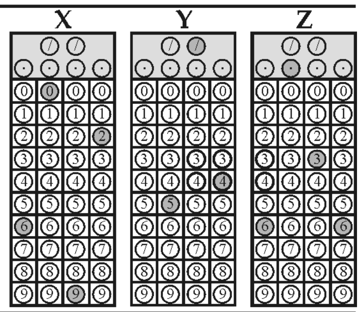
F NUMERIC/INTEGER ANSWER TYPE

The answer to each of the questions is either numeric (eg. 304, 40, 3010, 3 etc.) or a fraction (2/3, 23/7) or a decimal (2.35, 0.546).

The appropriate bubbles below the respective question numbers in the response grid have to be darkened.

For example, if the correct answers to question X, Y & Z are 6092, 5/4 & 6.36 respectively then the correct darkening of bubbles will look like the following.

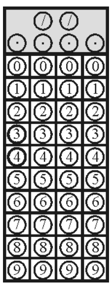
For single digit integer answer darken the extreme right bubble only.

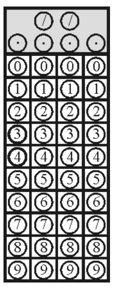


1. A wire of mass 9.8×10^{-3} kg per metre passes over a frictionless pulley fixed on the top of an inclined frictionless plane which makes an angle of 30º with the horizontal. Masses M_1 and M_2 are tied at the two ends of the wire. The mass M_1 rests on the plane and mass M_2 hangs freely vertically downwards. The whole system is in equilibrium. Now a transverse wave propagates along the wire with a velocity of 100 ms^{-1}. Find the value of $(M_1 + M_2)$ in kg.

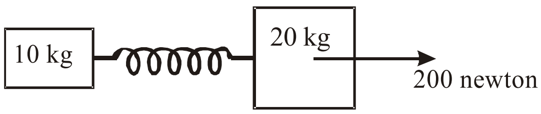
2. A block slides down a smooth inclined plane to the ground when released at the top, in time t seconds. Another block is dropped vertically from the same point, in the absence of the inclined plane and reaches the ground in $t/2$ second. Then find the angle (in degree) of inclination of the plane with the vertical.

MARK YOUR RESPONSE

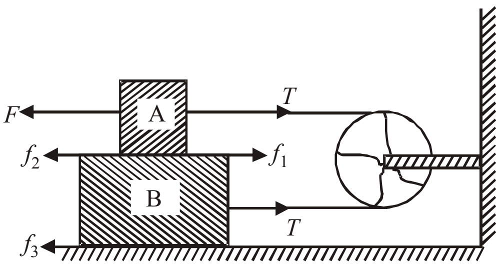
1.


2.


3. The masses of 10 kg and 20 kg respectively are connected by a massless spring in fig. A force of 200 newton acts on the 20 kg mass. At the instant shown, the 10 kg mass has acceleration 12 m/sec^2. What is the acceleration (in m/s^2) of 20 kg mass?

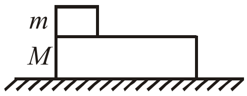


4.

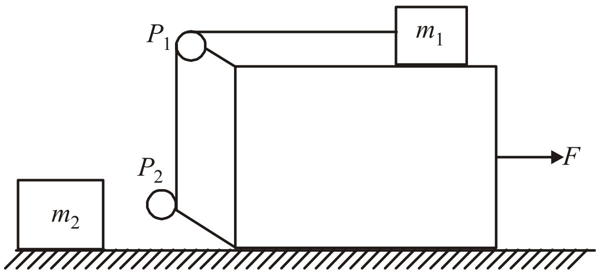


A block A of mass m_1(= 10 kg) rests on a block B of mass m_2 (=20 kg). B rests on fixed surface. The coefficient of friction between any two surfaces is $\mu(=0.3)$. A and B are connected by a massless string passing around a frictionless pulley fixed to the wall as shown in fig. With what force should A be dragged so as to keep both A and B moving with uniform speed?

5. Figure shows a small block of mass m (= 10 kg) kept at the left hand of a larger block of mass M (= 20 kg) and length L (= 4 cm). The system can slide on a horizontal road. The system is started towards right with an initial velocity v $\left(= 2\text{ms}^{-1}\right)$. The friction coefficient between road and bigger block is μ (= 0.3) and between the blocks is μ/2. Find the time (in second) elapsed before the smaller block separates from the bigger block.

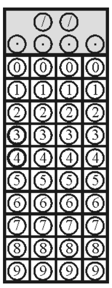


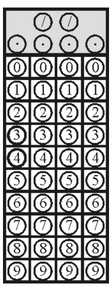
6. In the figure masses m_1, m_2 and M are 20 kg, 5 kg and 50 kg respectively. The coefficient of friction between M and ground is zero. The coefficient of friction between m_1 and M and that between m_2 and ground is 0.3. The pulleys and the strings are massless. The string is perfectly horizontal between 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.

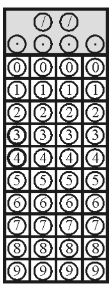


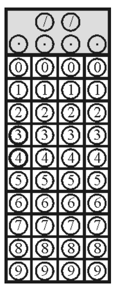
Let the magnitude of the force of friction between m_1 and M be f_1 and that between m_2 and ground be f_2. For a particular F it is found that $f_1 = 2f_2$. Find $(f_1 - f_2)$ in newton.

MARK YOUR RESPONSE

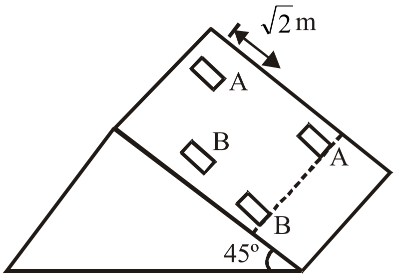
3.


4.


5.


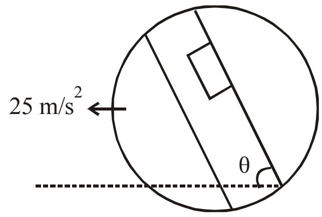
6.


7. Two blocks A and B of equal masses are placed on rough inclined plane as shown in figure. When will the two blocks come on the same line on the inclined plane if they are released simultaneously? Initially the block

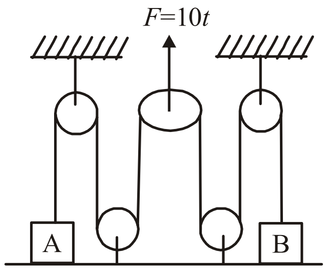


A is $\sqrt{2}$ m behind the block B. Coefficient of kinetic friction for the blocks A and B are 0.2 and 0.3 respectively ($g = 10$ m/s^2).

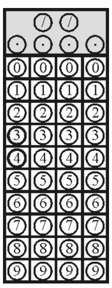
8. A circular disc with a groove along its diameter is placed horizontally on a rough surface. A block of mass 1 kg is placed as shown. The co-efficient of friction between the block and all surfaces of groove and horizontal surface in contact is $\mu = \frac{2}{5}$. The disc has an acceleration of 25 m/s^2 towards left. Find the acceleration (in m/s^2) of the block with respect to disc. (Given $\cos\theta = \frac{4}{5}$, $\sin\theta = \frac{3}{5}$.)

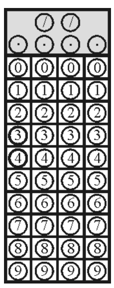


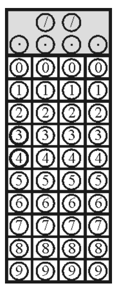
9. In the arrangement shown in figure $m_A = 1$ kg and $m_B = 2$ kg, while all the pulleys and strings are massless and frictionless. At $t = 0$, a force $F = 10\,t$ starts acting over central pulley in vertically upward direction. Find the velocity of A (in m/s) when B loses contact with floor.



MARK YOUR RESPONSE

7. 

8. 

9. 

Answerkey

A SINGLE CORRECT CHOICE TYPE

1	(c)	**8**	(a)	**15**	(c)	**22**	(c)	**29**	(a)	**36**	(d)	**43**	(a)	**50**	(d)	**57**	(b)	**64**	(a)	**71**	(d)
2	(c)	**9**	(d)	**16**	(d)	**23**	(a)	**30**	(b)	**37**	(c)	**44**	(c)	**51**	(d)	**58**	(b)	**65**	(c)	**72**	(b)
3	(a)	**10**	(a)	**17**	(a)	**24**	(c)	**31**	(c)	**38**	(a)	**45**	(a)	**52**	(c)	**59**	(d)	**66**	(d)	**73**	(a)
4	(c)	**11**	(b)	**18**	(d)	**25**	(c)	**32**	(a)	**39**	(b)	**46**	(a)	**53**	(b)	**60**	(c)	**67**	(d)	**74**	(a)
5	(b)	**12**	(c)	**19**	(b)	**26**	(d)	**33**	(a)	**40**	(b)	**47**	(a)	**54**	(b)	**61**	(a)	**68**	(a)		
6	(c)	**13**	(a)	**20**	(c)	**27**	(d)	**34**	(a)	**41**	(a)	**48**	(b)	**55**	(c)	**62**	(b)	**69**	(c)		
7	(a)	**14**	(c)	**21**	(b)	**28**	(b)	**35**	(a)	**42**	(b)	**49**	(d)	**56**	(a)	**63**	(a)	**70**	(b)		

B COMPREHENSION TYPE

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

C REASONING TYPE

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

D MULTIPLE CORRECT CHOICE TYPE

1	(a, b)	**4**	(c, d)	**7**	(a, b, c, d)	**10**	(a, d)	**13**	(b, d)	**16**	(a, b, c)	**19**	(a, b)	**22**	(b, c)
2	(a, c, d)	**5**	(a, b, d)	**8**	(b, c, d)	**11**	(c, d)	**14**	(b, c)	**17**	(c, d)	**20**	(b)	**23**	(a)
3	(a, b, c, d)	**6**	(c, d)	**9**	(a, c)	**12**	(c, d)	**15**	(a, d)	**18**	(c, d)	**21**	(b, d)		

E MATRIX-MATCH TYPE

1. **A - p, s; B - q, r; C - q, r; D - q, r**
2. **A - q; B - r; C - p; D - s**
3. **A - p, s; B - r; C - q, s; D - q, r**
4. **A - q, r; B - r, q; C - p; D - s**
5. **A - s; B - r; C - p, s**
6. **A - q; B - q; C - r; D - s**
7. **A - q; B - p; C - r**
8. **A - r; B - q; C - s; D - p**
9. **A - p, r; B - p, r ; C - q, s ; D - q, s**
10. **A - p, s; B - p, s; C - q, s; D - r**
11. **A - p, q, t; B - s; C - s; D - p, s**
12. **A - s; B - r; C - q; D - r**

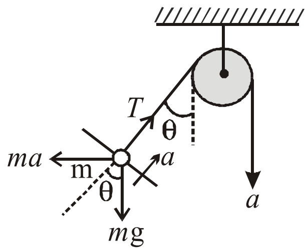
F NUMERIC/INTEGER ANSWER TYPE

1	30	**2**	60	**3**	4	**4**	150	**5**	0.12	**6**	15	**7**	2	**8**	10	**9**	10

Solutions

A SINGLE CORRECT CHOICE TYPE

1. (c)



(Force diagram in the frame of the car)

Applying Newton's law perpendicular to string

$mg\sin\theta = ma\cos\theta$

$\Rightarrow \tan\theta = \frac{a}{g}$

Applying Newton's law along string

$\Rightarrow T - m\sqrt{g^2 + a^2} = ma$

or $T = m\sqrt{g^2 + a^2} + ma$

2. (c) As m would slip in vertically downward direction, then $mg = \mu N$

$\Rightarrow N = \frac{mg}{\mu} = \frac{100}{0.5} = 200$ Newton

Same normal force would accelerated M, thus $a_M = \frac{200}{50} = 4\ m/s^2$

Taking $m + M$ as system

$F = (m + M)\,4 = 240$ N

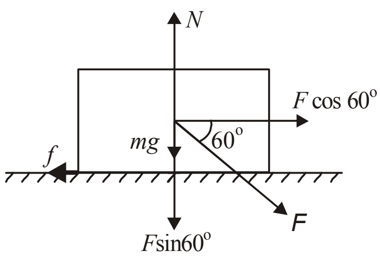
3. (a) The forces acting on the block are shown. Since the block is not moving forward for the maximum force F applied, therefore

$F\cos 60° = f = \mu N$ ... (i) (Horizontal Direction)

For maximum force F, the frictional force is the limiting friction $= \mu N$]

and $F\sin 60° + mg = N$... (ii)

From (i) and (ii)



$F\cos 60° = \mu\,[F\sin 60° + mg]$

$\Rightarrow F = \frac{\mu mg}{\cos 60° - \mu\sin 60°}$

$= \frac{\frac{1}{2\sqrt{3}} \times \sqrt{3} \times 10}{\frac{1}{2} - \frac{1}{2\sqrt{3}} \times \frac{\sqrt{3}}{2}} = \frac{5}{\frac{1}{4}} = 20\ N$

4. (c) Blocks A and C both move due to friction. But less friction is available to A as compared to C because normal reaction between A and B is less. Maximum friction between A and B can be :

$f_{max} = \mu m_A g = \left(\frac{1}{2}\right) mg$

$\therefore$ Maximum acceleration of A can be

$a_{max} = \frac{f_{max}}{m} = \frac{g}{2}$

Further, $a_{max} = \frac{m_D g}{3m + m_D}$

or $\frac{g}{2} = \frac{m_D g}{3m + m_D}$

5. (b) For uniform speed of the blocks

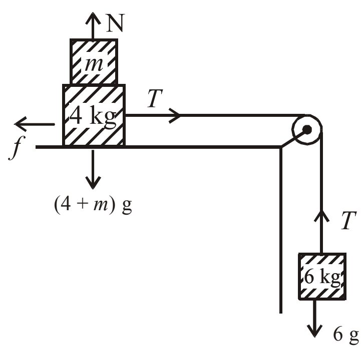
$T = 6g$ ...(i)

$T = f = \mu N$ ...(ii)

$\therefore \quad \mu N = 6g$

or $\quad 0.4\,(4 + m)g = 6g$

$\therefore \quad m = 15 - 4 = 11$ kg



6. **(c)** $F = ma$

$\Rightarrow \quad a = \frac{F}{m} = \frac{5\times10^4}{3\times10^7} = \frac{5}{3}\times10^{-3}\,\text{ms}^{-2}$

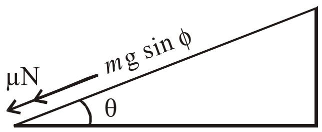
Also, $v^2 - u^2 = 2as$

$\Rightarrow \quad v^2 - 0^2 = 2\times\frac{5}{3}\times10^{-3}\times3 = 10^{-2}$

$\Rightarrow \quad v = 0.1\ \text{ms}^{-1}$

7. **(a)** Here ϕ is the angle of repose.

