LAWS OF MOTION

Force, a vector quantity, will arise due to the interaction of a body or system with its surroundings.

When several forces act on a body, the effect on its motion is the same as when a single force, (known as net force, represented by $\sum \vec{F}$) equal to the vector sum or resultant of the forces, acts on the body.

C1 Newton's First Law

When no net external force acts on a body, its motion does not change, that means the body is either at rest or moving with constant velocity.

Significance of this Law

(i) According to this law, the acceleration of the body or force acting on the body is zero.

(ii) This law defines the concept of equilibrium.

$$\sum \vec{F} = 0 \text{ or } \sum F_x = 0, \sum F_y = 0$$

(iii) This law is known as law of inertia. The tendency of a body to keep moving once it is set in motion results from a property called inertia. The inertial properties of a body is characterized by its mass.

(iv) Inertial frame of reference are those in which Newton's first law is valid.

C2 Newton's Second Law

The inertial properties of a body are characterized by its mass. The acceleration of a body under the action of a given set of forces is directly properties to the vector sum of the forces (the net force) and inversely proportional to the mass of the body. This relationship is Newton's second law :

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

Like the first law, this is valid only in inertial frames of reference.

C3 Newton's Third Law

Newton's third law states that "action equals reaction"; when two bodies interact, they exert forces on each other that are equal in magnitude and opposite in direction. Each force in an action-reaction pair acts on only one of the two bodies; the action and reaction forces never act on the same body. Newtons third law is needed in equilibrium problems.

C4 Application of Newton's Law

Problem Solving Strategy

1. Identify one or more bodies to which Newton's laws will be applied.
2. Draw the free body diagram for each body. Free body diagram is the pictorial representation of all the forces acting on the body. Some of the common forces are weight of the body, normal reaction, tension in the string, spring force and frictional force.
3. Resolve all the forces (if possible) into components in the direction of acceleration and perpendicular to it. If the body is in equilibrium then resolve the forces into components in any two mutually perpendicular direction.
4. Write the equations according to Newton's Law and solve the equations to find the required unknown
5. If the variables (which has to be found) is more and equations (form using the Newton's Laws) are less then to get another equation use constrained relation. Constrained relations are used to find the relation between the acceleration of various bodies in the system.

Practice Problems :

1. A particle of mass m moving with speed u along a straight line path is stopped by a constant force F. In this process the particle moves a distance

(a) $\frac{mu^2}{2F}$ (b) $\frac{mu^2}{F}$ (c) $\frac{2mu^2}{F}$ (d) $\frac{mu^2}{4F}$

2. **A man is standing on a weighing machine placed in a lift. When stationary, his mass is m. Then choose the incorrect statement**

(a) **If the lift moves with constant velocity then machine record the weight mg.**

(b) **If the lift moves upward with constant acceleration *a* then machine records the weight m(g + a).**

(c) **If the lift moves downwards with constant acceleration *a* then machine records the weight m(g – a).**

(d) **If the lift moves upwards with constant retardation *a* then machine records the weight m(g + a).**

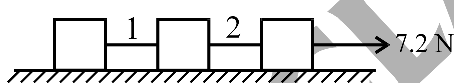
3. **A uniform rope of length *l* is pulled by a constant force F applied at one of the end. The tension in the rope at a distance x from the end where the force is applied as**

(a) **F** **(b)** $F\left(1+\frac{x}{l}\right)$ **(c)** $F\frac{x}{l}$ **(d)** $F\left(1-\frac{x}{l}\right)$

4. **A block of mass M is pulled along a horizontal frictionless surface by a rope of mass m by applying a force P at one end of the rope. The force exerted by the rope on the block is**

(a) $\frac{PM}{M-m}$ **(b)** $\frac{PM}{M+m}$ **(c)** $\frac{Pm}{M+m}$ **(d)** $\frac{Pm}{M-m}$

5. **Three blocks each of mass 0.6 kg are connected by two strings as shown in figure**



The horizontal surface is smooth and a force of 7.2 N is applied. The tension in the string 1 is

(a) **1.2 N** **(b)** **2.4 N** **(c)** **3.6 N** **(d)** **7.2 N**

6. **A balloon of total weight W descends with an acceleration f. The weight that must be thrown out in order to give the balloon an equal upward acceleration will be**

(a) $\frac{Wf}{g}$ **(b)** $\frac{2Wf}{g}$ **(c)** $\frac{2Wf}{g+f}$ **(d)** $\frac{W(g+f)}{f}$

7. **An elevator starts from rest with a constant upward acceleration. It moves 2 m in the first 0.6 second. A passenger in the elevator is holding a 3 kg package by a vertical string. When the elevator is moving, the tension in the string is**

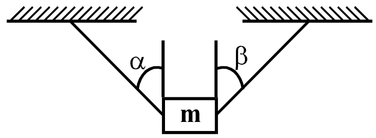
(a) **4 N** **(b)** **62.7 N** **(c)** **29.4 N** **(d)** **20.6 N**

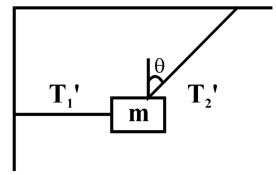
8. **A bob is hanging from the ceiling of a car using a massless string. If the car moves with an acceleration a towards right, the angle made by the string with the vertical is**

(a) $\sin^{-1}\left(\frac{a}{g}\right)$**, deflected towards right** **(b)** $\sin^{-1}\left(\frac{g}{a}\right)$**, deflected towards left(c)**

(c) $\tan^{-1}\left(\frac{a}{g}\right)$**, deflected towards left** **(d)** $\tan^{-1}\left(\frac{g}{a}\right)$**, deflected towards right**

9. **Find the tension in each string if the system is (a) stationary (b) moving upward with constant acceleration ‘a’ (c) moving downward with constant acceleration ‘a’ (d) moving right with acceleration ‘a’ (e) moving with constant velocity in any direction.**





[Answers : (1) a (2) d (3) d (4) b (5) b (6) c (7) b (8) c (9) (a) $T_1 = \frac{mg\sin\beta}{\sin(\alpha+\beta)}$, $T_2 = \frac{mg\sin\alpha}{\sin(\alpha+\beta)}$,

$T_1' = mg\tan\theta$, $T_2' = \frac{mg}{\cos\theta}$]

C5 <u>Constrained Relation</u>

Constrained relation is used to find the relation between the velocities and accelerations of different bodies in a system.

C6 <u>Friction</u>

When a force **F** attempts to slide a body along a surface, a **frictional force** is exerted on the body by the surface. The frictional force is parallel to