$\therefore \quad \mu = \tan\phi$



The retardation of the block

$a = \frac{F}{m} = \frac{\mu N + mg\sin\phi}{m}$

$= \frac{\tan\phi\times mg\cos\phi + mg\sin\phi}{m} = 2g\sin\phi$

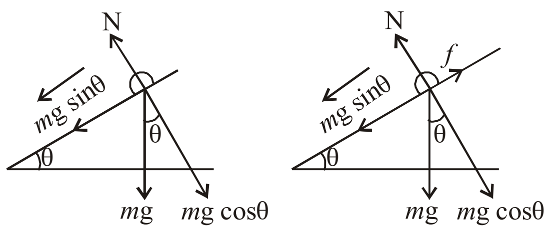
Let s is the distance travelled, then by third equation of motion

$v^2 = u_0^2 - 2as$

or $\quad 0 = u_0^2 - 2\times 2g\sin\phi\times s$

or $\quad s = \frac{u_0^2}{4g\sin\phi}$

8. **(a)**



For smooth surface, $s = \frac{1}{2}g\sin\theta\, t_1^2$ ...(i)

For rough surface, $a = g(\sin\theta - \mu\cos\theta)\, t_2^2$

$\therefore s = \frac{1}{2}g(\sin\theta - \mu\cos\theta)t_2^2$ ...(ii)

From (i) and (ii),

$\therefore s = \frac{1}{2}g\sin\theta\, t_1^2 = \frac{1}{2}g(\sin\theta - \mu\cos\theta)t_2^2$

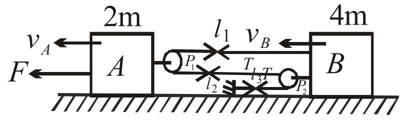
Given, $\theta = 45° \therefore t_1^2 = (1-\mu)t_2^2$

Also, given that, $t_2 = nt_1 \therefore t_1^2 = (1-\mu)n^2t_1^2$

$\frac{1}{n^2} = 1-\mu \qquad \therefore \mu = \left(1 - \frac{1}{n^2}\right)$

9. **(d)** $\ell_1 + \ell_2 + \ell_3 = C$

$\ell_1' + \ell_2' + \ell_3' = 0$



$-v_B + v_A - v_B + v_A - v_B = 0$

$3v_B = 2v_A$

$3a_B = 2a_A$

Applying Newton's law on A and B

$F - 2T = 2m_A$

$3T = 4ma_B$

$3F = (6a_A + 8a_B)\,m$

$3F = (9+8)\,a_B m \Rightarrow a_B = \frac{3F}{17m}$

10. **(a)** The forces acting on the masses are shown.

Applying Newton's second law on mass Q, we get

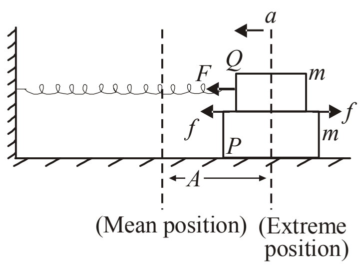
$F - f = ma$ ... (i)

where a is the acceleration at the extreme position. Now applying Newton's second law on mass P

$f = ma$ ... (ii)

[acceleration is same as no slipping occurs between Q and P]

From (i) and (ii)



$F = 2ma \Rightarrow a = \frac{F}{2m} = \frac{kA}{2m} \quad [\because F = kA]$

Substituting this value of a in eq. (ii), we get

$f = m\times\frac{kA}{2m} = \frac{kA}{2}$

Alternatively,

Let ω be the angular frequency of the system.

The maximum acceleration of the system,

$a = \omega^2 A = \left(\frac{k}{2m}\right)A \quad \left[\omega = \sqrt{\frac{k}{m+m}} = \sqrt{\frac{k}{2m}}\right]$

The force of friction provides this acceleration.

$\therefore \quad f = ma$

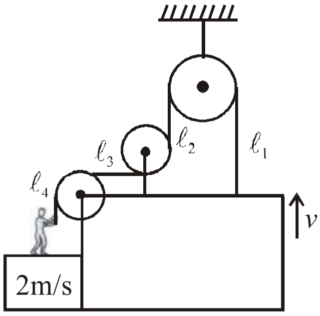
$= m\left(\frac{kA}{2m}\right) = \frac{kA}{2}$

11. **(b)** $\ell_1+\ell_2+\ell_3+\ell_4=C$

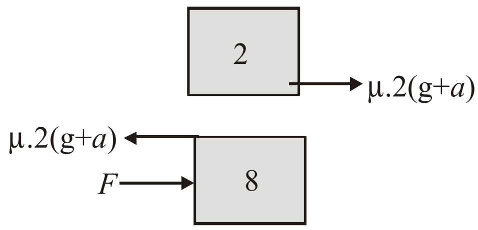
$$\frac{d\ell_1}{dt}+\frac{d\ell_2}{dt}+\frac{d\ell_3}{dt}+\frac{d\ell_4}{dt}=0$$

$-v-v+0+v+2=0$

$v=2$ m/s



12. **(c)** FBD in reference frame of the lift

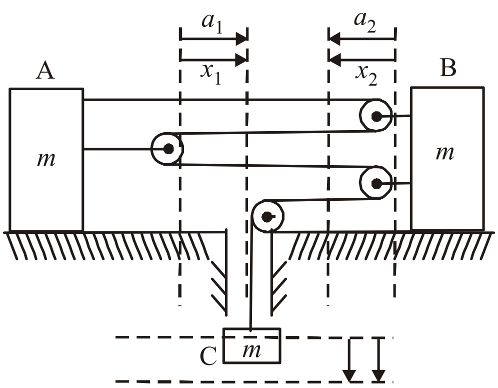


$$a_2=\frac{1}{5}\left(g+\frac{g}{4}\right)=\frac{g}{4}=2.5\ \text{m/s}^2$$

$$a_8=\frac{30-\left[\mu.2\left(g+\frac{g}{4}\right)\right]}{8}$$

$$=\frac{30-\left[\frac{1}{5}\times2\times\frac{50}{4}\right]}{8}=\frac{25}{8}\ \text{m/s}^2$$

13. **(a)**



$x=3x_1+4x_2$

$a=3a_1+4a_2$ ... (1)

$3T=ma_1$ ... (2)

$4T=ma_2$ ... (3)

$mg-T=ma$ ... (4)

From (1), (2), (3) & (4)

$a=2g/13$

14. **(c)** $\frac{m}{2}g-T=\frac{m}{2}a$ ....(i)

$$T\cos60°=\frac{ma}{\cos60°}$$ ...(ii)

Solving (i) and (ii)

acceleration of ring $=\frac{2g}{9}$

15. **(c)** $Mg=n\,m\,v\,(1+e)$

16. **(d)** $\mu\,m\,g=m\,2b\,t$

$$t=\frac{\mu g}{2b}$$

17. **(a)** For no slipping between m and M,

$F\le(M+m)\,g/3$

$F\le40\,N$

For no toppling of m block

$F\le(M+m)\,g/4$

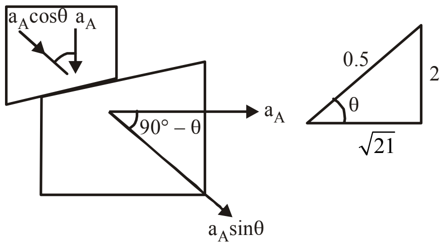
$F\le30$ N

$\therefore F_{min}=30N$

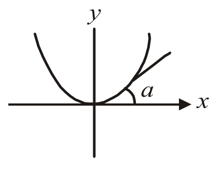
18. **(d)** Perpendicular to surface, their acceleration components must be equal.

$a_A\cos\theta=a_B\sin\theta$

$\sqrt{21}\,a_A=2a_B$



19. **(b)**



$x^2=4a\,(a)$ [since $y=a$]

$x^2=4a^2$

$x=\pm2a$

The slope of curve at point $(2a, a)$

$$m=\tan\theta=\frac{2x}{4a}=\frac{2}{4a}\times2a=1$$

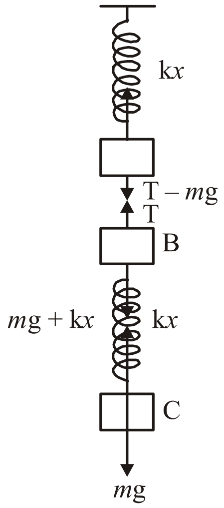
so, tangential acceleration $=g\sin\theta=\frac{g}{\sqrt{2}}$

20. **(c)** $a=b+c$

Net acceleration of A $=\sqrt{a^2+c^2+2ac\cos(\pi-\theta)}$

$=\sqrt{(b+c)^2+c^2-2(b+c).c.\cos\theta}$

21. **(b)** FBD of C $kx = mg$ ... (i)
FBD of B $T = 2\,mg$ ... (ii)
FBD of A $kx = mg + T$ ... (iii)
$kx = 3\,mg$



When string is out T = 0
$kx - mg = ma_A$
$3\,mg - mg = ma_A \Rightarrow a_A = 2\,g$
For B
$T - mg - kx = ma_B$
$-2\,mg = ma_B$
$a_B = -2g$

22. **(c)** The component of the velocity of the block C along the slanted segment of the string equals the velocity of the block B downwards, i.e., $u \cos\theta = v_B$. Differentiating this,

$$-u\sin\theta \cdot \frac{d\theta}{dt} = \frac{dv_B}{dt}$$

Putting the given values,

$$-u\sin 30^\circ \times 1 = \frac{dv_B}{dt}$$

$$\Rightarrow \quad -\frac{u}{2} = -10 \;\Rightarrow\; u = 20 \text{ m/s}$$

23. **(a)** Where the three ropes join, $T_1 \sin\theta_1 = T_2 \sin\theta_2$, so $T_1 = T_2$.
Also, $T_2 = T_3$ and $W_2 = T_3$. Further, the equilibrium condition for the vertical direction is $W_1 = 2T_1 \cos\theta_1$.

Therefore, $T_1 = T_2 = T_3 = W_2 = \dfrac{W_1}{2\cos\theta_1}$

24. **(c)** If the block is not to slide, it must have the same acceleration as the plane.
Hence, $f\cos\alpha - N\sin\alpha = ma$
$f\sin\alpha + N\cos\alpha - mg = 0$
From these,
$f = m\,(a\cos\alpha + g\sin\alpha)$
$N = m\,(g\cos\alpha - a\sin\alpha)$

and $\dfrac{f}{N} = \dfrac{a\cos\alpha + g\sin\alpha}{g\cos\alpha - a\sin\alpha} = \dfrac{a + g\tan\alpha}{g - a\tan\alpha}$

Now the maximum value of f/N in the absence of slipping is $\mu_s = \tan\theta$. Thus the acceleration a must satisfy $\dfrac{a + g\tan\alpha}{g - a\tan\alpha} \le \tan\theta$

or $\quad a \le g\,\dfrac{\tan\theta - \tan\alpha}{1 + \tan\theta\tan\alpha} = g\,\tan(\theta - \alpha)$

If $a > g\tan(\theta - \alpha)$ the block will slide.

25. **(c)** Since impulse would have been same

$\int F\,dt$ = constant and as time interval increases.

$\therefore$ average force decreases.

26. **(d)** When all are pulling

$\vec{F}_{net} = 100 \times 3\hat{i}$ .... (1)

When A stops

$\vec{F}_{net} - \vec{F}_A = 100 \times 1\,(-\hat{i})$ .... (2)

When B stops

$\vec{F}_{net} - \vec{F}_B = 100 \times 24\hat{j}$ .... (3)

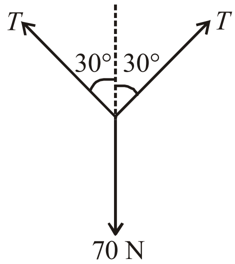
From these three we get

$\vec{F}_A + \vec{F}_B = 100\left(7\hat{i} - 24\hat{j}\right)$

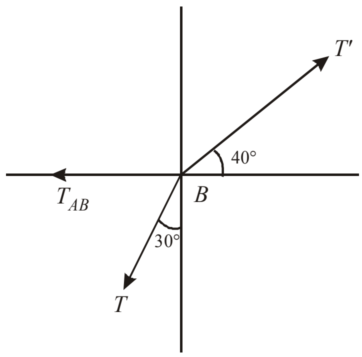
$\therefore$ Required $acc^n = \sqrt{7^2 + (-24)^2}$

$= 25 \text{ m/s}^2$

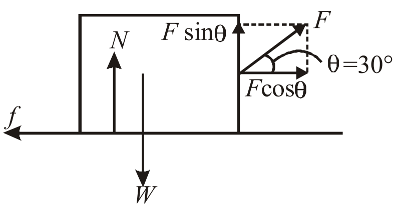
27. **(d)** First find the tension in the cords below the cord in question by balancing forces at the lower junction in figure: $2T\cos 30^\circ = 70$, so $T = 40.4$ N.



Equilibrium conditions for junction B (figure) are
$T'\cos 40^\circ = T_{AB} + T\sin 30^\circ$.
$T'\sin 40^\circ = T\cos 30^\circ$.
Solving above equations, $T_{AB} = 21.5$ N



28. **(b)** First draw a force diagram.



Next, consider the forces in the x-direction and apply the conditions for equilibrium, noting f equals its maximum value to start motion.

$\Sigma F_x = 0$, $F\cos\theta - f = 0$

$F\cos\theta = f$; $0.0866\,F = f = \mu_s N = 0.4$ N

Now apply the conditions for equilibrium to the forces in y-direction

$\Sigma F_y = 0$, $N + F\sin\theta - W = 0$

$N + 0.5\,F - 100 = 0$

$N = 100 - 0.5\,F$

Substituting this equation for N in

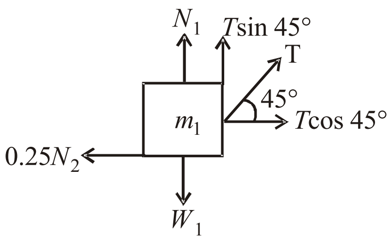
$0.866\,F = 0.4$ N above,

$0.866\,F = 0.4\,(100 - 0.5\,F)$

$0.866\,F + 0.2\,F = 40$

$F = 37.5$ N

29. **(a)**



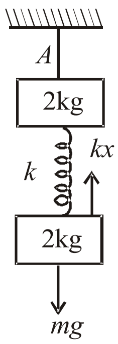
For m_1 :

$N_1 + T\sin 45° = 200$ .... (1)

$T\cos 45° = 0.25\,N_1$ .... (2)

$\Rightarrow T = 40\sqrt{2}$ N

30. **(b)** Before the string A is cut : Let x be elongation in the spring. As system is in equilibrium. Then for lower block,

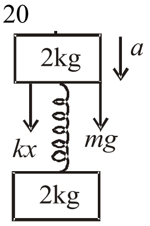


$kx = mg = 20$N

Just after the string A is cut : For upper block,

$ma = kx + mg$

$2a = 20 + 20$



$a = 20$ m/s^2

31. **(c)** The *FBD* of blocks is as shown

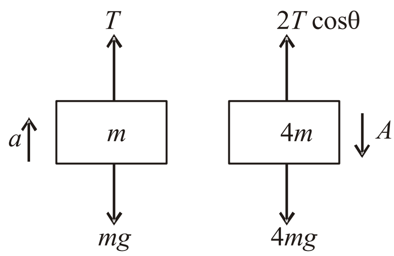
From Newton's second law

$4mg - 2T\cos\theta = 4mA$ .... (1)

and $T - mg = ma$ .... (2)

$\cos\theta = 4/5$ and from constraint we get

$a = A\cos\theta$ .... (3)

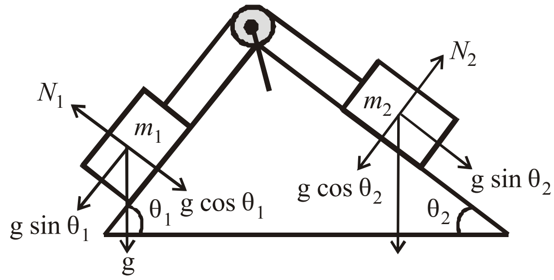


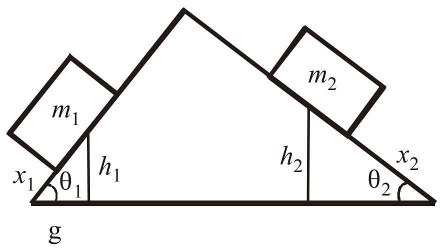
Solving eq. (1), (2) and (3)

we get acceleration of block of mass 4m,

$A = \dfrac{5g}{11}$ downwards.

32. **(a)** Acceleration of bodies of masses m_1 and m_2 are $g\sin\theta_1$ and $g\sin\theta_2$ respectively down the plane.





Time taken by body of mass m_1 is given by

$$t_1 = \sqrt{\frac{2x_1}{a_1}} = \sqrt{\frac{2\times h_1 \operatorname{cosec}\theta_1}{g\sin\theta_1}}$$

$$= \sqrt{\frac{2\times 1\times \operatorname{cosec}60°}{10\times \sin 60°}}$$

$$= \sqrt{\frac{2\times 2\times 2}{10\times\sqrt{3}\times\sqrt{3}}} = \sqrt{\frac{8}{30}}$$

$$= \sqrt{\frac{4}{15}} = 0.51 \text{ sec.}$$

Time taken by body of mass m_2 is given by

$$t_2 = \sqrt{\frac{2x_2}{a_2}} = \sqrt{\frac{2\times h_2 \operatorname{cosec}\theta_2}{g\sin\theta_2}}$$

$$= \sqrt{\frac{2\times 1\times \operatorname{cosec}30°}{10\times \sin 30°}}$$

$\sqrt{\frac{2\times2\times2}{10\times1}} = 0.89$ sec.

It is clear that the body with mass m_1 will reach the bottom of wedge first.

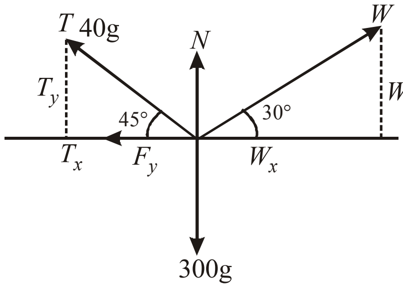
Alternatively,

The vertical component of acceleration of mass 1 and mass 2 are

$a_1 = g\sin^2 60°$, $a_2 = g\sin^2 30°$

Since vertical displacement for both masses is 1m, the block with larger acceleration will reach the base of wedge first. Hence block of mass m_1 shall reach base of wedge first.

33. **(a)** From the force diagram figure,



$T_x = (40\cos 45°) = 28.3$g

$T_y = (40\sin 45°) = 28.3$g

$\Sigma F_y = 0$, $T_y + W_y + N - 300\text{g} = 0$

$28.3\text{g} + W\sin 30° + N = 300\text{g}$

$N = 300\text{g} - 28.3\text{g} - 0.5W$

$\Sigma F_x = 0$, $W_x - T_x - \mu_s N = 0$

$\mu_s = 0.3$

$W\cos 30° - 28.3\text{g} - 0.3N = 0$

Substitute $N = 271.7\text{g} - 0.5W$

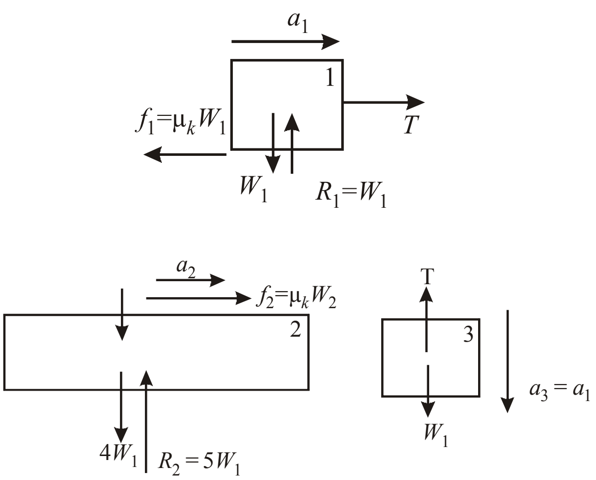
Solving for W gives W = 108kg

34. **(a)** From figure, the equations of motion are

$\Sigma F_1 = T - \mu_k W_1 = ma_1$

$\Sigma F_2 = \mu_k W_1 = 4ma_2$

$\Sigma F_3 = W_1 - T = ma_1$



Solve the first and third equations simultaneously to get $a_1 = (g/2)(1 - \mu_k)$, from the second equation, $a_2 = (g/4)\mu_k$. Then the displacements of blocks 1 and 2 are given by

$x = \frac{1}{2}at^2$, i.e., $x_1 = \frac{g}{4}(1-\mu_k)t^2$, $x_2 = \frac{g}{8}\mu_k t^2$

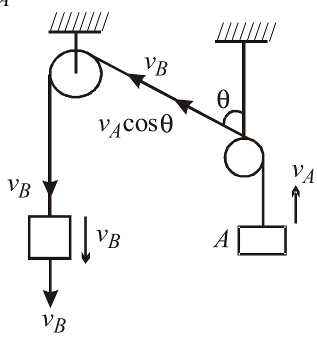
At the instant that one-fourth of block 1 remains on block 2, $x_2 + \ell = x_1 + (\ell/16)$, where ℓ is the length of block 2. Therefore, $\frac{g}{8}\mu_k t^2 \quad \ell \quad \frac{g}{4}(1-\mu_k)t^2 \quad \frac{\ell}{16}$

or $t^2 \quad \frac{15\ell}{2g(2-3\mu_k)}$

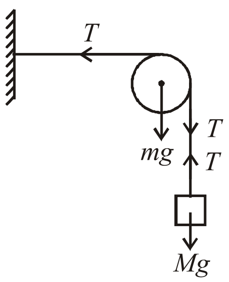
and $x_2 = \left(\frac{g}{8}\mu_k\right)\frac{15\ell}{2g(2-3\mu_k)} \quad \frac{15\mu_k}{16(2-3\mu_k)}$

$\ell \quad \frac{1}{7.47}$

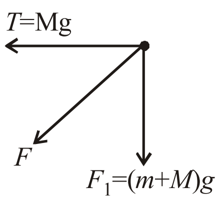
35. **(a)** $v_B = v_A\cos\theta$.



36. **(d)** At equilibrium $T = Mg$



F.B.D. of pulley



$F_1 = (m+M)g$

The resultant force on pulley is

$F = \sqrt{F_1^2 \quad T^2}$

$F = [\sqrt{(m \quad M)^2 \quad M^2}\,]g$

37. (c) Acceleration of mass at distance x

$a = g(\sin\theta - \mu_0 x\cos\theta)$

Speed is maximum, when $a = 0$

$g(\sin\theta - \mu_0 x\cos\theta) = 0$

$$x = \frac{\tan\theta}{\mu_0}$$

38. (a) $N_{AB}\sin\theta = mg$

$$N_{AB}\frac{4}{5} = 100\text{N} \Rightarrow N_{AB} = 125\text{N}$$

39. (b) At time t, let y be the height (in meters) of the body above its initial position. The pull in the chain is then

$T = (6000 - 360y)\,g$ and Newton's second law gives

$$T - 400g = 400\frac{d^2y}{dt^2}$$

$$\text{or } (5600 - 360y)g = 400\frac{d^2y}{dt^2}$$

The equation may be changed into one for $\frac{dy}{dt} = v$ (the velocity of the body) by use of the identity

$$2\frac{d^2y}{dt^2} = 2\frac{dv}{dt} = 2\frac{dv}{dy}\frac{dy}{dt} = 2v\frac{dv}{dy} = \frac{d(v^2)}{dy}$$

$$\text{Thus } 200\frac{d(v^2)}{dy} = (5600 - 360y)\,g$$

or $d(v^2) = g(28 - 1.8y)\,dy$

Let v be the velocity at height 10m.

Then, on integrating

$$\int_0^{v^2} d(v^2) = g\int_0^{10}(28 - 1.8y)\,dy$$

$$v^2 = g\,[28y - 0.9y^2]_0^{10}$$

$$= g\,[28(10) - 0.9(100)] = 190\text{g}$$

$$v = +\sqrt{190\text{g}} = +43.2 \text{ m/s}$$

The choice of the +sign for v (upward motion) should be checked. For $0 \le y \le 10$, the net force, $(5600 - 360y)$ g, is positive, and so the acceleration is positive. Then, since the body started from rest, v must be positive.

40. (b) String is light so speed of A = speed of B.

41. (a) As long as the block of mass m remains stationary, the block of mass M released from rest comes down by $\frac{2Mg}{k}$ (before coming it rest momentarily again). Thus the maximum extension in the spring is

$$x = \frac{2Mg}{k} \qquad \text{.......... (1)}$$

For block of mass m to just move up the incline

$$kx = mg\sin\theta + \mu\, mg\cos\theta \qquad \text{.......... (2)}$$

$$2Mg = mg\times\frac{3}{5} + \frac{3}{4}mg\times\frac{4}{5} \quad \text{or} \quad M = \frac{3}{5}m$$

42. (b) Let L_1 and L_2 be the portions (of length) of rope on left and right surface of wedge as shown.

$\therefore$ Magnitude of acceleration of rope

$$a = \frac{\frac{M}{L}(L_1\sin\alpha - L_2\sin\beta)g}{M} = 0$$

$$(\because L_1\sin\alpha = L_2\sin\beta)$$

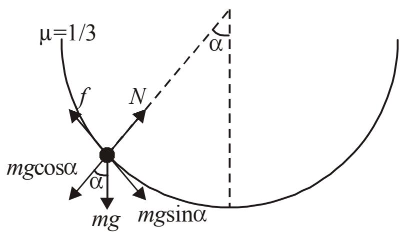
43. (a) For the maximum possible value of α,

$mg\sin\alpha$ will also be maximum.

In this case f is the limiting friction. The two forces acting on the insect are mg and N. Let us resolve mg into two components.

$mg\cos\alpha$ balances N.

$mg\sin\alpha$ is balanced by the frictional force.



$\therefore \quad N = mg\cos\alpha$

$f = mg\sin\alpha$ But $f = \mu N = \mu\, mg\cos\alpha$

$\therefore \quad \mu\, mg\cos\alpha = mg\sin\alpha$

$$\Rightarrow \cot\alpha = \frac{1}{\mu}$$

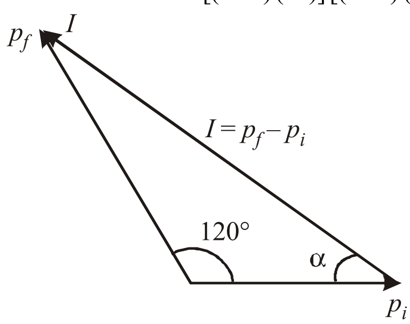
$\Rightarrow \cot\alpha = 3$

44. (c) The impulse is $\vec{I} = \vec{F}\Delta t$. The impulse momentum relation is shown in figure.

From the law of cosines,

$$I^2 = p_i^2 + p_f^2 - 2p_ip_f\cos 120°$$

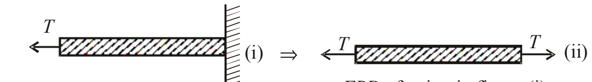
$$= [(0.11)(17)]^2 + [(0.11)(34)]^2 - 2[(0.11)(17)][(0.11)(34)](-0.5)$$



$$I = (0.11)(17)(\sqrt{7}) = 4.974 \text{ Ns}$$

$$\text{and } \vec{F} = \frac{I}{\Delta t} = \frac{4.947}{0.025} = 197.90 \text{ N}$$

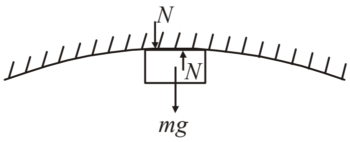
observed by making FBD of string in figure (i)



FBD of string in figure (i)

46. **(a)** $T = T_1 + T_2 = m_1(g+a) + m_2 g$
$= 10(10+2) + 8(10) = 120 + 80 = 200\text{N}$

47. **(a)** Since the body presses the surface with a force N hence according to Newton's third law the surface presses the body with a force N. The other force acting on the body is its weight mg.



For circular motion to take place, a centripetal force is required which is provided by $(mg + N)$.

$\therefore \quad mg + N = \dfrac{mv^2}{r}$

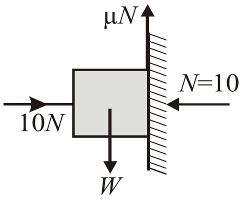
where r is the radius of curvature at the top.
If the surface is smooth then on applying conservation of mechanical energy, the velocity of the body is always same at the top most point. Hence, N and r have inverse relationship. From the figure it is clear that r is minimum for first figure, therefore N will be maximum.
If we do not assume the surface to be smooth, we cannot reach to a conclusion.

48. **(b)** $T_2 \sin\theta + T_1 \sin 60° = W$
$T_1 \cos 60° = T_2 \cos\theta$
$T_2 \sin\theta + T_2 \cos\theta \,.\, \tan 60° = W$
$T_2(\sin\theta + \sqrt{3}\cos\theta) = W$
$2T_2(\sin 30° \sin\theta + \cos 30° \cos\theta) = W$
$\cos(30° - \theta)$ is maximum
If $30° - \theta = 0$; $\theta = 30°$

49. **(d)** No relative motion $\Rightarrow$ no force.

50. **(d)** Total stretch $= \dfrac{Mg}{k_1} + \dfrac{Mg}{k_2} = Mg\left(\dfrac{k_1+k_2}{k_1k_2}\right)$

51. **(d)**



$W = \mu N$; $W = 0.2(10)$; $W = 2$

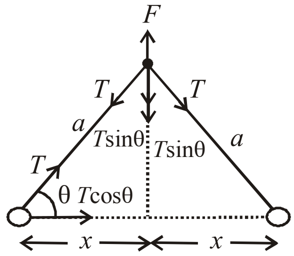
52. **(c)** For constant speed $\Rightarrow$ ext. force = frictional force (max.)
$F_{ext} = F_{max} = \mu R$

$\therefore \quad T\cos\theta = ma$

$\Rightarrow \quad a = \dfrac{T\cos\theta}{m}$ ... (i)

also, $F = 2T\sin\theta$

$\Rightarrow \quad T = \dfrac{F}{2\sin\theta}$ ... (ii)



From (i) and (ii)

$$a = \left(\frac{F}{2\sin\theta}\right)\frac{\cos\theta}{m} = \frac{F}{2m\tan\theta} = \frac{F}{2m}\frac{x}{\sqrt{a^2-x^2}}$$

$$\left[\because \tan\theta \frac{\sqrt{a^2-x^2}}{x}\right]$$

54. **(b)** $4TX_A = TX_B$; $4v_A = v_B$; $v_A = v/4$

55. **(c)** $\dfrac{1}{2}\left(\dfrac{u}{\cos\theta} + \dfrac{v}{\cos\theta}\right) = \dfrac{u+v}{2\cos\theta}$

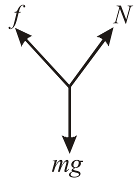
56. **(a)** $T\cos\theta - f = ma$
$f = \mu N$
$T\sin\theta + N = mg$

57. **(b)** Let $m_1 + m_2 = m$ = constant and
$m_1 = x \Rightarrow m_2 = m - x$

$a = \dfrac{x - (m-x)}{m} g$

$T = \dfrac{2x(m-x)}{m} g \Rightarrow T = \dfrac{m}{2g}(g^2 - a^2)$

58. **(b)**



Total force $\vec{f} + \vec{N}$; $f = mg\sin\theta$; $N = mg\cos\theta$

Total force $= \sqrt{mg(\cos\theta)^2 + (mg\sin\theta)^2} = mg = 10\text{N}$

59. **(d)** $\vec{p}(t) = A[\hat{i}\cos(kt) - \hat{j}\sin(kt)]$

$$\vec{F} = \frac{d\vec{p}}{dt} = Ak\,[-\hat{i}\sin(kt) - \hat{j}\cos(kt)]$$

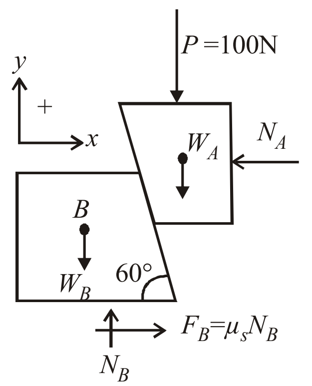
$$\vec{F}.\vec{P} = 0$$

$$\vec{F}.\vec{p} = Fp\cos\theta$$

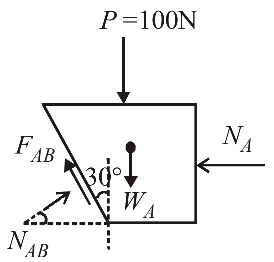
But $\vec{F}.\vec{p} = 0 \Rightarrow \cos\theta = 0$

$\Rightarrow \theta = 90°$.

60. **(c)** Given : $m_A = 10$ kg, $W_A = m_A g = 98$ N, $m_B = 50$ kg
$\therefore W_B = 50 \times 9.8 = 490$ N
$\mu_s = 0$ between wall and block A
$P = 100$ N (vertically downward)
FBD of system and FBD of block A are shown in figure:
Since slip is impending, we can use $F = \mu_s N$
From FBD of combined system :



$\Sigma F_y = 0 : N_B - P - W_A - W_B = 0$
$N_B = 100 + 98 + 490 = 688$ N
$\Sigma F_x = 0 : N_A - F_B = 0$
$N_A = F_B = \mu_s N_B$
$= 688\,\mu_s$ .... (1)
From FBD of block A :
Equilibrium equations yield $\Sigma F_y = 0$
$F_{AB}\cos 30° + N_{AB}\sin 30° - P - W_A = 0$
where F_{AB} is the frictional force between blocks A and B.



$$F_{AB}\frac{\sqrt{3}}{2} + \frac{N_{AB}}{2} - 100 - 98 = 0$$

$$\frac{\sqrt{3}F_{AB}}{2} + \frac{N_{AB}}{2} = 198 \qquad \text{........... (2)}$$

$\Sigma F_x = 0, N_{AB}\cos 30° - N_A - F_{AB}\sin 30° = 0$

$$\frac{N_{AB}\sqrt{3}}{2} - 688\mu_s - \frac{F_{AB}}{2} = 0$$

Also $\mu_s = \dfrac{F_{AB}}{N_{AB}}$ (by definition)

Using (2) and (3), we get

$$\frac{\sqrt{3}N_{AB} - F_{AB}}{N_{AB} + \sqrt{3}F_{AB}} = \frac{344\mu_s}{99}$$

or $\dfrac{\sqrt{3} - \mu_s}{1 + \sqrt{3}\mu_s} = \dfrac{344\mu_s}{99}$

or $344\sqrt{3}\,\mu_s^2 + 344\mu_s = 99\sqrt{3} - 99\mu_s$

or $595.8\,\mu_s^2 + 443\,\mu_s - 171.5 = 0$

$$\therefore \mu_s = \frac{-443 \pm [(443)^2 - 4\,(595.8)\,(-171.5)]^{1/2}}{2 \times 595.8}$$

$$= \frac{-443 \pm 874}{1191.6} = \frac{431}{1191.6} \text{ (taking positive sign)}$$

$\mu_s = 0.362$

61. **(a)** The acrobat has a force acting on his hand that we resolve into two perpendicular components: the vertical one is the reaction to the weight (115×9.8 N $= 1127$ N) and the horizontal one balances the 130 N force from the wall. These two forces give a resultant force F of

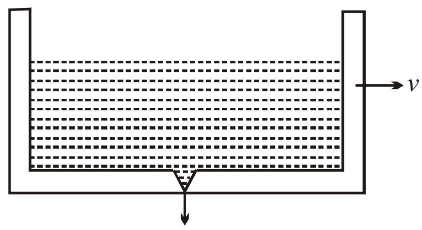
$$F = \sqrt{1127^2 + 130^2} = 1134 \text{ N}$$

62. **(b)** $\dfrac{dy}{dx} = \dfrac{x}{10} = \tan\theta$; $\mu N\cos\theta = N\sin\theta$.

$\tan\theta = \mu = \dfrac{1}{2} \Rightarrow x = 5\text{m} \Rightarrow y = \dfrac{25}{20} = 1.25\text{m}$

63. **(a)** Tension will balance the weight.

64. **(a)**



$F_{thrust} + F_{ext} = m\dfrac{dv}{dt}$; $F_{ext} = 0$

$F_{thrust} = u_{rel} \times \dfrac{dm}{dt}$ and

As $u_{rel} = 0 \Rightarrow F_{thrust} = 0$

$\Rightarrow \dfrac{mdv}{dt} = 0$

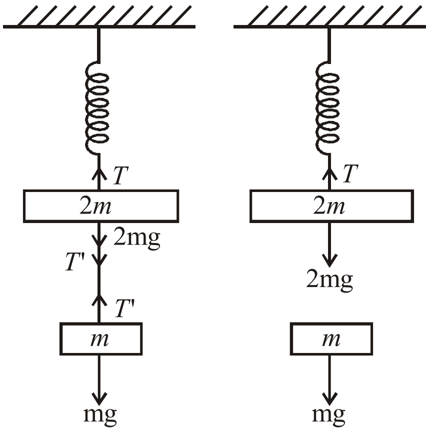
$\Rightarrow$ constant velocity.

65. **(c)** Just before the string is cut by equilibrium of mass m,

$T' = \text{mg}$ ... (i)

By equilibrium of mass $2m$, $T = 2mg + T'$ ... (ii)

From (i) and (ii), $T = 2mg + mg = 3mg$ ... (iii)



Situation 1 Situation 2

When the string is cut :

For mass m :

$$F_{\text{net}} = ma_m \Rightarrow mg = ma_m \Rightarrow a_m = g \text{ (downwards)}$$

For mass $2m$:

$$F_{\text{net}} = 2ma_{2m}$$

$$\Rightarrow 2mg - T = 2ma_{2m}$$

$$\Rightarrow 2mg - 3mg = 2ma_{2m} \Rightarrow a_{2m} = \frac{-g}{2}$$

The negative sign indicates that the acceleration is in upwards direction.

Alternatively,

In situation 1, the tension T has to hold both the masses $2m$ and m therefore,

$T = 3mg$

In situation 2, when the string is cut, the mass m is a freely falling body and its acceleration due to gravity is g.

For mass $2m$, just after the string is cut, T remains $3mg$ because of the extension of string (or otherwise it would quickly changed to $2mg$).

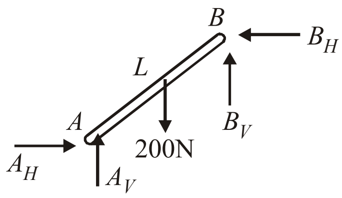
$\therefore$ $3mg - 2mg = 2m \times a$

$\therefore$ $\frac{g}{2} = a$

66. **(d)** Since the ball is moving upwards at a constant velocity, the net force acting on it is zero. The only forces are gravity and the force of the rope. These must be equal and opposite.

67. **(d)** This is an example of Newton's Third Law of Motion.

68. **(a)** Consider FBD of structure.

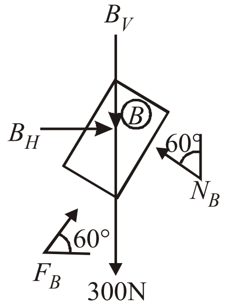


Applying equilibrium equations,

$Av + Bv = 200$ N .... (1)

$A_H = B_H$ .... (2)

From FBD of block B,



$B_H + F_B \cos 60° - N_B \sin 60° = 0$

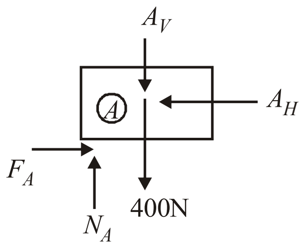
$N_B \cos 60° - B_V - 300 + F_B \sin 60° = 0$

$F_B = 0.25\, N_B$

$B_H - 0.74\, N_B = 0$ .... (3)

$-B_V + 0.71\, N_B = 300$ .... (4)

FBD of block A



$F_A - A_H = 0$

$N_A - A_V = 400$ .... (5)

$F_A = \mu_A N_A$

$\therefore \mu_A N_A - A_H = 0$ .... (6)

On solving above equations, we get

$N_A = 650$ N, $F_A = 260$N, $F_A = \mu_A N_A$

$$\therefore \mu_A = \frac{260}{250} = 0.4$$

69. **(c)** At $t = 0$, $f_r = \text{mg} \sin\theta$

when $kt = \text{mg} \sin\theta$, $f_r = 0$

$$\frac{mg \sin\theta}{k} < t < \frac{mg \sin\theta + \mu mg \cos\theta}{k}$$

Frictional force increases,

$$t > \frac{mg \sin\theta + \mu mg \cos\theta}{k}$$

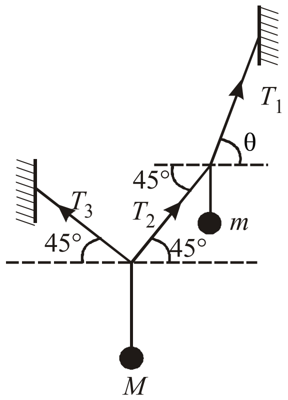
$f_r = \mu \text{ mg} \cos\theta$ = constant

70. **(b)** $T_1 \cos\theta = T_2 \cos 45°$

$T_2 \cos 45° = T_3 \cos 45°$

$T_1 \sin\theta = T_2 \sin 45° + mg$

$T_2 \sin 45° + T_3 \sin 45° = Mg$

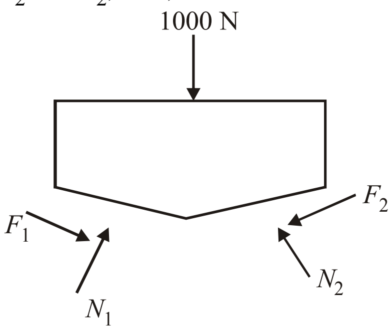


$\Rightarrow T_2 = T_3 = \dfrac{Mg}{\sqrt{2}}$

$T_1 \cos\theta = \dfrac{Mg}{2}$,

$T_1 \sin\theta = \dfrac{Mg}{2} + mg \Rightarrow \tan\theta = \left(1 + \dfrac{2m}{M}\right)$

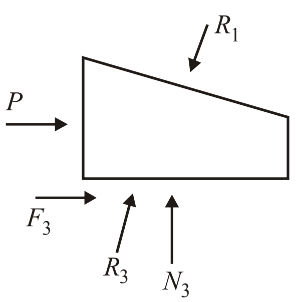
71. **(d)** Consider FBD of block.
We can write from force polygon as follows :
Consider R_1 as resultant of F_1, N_1 and R_2 as resultant of F_2 and N_2, then,



$\dfrac{R_1}{\sin 25°} = \dfrac{1000}{\sin 130°}$

$\therefore R_1 = R_2 = 551.7$ N

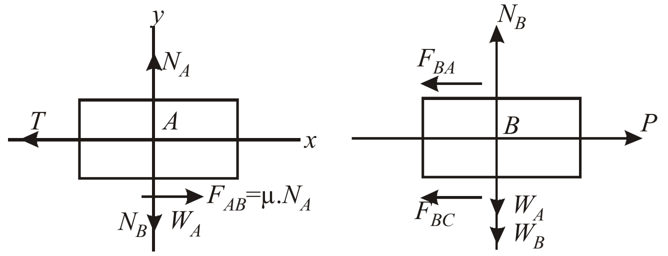
Consider FBD of wedge, $F_3 = \mu N_3$,
Resultant of F_3 & N_3 is R_3.



Applying equilibrium equations we get
$R_1 \cos 25° = R_3 \cos 10°$
$\Rightarrow R_3 = 507.72$ N

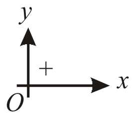
Also we can write,
$P = R_1 \sin 25° + R_3 \sin 10°$
$= 551.7 \times \sin 25° + 507.72 \times \sin 10°$
$= 321.32$ N

72. **(b).**



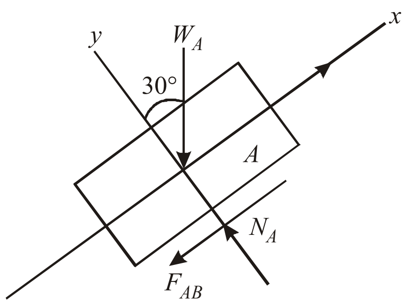
FBD of block *A* FBD of block *B*

The FBD of block *A* and block *B* shown in figure. Taking sign convention for force system as



Consider FBD of block A
The equilibrium equation for block A yields :
$\Sigma F_x = 0;\ T - \mu N_A = 0$
or $T = \mu N_A = 0.3 \times N_A$ .... (1)
$\Sigma F_y = 0;\ N_A - W_A = 0$
$N_A = W_A = M_A g$
$N_A = 29.4$ N .... (2)
$\therefore\ T = 8.82$ N
Considering FBD of block *B* :
Equilibrium equation for block B yields :
$\Sigma F_x = 0;\ P - F_{AB} - F_{BC} = 0$
or $P - \mu.N_A - \mu N_B = 0$
$P = \mu (N_A + N_B)$
$P = 0.3\,(29.4 + N_B)$ .... (3)
$\Sigma F_y = 0;\ N_B = N_A + W_B$
$N_B = W_A + W_B$
$N_B = 29.4 + 5 \times 9.8$
$N_B = 78.4$ N .... (4)
Putting value of $N_B = 78.4$ N in (3) we get
$P = 0.3\,(29.4 + 78.4)$ N $= 32.34$ N

73. **(a)** For the impending motion, block *A* must slip up and block *C* down the inclined plane. Since the normal force between *A* and *B* is less than that between block *B* and *C*, the maximum frictional force (limiting friction) will be reached first between *A* and *B* while *B* and *C* will stay together.
From FBD of block A :



Writing equilibrium equations :

$\Sigma F_y = 0$;

$N_A - W_A \cos 30° = 0$

$N_A = W_A \cos 30°$

$N_A = 20\sqrt{3}\text{N}$

Also for impending motion if F_{AB} is frictional force between blocks A and B, then

$$F_{AB} = \mu_s . N_A = 20\sqrt{3}\ \mu_s N \qquad \text{.........(1)}$$

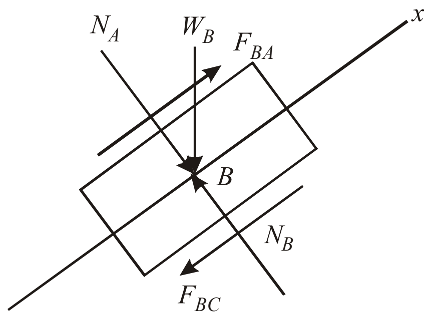
$\Sigma F_x = 0$:

$T - W_A \sin 30° - F_{AB} = 0$

$$T - 40.\frac{1}{2} - 20\sqrt{3}\mu_s = 0$$

$$T = 20\,(1 + \sqrt{3}\mu_s) \qquad \text{.........(2)}$$

From FBD of block B and C combined



Writing equilibrium equation

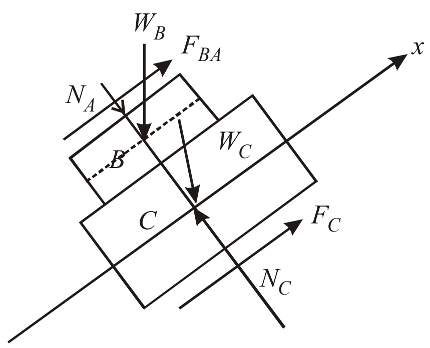
$\Sigma F_y = 0$;

$N_C - N_A - (W_B + W_C) \cos 30° = 0$

$$N_C - 20\sqrt{3} - 110.\frac{\sqrt{3}}{2} = 0$$

$N_C = 75\sqrt{3}$ N

Also for impending motion :



$$F_C = \mu_s . N_C = 75\sqrt{3}\ \mu_s \qquad \text{.........(3)}$$

For $\Sigma F_x = 0$, we have

$T_A + (F_{BA} + F_C) - (W_B + W_C) \sin 30° = 0$

$$T + [20\sqrt{3} + 75\sqrt{3}\mu_s] - \frac{110}{2} = 0$$

$T = (55 - 95\sqrt{3}\mu_s)$

Since tension is same, so from (2) and (4), we get

$20\,(1 + \sqrt{3}\mu_s) = (55 - 95\sqrt{3}\ \mu_s)$

Solving for μ_s we get, $115\sqrt{3}.\mu_s = 35$

or $$\mu_s = \frac{35}{115\sqrt{3}} = 0.1757$$

$\therefore$ Minimum $\mu_s = 0.1757$

74. (a)

Free body diagram at start

Free body diagram when $a = 0$

$m_1 g - F_c = m_1 a$; $F_c = m_1\,(g - a)$

$F_c - m_2 g = 0$; $F_c = m_2 g$

$m_1\,(g - a) = m_2 g$

$$m_2 = \frac{m_1 (g - a)}{g} = 50.8 \text{ kg} \ ; \ \Delta m = 9.2 \text{ kg}$$

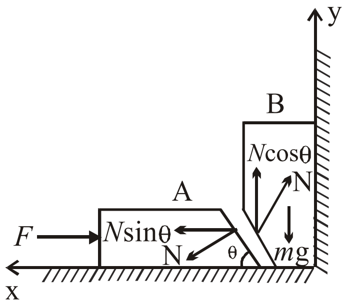
B COMPREHENSION TYPE

1. (c) For equilibrium of block (A)

$F = N \sin\theta$.

$N = F/\sin\theta$.

To lift block B from ground



$N\cos\theta \geq mg$

$F \geq mg\tan\theta = mg\left(\frac{3}{4}\right)$

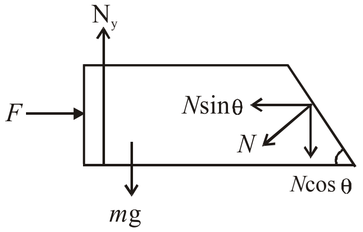
So $F_{\min} = \frac{3}{4}mg$

2. (c) If both the blocks are stationary,
Balancing forces along x-direction

$F = N\sin\theta \Rightarrow N / F\sin\theta$

Balancing forces along y-direction

$N_y = mg + N\cos\theta$



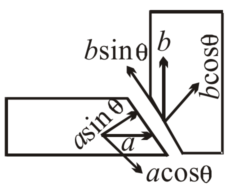
$= mg + \left(\frac{F}{\sin\theta}\right)\cos\theta = mg + F\cot\theta$

$N_y = mg + \frac{4F}{3}$

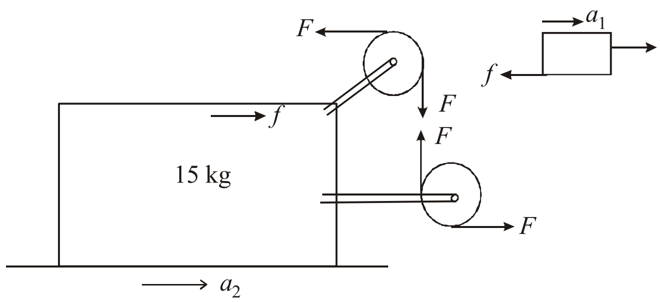
3. (a) To keep regular contact

$a\sin\theta = b\cos\theta$

$b = a\tan\theta = \frac{3}{4}a$



4. (a) First, let us check upto what value of F, both blocks move together. Till friction becomes limiting, they will be moving together. Using the FBDs



10 kg block will not slip over the 15 kg block till acceleration of 15 kg block becomes maximum as it is created only by friction force exerted by 10 kg block on it.

$a_1 > a_{2(\max)}$

$\frac{F-f}{10} = \frac{f}{15}$ for limiting condition as f maximum is 60N.

$F = 100$ N

Therefore for $F = 80$N, both will move together.

Their combined acceleration, by applying NLM using both as system, $F = 25a$

$a = \frac{80}{25} = 3.2\ \text{m/s}^2$

5. (b) See explanation of previous question.

6. (b) If $F = 120$N, then there will be slipping, so using FBDs of both (friction will be 60 N)

For 10 kg block,

$120 - 60 = 10a$

$\Rightarrow a = 6\ \text{m/s}^2$.

For 15 kg block,

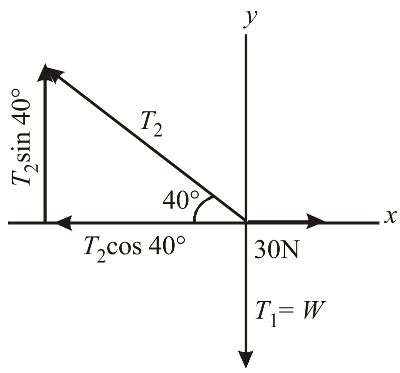
$60 = 50a$

$\Rightarrow a = 4\ \text{m/s}^2$.

7. (a) The tension in cord 1 is equal to the weight of the object hanging from it. Therefore, $T_1 = W$, and we wish to find T_1 or W.

Note that the unknown force, T_1, and the known force, 30N, both pull on the knot at point P. It, therefore, makes sense to isolate the knot at P as our object.

The free-body diagram showing the force on the knot is drawn as given in figure. The force components are also found there.



Next write the first condition for equilibrium for the knot. From the free body-diagram,

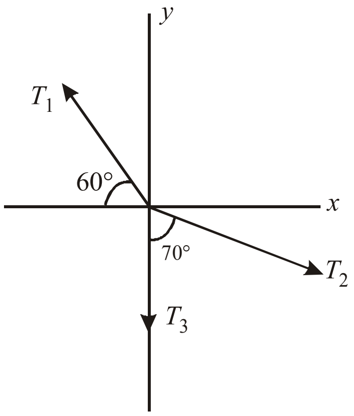
$\Sigma F_x = 0$ becomes $30N - T_2 \cos 40° = 0$

$\Sigma F_y = 0$ becomes $T_2 \sin 40° - W = 0$

Solving the first equation for T_2 gives T_2 = 39.2 N. Substituting this value in the second equation gives W = 25.2 N as the weight of the object.

8. **(b)** The knot is in equilibrium under the action of three forces, and the free-body diagram is as shown in figure (b).

$T_3 = W = 40$ N.



$\Sigma F_x = 0$

$\Rightarrow$ $T_2 \sin 70° - T_1 \cos 60° = 0$

or $(0.940)\, T_2 = (0.500)\, T_1$, $T_1 = 1.88\, T_2$

$\Sigma F_y = 0$

or $T_1 \sin 60° - T_2 \cos 70° - T_3 = 0$

or $(0.866)\, T_1 - (0.342)\, T_2 = T_3 = 40$ N

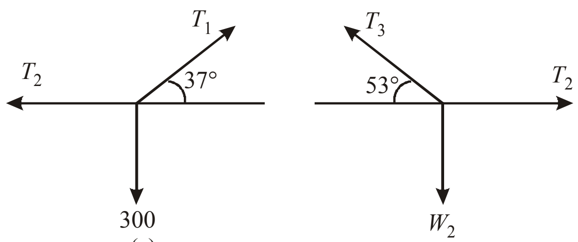
Substituting for T_1,

$(0.866)(1.88\, T_2) - (0.342)\, T_2 = 40$N

$1.29\, T_2 = 40$ N,

$T_2 = 31.0$ N and $T_1 = (1.88)(31.0) = 58.3$ N

9. **(a)** From figure (a), $T_1 \sin 37° = 300$ so $T_1 = 500$N.



(a) (b)

Also $T_2 = T_1 \cos 37° = 400$ N.

From figure (b),

$T_3 \sin 53° = T_2$ so $T_3 = 670$ N.

But $T_3 \sin 53° = W_2$ so $W_2 = 530$ N.

10. **(a), 11. (b), 12. (a).**

Mass B will rise and mass A will fall. You can see this by noting that the forces acting on pulley P_2 are $2T_2$ up and T_1 down. Therefore, $T_1 = 2T_2$ (the inertialess object transmits the tension). Twice as large a force is pulling upward on B as on A.

Let a = downward acceleration of A.

Then $\frac{1}{2}a$ = upward acceleration of B.

[As the cord between P_1 and A lengthens by 1 unit, the segments on either side of P_2 each shorten by $\frac{1}{2}$ unit.

$$\text{Hence, } \frac{1}{2} = \frac{S_B}{S_A} = \frac{\left(\frac{1}{2}a_B t^2\right)}{\left(\frac{1}{2}a_A t^2\right)} = \frac{a_B}{a_A}$$

Write $\Sigma F_y = ma_y$ for each mass in turn, taking the direction of motion as positive in each case. We have

$$T_1 - 300N = m_B\left(\frac{1}{2}a\right) \text{ and } 200\,N - T_2 = m_A a$$

But $m = w/g$ and so $m_A = (200/9.8)$ kg and $m_B = (300/9.8)$ kg. Further $T_1 = 2T_2$.

Substitution of these values in the two equations allows us to compute T_2 and then T_1 and a. The results are :

$T_1 = 327$ N, $T_2 = 164$ N, $a = 1.78$ m/s^2.

13. (c), 14. (a), 15. (a)

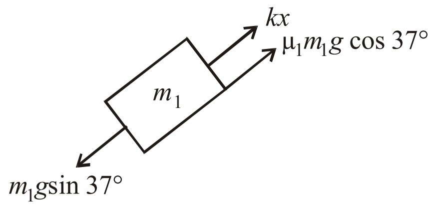
m_2 will not move as applied force ($m_2 g \sin\theta$) is less than the maximum frictional force ($\mu_2 m_2 g \cos\theta$).

At the instant maximum speed, net force on the m_1 block should be zero.

$m_1 g \sin 37° = kx + \mu_1 m_1 g \cos 37°$

$$x = \frac{m_1 g\,(\sin 37° - \mu_1 \cos 37°)}{k}$$

$$x = \frac{100\left(\frac{3}{5} - 0.5 \times \frac{4}{5}\right)}{100} = 20\,\text{cm}$$



At this instant, speed of m_2 block is zero.

Hence, maximum force exerted by block of mass m_1 on block of mass m_2 will be zero.

16. **(b)** For $5 < t < 5.5$

$N = m(g - a) = m(10 - 10) = 0$

So man leaves the contact when $t > 5$ sec

So correct option $t = 5.1$ sec.

17. **(a)** $N_{max} = m(g + a) = 60(10 + 5) = 900$ N

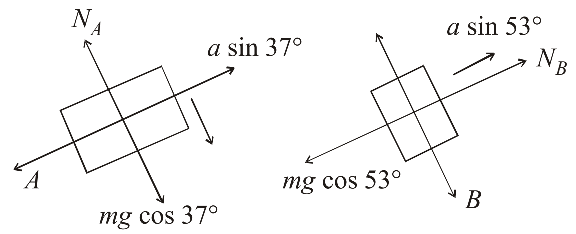
Weighing machine reads 90 kg.

18. **(c)** $T_{max} = (m + m)(g + a) = 150(10 + 5)$

$150 \times 15 = 2250$ N

19. (c), 20. (b), 21. (d)

The FBD of A and B are as shown in the fig.
Applying Newton's second law to block A and B along normal to inclined surface



$N_B - mg\cos 53° = ma\sin 53°$
$mg\cos 37° - N_A = ma\sin 37°$

Solving $N_A = \frac{m}{5}(4g - 3a)$ and

$N_B = \frac{m}{5}(3g + 4a)$

For N_A to be non-zero

$4g - 3a \geq 0$ or $a \leq \frac{4g}{3}$

22. (b) The friction force absorb x mechanical energy from upper block but supply only y mechanical energy to lower block.
$\therefore$ Net loss $= x - y$

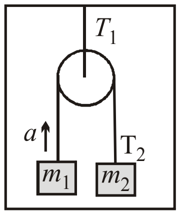
23. (a) $v_A \downarrow v_B \uparrow$ and attain common velocity.

24. (c) $v = 10 - 0.4 \times 10 \times t$ for upper block
$v = 0 + 0.4 \times 10 \times t$ for lower block

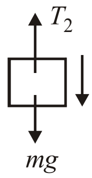
$t = \frac{10}{2 \times 0.4 \times 10} = 1.25$ sec.

25. (c), 26. (b), 27. (c).

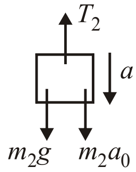
(1) If lift has acceleration zero, then the acceleration of centre of mass of the two blocks is downwards
$\Rightarrow T_1 < (m_1 + m_2)g$
If masses are equal then no acceleration of centre of mass
$\Rightarrow T = (m_1 + m_2)g$

(2) 

In frame of lift



$m_1a_0 \Rightarrow T_2 - m_1g - m_1a_0 = m_1a$



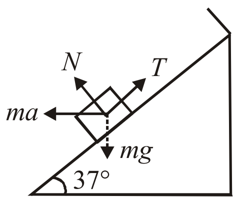
$a \Rightarrow m_2g + m_2a_0 - T_2 = m_2a$

Solving, $T_2 = \frac{2(m_1m_2)(g + a_0)}{m_1 + m_2}$

From $m_1 << m_2$

(3) If $m_1 = m_2$
Relative velocity remains constant.

28. (d)



$N = mg\cos 37° - ma\sin 37° = \frac{3}{4}mg$; $a = \frac{5}{6}\,\text{m/s}^2$

29. (a) $T = mg\sin 37° + ma\cos 37°$; $T = 12$N

30. (a) $mg\cos 37° = ma\sin 37°$

$a = \frac{40}{3}\,\text{m/s}^2$

C REASONING TYPE

1. (a) Due to rain, path becomes slippery, so coefficient of friction which provides driving power to a car becomes lowered. So it is difficult to drive a car on a rainy day.

2. (a) A rocket moves forward taking the help of reaction force. For that it has to exert a force on the surrounding air so that it receives reaction force as per Newton's third law.

3. (c) A vehicle moving with constant speed on a straight road is an inertial frame. Newton's laws of motion is applicable only in inertial frame.

4. (c) Ball bearings are used to convert sliding friction to rolling friction. Sliding friction is less than rolling friction.

5. (a) A and R are correct, R explains A.

6. (b) Cloth can be pulled out without dislodging the dishes from the table because of inertia. Therefore, statement – 1 is true.
Statement 2 is Newton's third law and hence true. But statement 2 is not a correct explanation of statement 1.

7. **(d)** W = (force) × (displacement of point of application)

8. **(c)** Statement – 2 is false because friction force may be more than applied force when body is retarding and external force is acting on body.

9. **(d)** Statement – 1 is false because sun is also rotating about their common centre of mass.

10. **(b)** Both statements are correct.
But reason is Newton's 3rd law.
Friction force = $m \times a = 100 \times 2 = 200$ N

11. **(c)** Tension at a point on rod (length L) at a distance x from point of application of force is $T = F\left(1-\dfrac{x}{L}\right)$ in both cases. Hence weight has no effect on tension in situation of figure (ii). Extension in rod occurs due to force acting at any point on the rod. In certain cases when net force acts at the centre of rod like weight, extension due to this force may not occur like the given case.

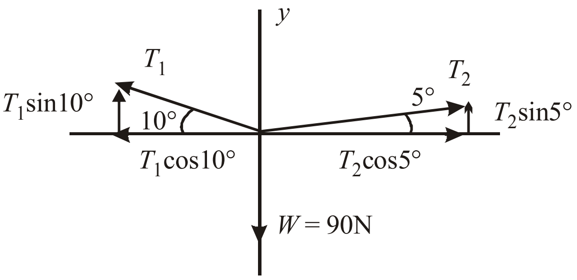
12. **(c)** A compressed spring always pushes both the blocks attached at its ends.

13. **(c)** Net force on system does not depend on internal forces within the system but vice-versa is not true.

14. **(d)** Newton's first law can't be derived from Newton's second law.

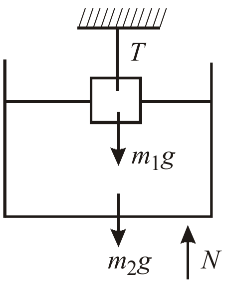
D MULTIPLE CORRECT CHOICE TYPE

1. **(a, b)** Label the two tensions T_1 and T_2, and isolate the rope at the boy's hands as the object. The free-body diagram for this object is shown in figure.



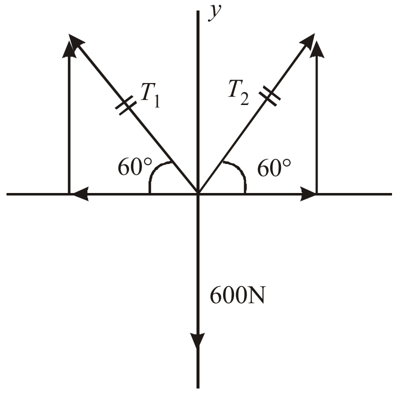
$\Sigma F_x = 0$ becomes
$T_2 \cos 5° - T_1 \cos 10° = 0$
$\Sigma F_y = 0$ becomes
$T_2 \sin 5° + T_1 \sin 10° - 90\text{N} = 0$
Evaluating the sines and cosines, these equations becomes
$0.996T_2 - 0.985T_1 = 0$
and $0.087\, T_2 + 0.174\, T_1 - 90 = 0$
Solving the first for T_2 gives $T_2 = 0.987\, T_1$.
Substituting this in the second equation gives
$0.086\, T_1 + 0.174\, T_1 - 90 = 0$
from which $T_1 = 346$ N. Then, because $T_2 = 0.989\, T_1$, we have $T_2 = 342$ N.

2. **(a, c, d)**



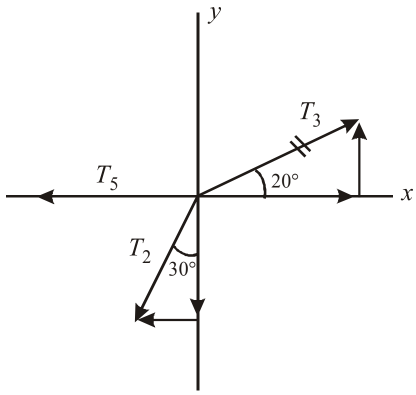
$N = (m_1g + m_2g) - T$
if $T = 0 \Rightarrow N = (m_1g + m_2g)$
if $T > 0 \Rightarrow N < (m_1g + m_2g)$
and T cannot be negative.

3. **(a, b, c, d)** Let us select as our object the knot at A because we know one force acting on it. The weight pulls down on it with a force of 600N and so the free-body diagram for the knot is as shown in figure (a).
Applying the first condition for equilibrium to that diagram, we have
$\Sigma F_x = 0$ or $T_2 \cos 60° - T_1 \cos 60° = 0$
$\Sigma F_y = 0$ or $T_1 \sin 60° + T_2 \sin 60° - 600 = 0$
The first equation yields $T_1 = T_2$. Substitution of T_1 for T_2 in the second equation gives $T_1 = 346$ N, and this is also T_2.



(a)

Let us now isolate knot at B as our object. Its free-body diagram is shown in figure (b).



(b)

We have already found that $T_2 = 346$ N and so the equilibrium equations are

$\Sigma F_x = 0$

or $T_3 \cos 20° - T_5 - 346 \sin 30° = 0$

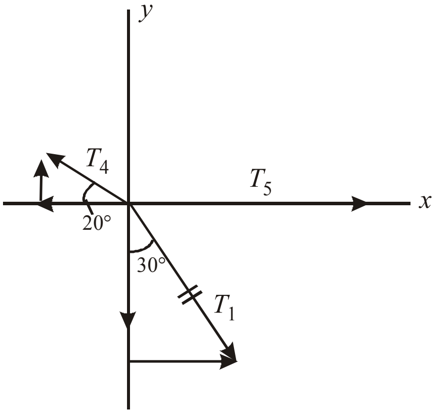
$\Sigma F_y = 0$

or $T_3 \sin 20° - 346 \cos 30° = 0$

The last equation yields $T_3 = 877$ N.

Substituting this in the prior equation gives $T_5 = 651$ N

We can now proceed to the knot at C and the free-body diagram of figure (c).



(c)

Recalling that $T_1 = 346$ N,

$\Sigma F_x = 0$ becomes

$T_5 + 346 \sin 30° - T_4 \cos 20° = 0$

$\Sigma F_y = 0$ becomes

$T_4 \sin 20° - 346 \cos 30° = 0$

The latter equation yields $T_4 = 877$ N

From the symmetry of the system $T_1 = T_2$ and $T_4 = T_3$.

4. (c, d) If θ is the angle made by the direction of force with the horizontal, we have

$F_1 \cos\theta = \mu (mg + F_1 \sin\theta)$ and

$F_2 \cos\theta = \mu (mg - F_2 \sin\theta)$.

Clearly $F_1 > F_2$ so that option (c) is correct.

If $\sin\theta = mg/4F_2$, two relations written above becomes

$F_1 \cos\theta = \mu [mg + mg F_1/(4F_2)]$ and

$F_2 \cos\theta = \mu [mg - mg F_2/4F_2)]$.

From this we get $\dfrac{F_1}{F_2} = \dfrac{1+(F_1/4F_2)}{(3/4)}$.

Solving this we get $F_1 = 2F_2$, so that (d) is correct.

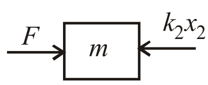
5. (a, b, d) Let F be the force exerted by mass m on mass M.

FBD of mass M

$F = k_1 x_1 = 2 \times 3 = 6$N

FBD of mass m

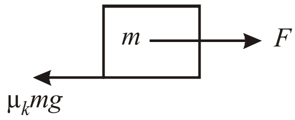
$k_2 x_2 = F = 6$N



Hence, the force exerted on block of mass m by the right spring ($k_2 x_2$) is 6N to the left. From FBD, the normal reaction (F) between blocks is 6N.

As system is at rest, net force on block of mass m is zero.

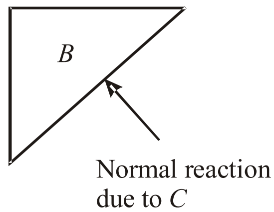
6. (c, d) The FBD for the moving block is



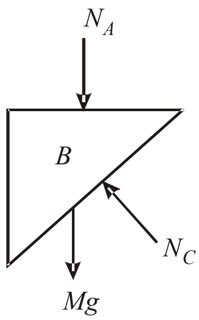
Clearly, $a = \dfrac{F - \mu_k mg}{m}$

7. (a, b, c, d) There is no horizontal force on block A, therefore it does not move in x-direction, whereas there is net downward force $(mg - N)$ is acting on it, making its acceleration along negative y-direction.

Block B moves downward as well as in negative x-direction. Downwards acceleration of A and B will be equal due to constrain, thus w.r.t. B, A moves in positive x-direction.

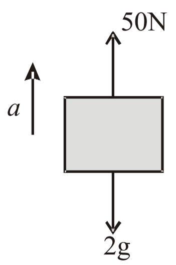


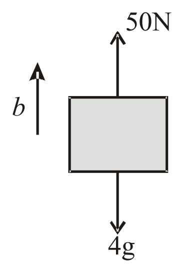
Due to the component of normal exerted by C on B, it moves in negative x-direction.



The force acting vertically downward on block B are mg and N_A (normal reaction due to block A). Hence the component of net force on block B along the inclined surface of B is greater than $mg \sin\theta$. Therefore the acceleration of B relative to ground directed along the inclined surface of C is greater than $g \sin\theta$.

8. (b, c, d)





$50 - 2g = 2a$ and also $50 - 4g = 4b$

$\dfrac{50-20}{2} = a$ $\qquad$ $\dfrac{50 - 4\times 10}{4} = b$

$a = 15$ m/sec^2 upwards $\qquad$ $b = 2.5$ m/sec^2 upwards

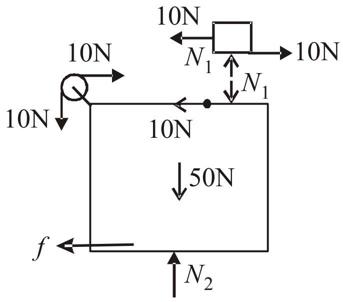
The acceleration of both the masses is upward.

9. (a, c)

(a) $\Sigma F_x = 0$ (c) By symmetry

10. (a, d) The frictional force on block A is

$$\mu N_1 = 10 \Rightarrow N_1 = \frac{10}{0.2} = 50\text{N}$$



The net force on block B in vertical direction is zero

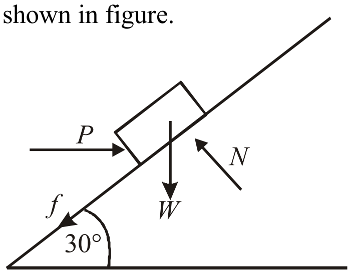
$\therefore N_2 = 50 + N_1 + 10 = 110$ N

$\Rightarrow$ Normal reaction exerted by ground on block B is 110N. The net force on block B in horizontal direction is zero

$\therefore f + 10 - 10 = 0$

$\Rightarrow$ Frictional force exerted by ground on block B is zero.

11. (c, d) Here we choose the x-axis along the incline with positive upward. All the forces on the block are shown in figure.

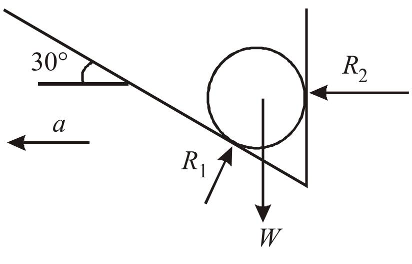


From $\Sigma F_x = ma_x$ we have $P\cos 30° - W\sin 30° - f = ma_x$, where $m = 20$ kg, $W = mg = 196$ N, and $f = 80$ N

For $a_x = 0$, $P = 206$ N.

For $a_x = 0.75$ m/s^2, $P = 223$ N

12. (c, d) From figure, $\Sigma F_{ver} = R_1 \cos 30° - W = ma_{ver} = 0$ and $\Sigma F_{hor} = R_2 - R_1 \sin 30° = ma$.



Thus, the acting forces are

$$R_1 = \frac{W}{\cos 30°} = 1.15\text{W}$$

$$R_2 = R_1 \sin 30° + \frac{W}{g}a$$

$$= (1.15\,W)(0.5) + \frac{W}{g}a$$

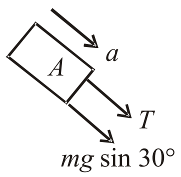
$$= W\left(0.58 + \frac{a}{g}\right)$$

13. (b, d) Let a be acceleration of system and T be tension in the string.

F.B.D. of block A

$mg\sin 30° + T = ma$

$$\frac{mg}{2} + T = ma \qquad \text{....... (1)}$$

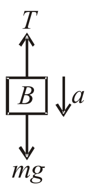


F.B.D. of block B

$mg - T = ma$ .... (2)

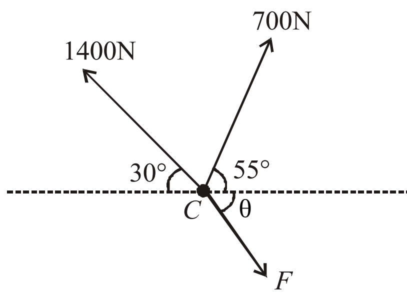
Adding equation (1) and (2), we get

$$2ma = \frac{3mg}{2} \Rightarrow a = \frac{3}{4}g$$

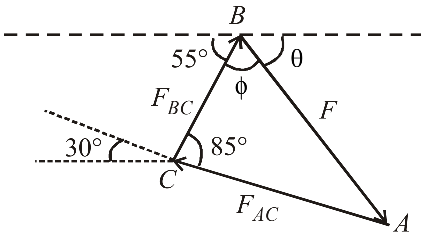


From eq. (1) $T = \dfrac{mg}{4}$

14. (b, c) Free-body diagram at point C:



(a) FBD at C



(b) Force triangle

(a) Using law of cosines

$F^2 = (1400\,N)^2 + (700)^2 - 2\,(1400\,N)\,(700\,N)\cos 85°$

$F = 1510\,N$

(b) Using law of sines

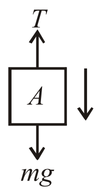
$$\frac{\sin\phi}{1400N} = \frac{\sin 85°}{1510N}$$

$\sin\phi = 0.92362$

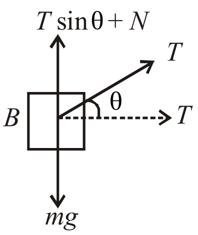
$\phi = 67.461°$

$\therefore\ \theta = 180° - 55° - 67.461° = 57.5°$

15. (a, d)



$a \Rightarrow mg - T = ma \Rightarrow T = m\,(g - a)$..... (1)



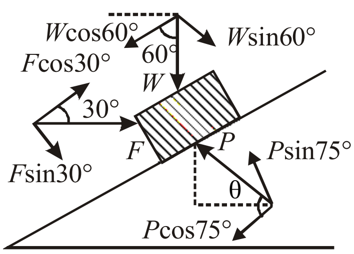
$\Rightarrow N = mg - T\sin\theta$. (2)

From (1), $\therefore\ T < mg$; $T\sin\theta < mg \Rightarrow N \neq 0$

As string length remains constant, velocity of both ends along length remains same.

$v_B\cos\theta = u \Rightarrow v_B = u\sec\theta$.

16. (a, b, c) By geometry, $\theta = (45° + 30°) = 75°$



For resolution refer figure shown. Let R be the resultant force acting along incline towards right, so that $\Sigma x = R$.

Now as resultant lies along X-direction summation of forces along Y-direction should equal to zero.

$\therefore\ \Sigma x = F\cos 30° - W\cos 60° - P\cos 75° = R$ .... (1)

$\Sigma y = P\sin 75° - W\sin 60° - F\sin 30° = 0$...... (2)

From eq. (1),

$600\cos 30° - 400\cos 60° - P\cos 75° = R$

From eq. (2),

$P\sin 75° = 400\sin 60° + 600\sin 30°$

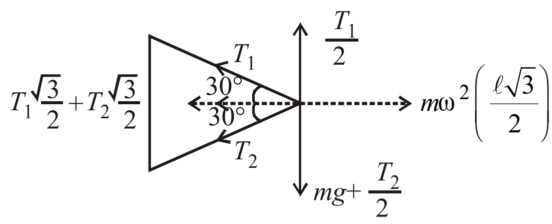
$$\therefore\quad P = \frac{(346.41 + 300)}{\sin 75°} = 670N$$

So from eq. (1),

$R = 146.2\,N$

As the value of R is positive, it means that the assumed direction was correct. So the block is moving upwards.

17. (c, d)



$$\therefore\ \frac{T_1}{2} = mg + \frac{T_2}{2}$$

$\Rightarrow T_1 - T_2 = 2mg$

$$\frac{\sqrt{3}}{2}(T_1 + T_2) = m\omega^2\ell\frac{\sqrt{3}}{2}$$

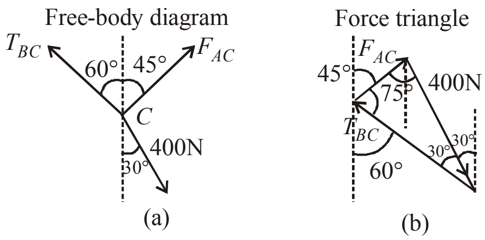
$\Rightarrow T_1 + T_2 = m\omega^2\ell$

$T_1 + T_2 > T_1 - T_2 = 2mg$

$\therefore\ m\omega^2\ell > 2mg$

$$\Rightarrow \omega > \sqrt{\frac{2g}{\ell}}$$

18. (c, d)



From force triangle and applying Lami's theorem

$$\frac{F_{AC}}{\sin 30°} = \frac{T_{BC}}{\sin 75°} = \frac{400N}{\sin 75°}$$

$$F_{AC} = \frac{400\text{N}}{\sin 75°}\sin 30° = 207 \text{ N}$$

$$T_{BC} = \frac{400}{\sin 75°}\sin 75° = 400 \text{ N}$$

19. (a, b) Given $W_A = 40\text{ N}$, $m_A = \frac{40}{g}\text{kg}$

$W_B = 50\text{ N}$, $m_B = \frac{50}{g} kg$

$W_C = 150\text{ N}$, $m_C = \frac{150}{g}\text{kg}$

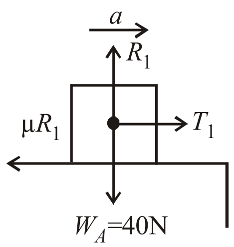
$\alpha = \tan^{-1}\frac{3}{4}$

$\therefore\ \sin\alpha = 0.6$ and $\cos\alpha = 0.8$

$\mu_1 = \mu_2 = 0.25$

Let acceleration of the bodies be 'a' and tension in the two strings connected to A and B be T_1 and T_2 respectively.

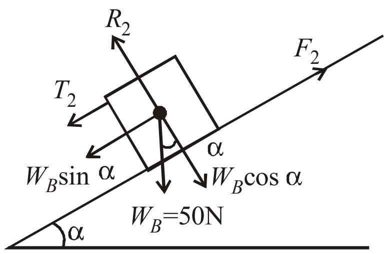
Considering the motion of A :



$F_1 = \mu_1 R_1 = 0.25 \times 40 = 10\text{ N}$

$T_1 - F_1 = m_A a$ or $T_1 - 10 = \frac{40}{g}a$

Considering the motion of B :



$R_2 = W_B\cos\alpha = 50 \times 0.8 = 40\text{ N}$

$F_2 = \mu_2 R_2 = 0.25 \times 40 = 10\text{ N}$

$T_2 + W_B\sin\alpha - F_2 = m_B a$

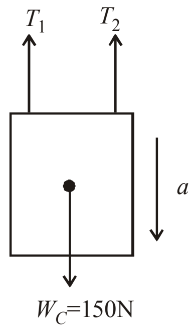
or $T_2 + 50 \times 0.6 - 10 = \frac{50}{g}$

or $T_2 + 20 = \frac{50}{g}a$ .... (2)

Considering motion of C :

$W_C - (T_1 + T_2) = m_C a$

$150 - T_1 - T_2 = \frac{150}{g}a$ .... (3)



Adding (1), (2) and (3)

$160 = \frac{240}{g}a$ or $a = \frac{160 \times 9.8}{240} = 6.53\text{ m/s}^2$

From (1),

$T_1 = 10 + \frac{40}{g}a = 10 + \frac{40}{9.8} \times 6.53 = 36.65\text{ N}$

From (2),

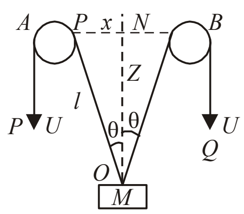
$T_2 = \frac{50}{g}a - 20 = \frac{50 + 6.53}{9.8} - 20 = 13.32\text{ N}$

20. (b) This is a problem based on constraint motion. The motion of mass M is constraint with the motion of P and Q. Let $PN = x$, $NO = z$. Then velocity of mass is $\frac{dz}{dt}$.

Also, let $OP = \ell$. then $\frac{d\ell}{dt} = U$

From ΔPNO, using pythagorous theorem

$\therefore\ x^2 + z^2 = \ell^2$



Here x is a constant. Differentiating the above equation w.r.t to t

$$0 + 2z\frac{dz}{dt} = 2\ell\frac{d\ell}{dt}$$

$$\Rightarrow \quad zv_M = \ell U$$

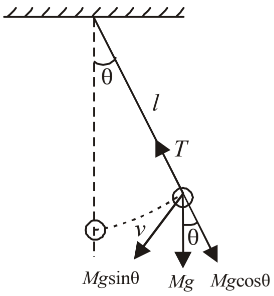
$$\Rightarrow \quad v_M = \frac{\ell}{z}U = \frac{U}{z/\ell} = \frac{U}{\cos\theta} \qquad \left(\because \cos\theta = \frac{z}{\ell}\right)$$

21. (b, d)

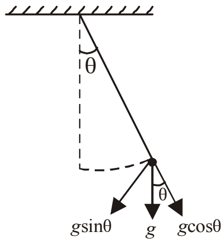
Since earth is an accelerated frame and hence, cannot be an inertial frame.
Strictly speaking Earth is accelerated reference frame. Earth is treated as a reference frame for practical examples and Newton's laws are applicable to it only as a limiting case.

22. (b, c)

Since the body is moving in a circular path therefore it needs centripetal force $\left(\frac{Mv^2}{\ell}\right)$

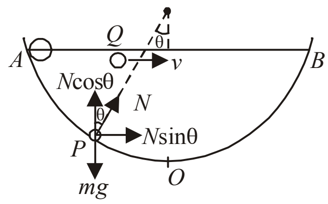


$$\therefore \quad T - Mg\cos\theta = \frac{Mv^2}{\ell}$$



Also, the tangential acceleration acting on the mass is $g\sin\theta$.

23. (a) At A the horizontal speeds of both the masses is the same. The velocity of Q remains the same in horizontal as no force is acting in the horizontal direction. But in case of P as shown at any intermediate position, the horizontal velocity first increases (due to $N\sin\theta$), reaches a max value at O and then decreases. Thus it always remains greater than v. Therefore $t_P < t_Q$.

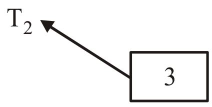


E MATRIX-MATCH TYPE

1. (A) → p, s; (B) → q, r; (C) → q, r; (D) → q, r

For case I, take torque about COM
For case II, take torque about any point on the ground.

2. (A) → q; (B) → r; (C) → p; (D) → s



$T_2\sin 37° = 30$

$\Rightarrow \quad T_2 = 50\text{ N}$

Acceleration of 5 kg $= \dfrac{50\cos 37°}{5} = 8\ \text{m/s}^2$

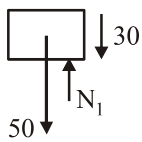
$F = 8 \times 9 = 72\text{ N}$

On 1 kg block

$\Rightarrow \quad 72 - T_1 = 1 \times 8$

$T_1 = 64\text{ N}.$

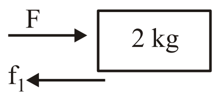
On 5 kg

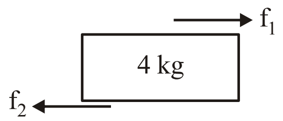


$N_1 = 80\text{ N}.$

Net force on 3 kg block $= T_1 - T_2\cos 37°$
$= (64 - 40)\text{ N} = 24\text{ N}$

3. (A) → p, s; (B) → r; (C) → q, s; (D) → q, r





Limiting friction on 2 kg = 0.2 × 2 × 10 = 4 N

Limiting friction on 4 kg at lower surface

$= 0.2 \times 6 \times 10 = 12$

When force is 3 N, 2 kg block does not move as F < 4.

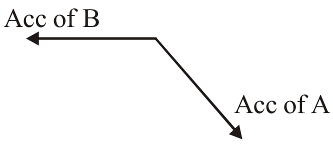
∴ friction on 2 kg is 3 N.

When F = 10 N, friction on 2 kg is 4 and net friction on 4 kg will be zero.

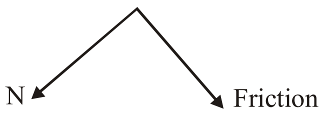
As it cannot move since $(f_2)_{max} > (f_1)_{max}$.

4. (A) $\rightarrow$ **q, r; (B) $\rightarrow$ r, q ; (C) $\rightarrow$ p; (D) $\rightarrow$ s**

(A) This vector sum is along q and r

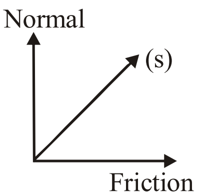


(B) Sum of these forces can be r and q.

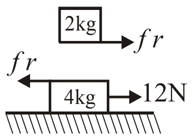


(C) Only P.

(D) Sum of normal and friction is s.

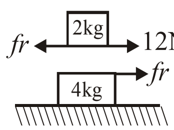


5. **(A) $\rightarrow$ s; (B) $\rightarrow$ r; (C) $\rightarrow$ p, s**

(p) 

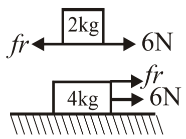
$fr = 2 \times 2 = 4 \Rightarrow fr = 4$

$12 - fr = 4 \times 2 \Rightarrow fr = 4$

(q) 

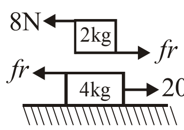
$12 - fr = 2 \times 2 \Rightarrow fr = 8$

$fr = 4 \times 2 \Rightarrow fr = 8$

(r) 

$6 - fr = 2 \times 3 \Rightarrow fr = 2$

$fr + 6 = 4 \times 2 \Rightarrow fr = 2$

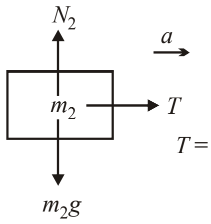
(s) 

$20 - fr = 4 \times 2 \Rightarrow fr = 12$

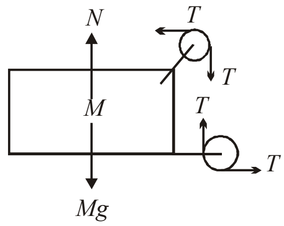
$fr - 8 = 2 \times 2 \Rightarrow fr = 12$

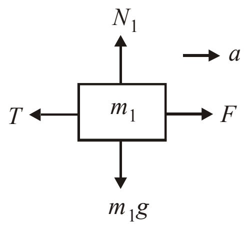
6. **(A) $\rightarrow$ q; (B) $\rightarrow$ q; (C) $\rightarrow$ r; (D) $\rightarrow$ s**

FBD's



$T = m_2 a$





$F - T = m_1 a$

$F = (m_1 + m_2)\, a \quad \because\ T = m_2 a$

$a = \dfrac{F}{m_1 + m_2} \qquad \because\ T = \dfrac{m_2 F}{m_1 + m_2},\ F_x = 0, a_M = 0$

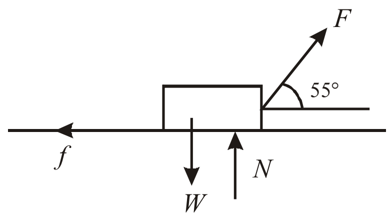
7. **(A) $\rightarrow$ q; (B) $\rightarrow$ p; (C) $\rightarrow$ r**

In each case friction is necessary for equilibrium. But friction does not enter in solving for N.

(A) Free-body diagram in figure (a) ($F = 20$N, $W = 50$N)

$\Sigma F_y = 0 \Rightarrow N - W + F \sin 55° = 0$

$N = 50\text{N} - (20\text{N})(0.819) = 33.6\text{ N}$

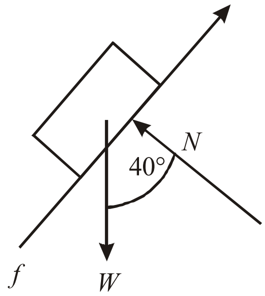


(a)

(B) Free-body diagram in figure (b) : ($W = 60$ N)

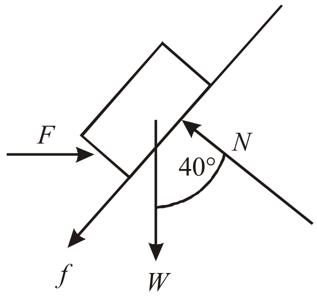
$\Sigma F_y = 0 \Rightarrow N - W \cos 40° = 0$

$N = (60\text{N})(0.766) = 46.0\text{ N}$



(b)

(C) Free-body diagram in figure (c) :
$(F = 70\text{ N}, W = 60\text{N})$
$\Sigma F_y = 0 \Rightarrow N - W\cos 40° - F\sin 40° = 0$
$N = 60\,(0.766) + 70\,(0.643) = 91.0\text{ N}$



(c)

8. (A) → r; (B) → q; (C) → s; (D) → p

(A) As velocity = 0 ⇒ no radial acceleration

$$\Rightarrow T = mg\cos 53° = \frac{3mg}{5}$$

(B) Motion in horizontal plane ⇒ no acceleration in vertical direction

$$\Rightarrow T\cos 37° = mg \Rightarrow T = \frac{mg \times 5}{4}$$

(C) Acceleration of particle w.r.t. cart is zero

$$\Rightarrow T\cos 53° = mg \Rightarrow T = \frac{5mg}{3}$$

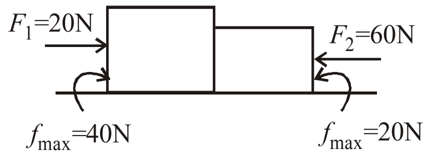
(D) $T = mg\cos 37° \Rightarrow T = \dfrac{4mg}{5}$

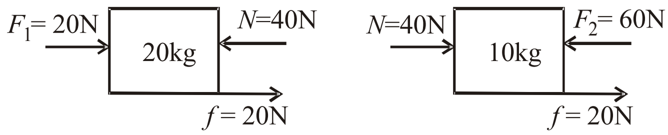
9. (A) → p, r ; (B) → p, r ; (C) → q, s ; (D) → q, s

At positions P and R frictional force is maximum and normal reaction is mg. At positions S and Q frictional force is zero and normal reaction points towards centre.

10. (A) → p, s; (B) → p, s; (C) → q, s; (D) → r

The minimum horizontal force required to push the two block system towards left
$= 0.2 \times 20 \times 10 + 0.2 \times 10 \times 10 = 60\text{ N}$
Hence the two block system is at rest. The FBD of both of blocks is as shown. The friction force f and normal reaction N for each block is as shown.





FBD of both blocks

Hence, magnitude of friction force on both blocks is 20N and is directed to right for both blocks. Normal reaction exerted by 20kg, block on 10 kg. block has magnitude 40N directed towards right. Net force on system of both blocks is zero.

11. (A) → p, q, t; (B) → s; (C) → s; (D) → p, s

(A) $20 - 0.5 \times 2 \times 10 = ma$; $a = 5\text{ m/s}^2$, $f = 10\text{N}$
Tension at mid point,
$T - 0.5 \times 1 \times 10 = 1 \times 5 \Rightarrow T = 10\text{ N}$

(B) Speed constant ⇒ $a = 0$
Pulling force = mg sin θ + f

(C) $F_{net} = 7.5 - 0.75 \times g \times \sin 30° - \dfrac{1}{\sqrt{3}} \times 0.75g\cos 30°$

$$= 7.5 - 0.75g \times \frac{1}{2} - \frac{1}{\sqrt{3}}0.75g\frac{\sqrt{3}}{2} = 0$$

(D) $F_{net} = 20 - 2g = 0$; $T - 1\text{g} = 1 \times 0 \Rightarrow T = 10\text{ N}$

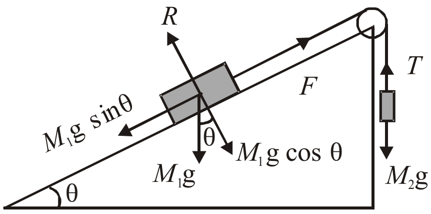
12. (A) → s; (B) → r; (C) → q; (D) → r

In (A) we try to decrease ω of the rear wheel then friction will try to increase it. On front wheel at the point of contact with the ground $(\vec{\omega} \times \vec{r})$ is greater than v as v decreases due to break. So that friction will act in forward direction on it.
In (B) we try to decrease ω of the front wheel, friction will try to increase it.
In (C) sliding will start hence f_k will act.
In (D) we try to increase ω of rear wheel then friction will try to decrease it.

F NUMERIC/INTEGER ANSWER TYPE

1. 30

Resolving M_1g into rectangular components, we have M_1g sin 30º acting along the plane downwards, and M_1g cos30º acting perpendicular to the plane downwards. The situation has been shown in Fig.



Let T be the tension in the wire and R be the reaction of plane on the mass M_1. Since the system is in equilibrium, therefore,

$T = M_1$g sin30º ...(i)

and $R = M_1$g cos30º ...(ii)

$T = M_2$g ...(iii)

From (i) and (iii), we have

$T = M_1$g sin30º $= M_2$g ...(iv)

Velocity of transverse wave, $v = \sqrt{\frac{T}{m}}$,

where m is the mass per unit length of the wire.

$\therefore\ v^2 = T/m$, or $T = v^2 m = (100)^2 \times (9.8 \times 10^{-3}) = 98$N

From (iii), $M_2 = T/g = 98/9.8 = 10$kg.

From (iv), $M_1 = 2M_2 = 2 \times 10 = 20$kg.

$\therefore\ M_1 + M_2 =$ **30 kg**

2. 60

If θ is the angle which the inclined plane makes with the vertical direction, then the acceleration of the block sliding down the plane of length ℓ will be g cosθ.

Using the formula, $s = ut + \frac{1}{2}at^2$, we have $s = \ell$, $u = 0$, $t = t$ and $a = $ g cos θ.

So $\ell = 0 \times t + \frac{1}{2}\text{g}\cos\theta\, t^2 = \frac{1}{2}(\text{g}\cos\theta)t^2$ ...(i)

Taking vertical downward motion of the block, we get

$\therefore\ h = 0 + \frac{1}{2}\text{g}(t/2)^2 = \frac{1}{2}\text{g}t^2/4$ ...(ii)

Dividing (ii) by (i), we get $\frac{h}{\ell} = \frac{1}{4\cos\theta}$ $[\because \cos\theta = h/\ell]$

or $\cos\theta = \frac{1}{4\cos\theta}$; or $\cos^2\theta = \frac{1}{4}$; or $\cos\theta = \frac{1}{2}$

or θ = **60º**

3. 4

Force on 10 kg mass = 10 × 12 = 120 N

The mass of 10 kg will pull the mass of 20 kg in the backward direction with a force of 120 N.

∴ Net force on mass 20 kg = 200 – 120 = 80 N

Its acceleration $= \frac{80\,N}{20\,kg} =$ **4 m/s²**

4. 150

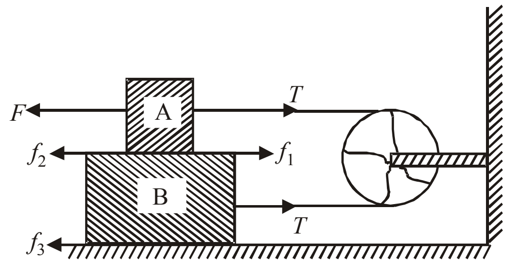
The situation is shown in fig.

Let F be the horizontal force applied on A.

For block A, $F = T + f_1 = T + \mu m_1$g .....(1)

($\because$ Block A moves towards left, frictional force f_1 acts towards right)

For block B, $f_B = f_2 + f_3$



($\because$ Block B moves towards right, frictional forces f_2 and f_3 acts towards left).

$T = \mu m_1\text{g} + \mu(m_1 + m_2)\text{g} = \mu\text{g}(2m_1 + m_2)$ ...(2)

From eqs. (1) and (2), we get

$F = \mu\text{g}(2m_1 + m_2) + \mu m_1\text{g}$ or $F = \mu\text{g}(3m_1 + m_2)$

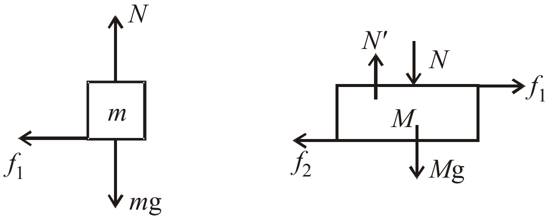
$\therefore\quad F = 0.3 \times 10(3 \times 10 + 20)$

= **150 N**

5. 0.12

Make free body diagram of m

Take right as the positive direction. Let $a_{1/g}$ be the acceleration of m w.r.t. ground.



$a_{1/g} = \frac{-f_1}{m}$ $\left[\because f_1 = \frac{\mu}{2}mg\right]$

$\Rightarrow a_{1/g} = \frac{-\mu g}{2} = \frac{-\mu g}{2}$ ...(1)

$N' = N + Mg$ and $N' = (m + M)$g ...(2)

$f_2 = \mu N' = \mu(m+M)g$ ...(3)

$$a_{2/g} = \frac{-(f_2 - f_1)}{M}$$

[$\because$ $a_{2/g}$ is acceleration of M w.r.t. ground]

$$= \frac{\{\mu(m+M)g - \mu/2\, mg\}}{M} = -Mg\left[1+\frac{m}{2M}\right]$$

$a_{1/2}$ = acceleration of m w.r.t. to M $= a_{1/g} - a_{2/g}$

$$= -\frac{\mu g}{2} + Mg\left[1+\frac{m}{2M}\right] = Mg\left[-\frac{1}{2}+1+\frac{m}{2M}\right]$$

$$= Mg\frac{[m+M]}{2M}$$

Now $L = \frac{1}{2}a_{1/2}t^2 \Rightarrow t = \sqrt{\frac{4ML}{(M+m)\mu g}}$

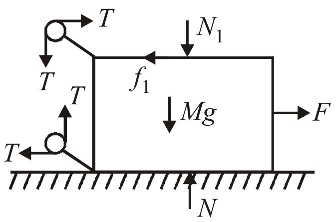
$$= \sqrt{\frac{4\times 20\times 0.04}{(20+10)\times 0.3\times 10}} = \mathbf{0.12\ s}$$

6. 15

Given

$m_1 = 20$ kg, $m_2 = 5$ kg, $M = 50$ kg, $\mu = 0.3$ and $g = 10$ m/s^2

(A) Free body diagram of mass M is :



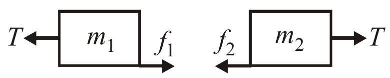
(B) The maximum value of f_1 is

$(f_1)_{max} = (0.3)(20)(10) = 60$ N

The maximum value of f_2 is

$(f_2)_{max} = (0.3)(5)(10) = 15$ N

Forces on m_1 and m_2 in horizontal direction are as follows :



Now, there are only two possibilities.

(1) either both m_1 and m_2 will remain stationary (w.r.t. ground) or (2) both m_1 and m_2 will move (w.r.t. ground). First case is possible when

$T \le (f_1)_{max}$ or $T \le 60$ N

and $T \le (f_2)_{max}$ or $T \le 15$ N

These conditions will be satisfied when $T \le 15$ N say $T = 14$ then $f_1 = f_2 = 14$ N.

Therefore the condition $f_1 = 2f_2$ will not be satisfied. Thus m_1 and m_2 both can't remain stationary.

In the second case, when m_1 and m_2 both move

$f_2 = (f_2)_{max} = 15$ N

Therefore, $f_1 = 2f_2 = 30$ N

$\therefore$ $f_1 - f_2 = \mathbf{15\ N}$

7. 2

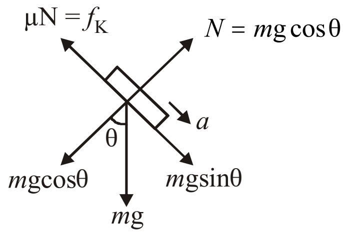
$$a = \frac{mg\sin\theta - \mu_k mg\cos\theta}{m}$$

$\therefore$ $a_A = g\sin\theta - \mu_{k,A}\, g\cos\theta$ ... (i)

and $a_B = g\sin\theta - \mu_{k,B}\, g\cos\theta$ ... (ii)

Putting values, we get

$$a_A = \frac{0.89}{\sqrt{2}} \text{ and } a_B = \frac{0.79}{\sqrt{2}}$$



a_{AB} is relative acceleration of A w.r.t. B

$$\vec{a}_{AB} = \vec{a}_A - \vec{a}_B$$

$$L = \sqrt{2}\text{ m} \Rightarrow L = \frac{1}{2}a_{AB}t^2$$

[where L is the relative distance between A and B]

or $t^2 = \frac{2L}{a_{AB}} = \frac{2L}{a_A - a_B}$

Putting values we get, $t^2 = 4$ or $t = \mathbf{2s.}$

8. 10

Applying pseudo-force ma and resolving it.

Applying $F_{net} = ma_x$ for x-direction

$ma\cos\theta - (f_1 + f_2) = ma_x$

$ma\cos\theta - \mu N_1 - \mu N_2 = ma_x$

$ma\cos\theta - \mu ma\sin\theta - \mu mg = ma_x$

$\Rightarrow$ $a_x = a\cos\theta - \mu a\sin\theta - \mu g$

$$= 25\times\frac{4}{5} - \frac{2}{5}\times 25\times\frac{3}{5} - \frac{2}{5}\times 10 = \mathbf{10\ m/s^2}$$

9. **10**

$10t = 2T$

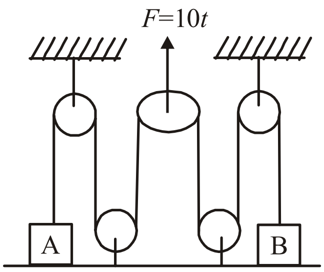
$\Rightarrow T = 5t$

Block A will lose contact when

$T = m_A g$

$5t = m_A g$

$\Rightarrow t_1 = \dfrac{m_A g}{5}$ sec = **2sec**



While block B will lose contact, when

$T' = m_B g$

$\Rightarrow 5t = 2m_B g$

or $t_2 = \dfrac{2g}{5}$ sec = 4 sec

At $t_1 \le t$ for block A

$T - mg = ma$

$5t - mg = \dfrac{mdv}{dt}$

$\Rightarrow m\int_0^v dv = \int_{t_1}^{t_2} (5t - mg)dt$

$v =$ **10 m/s**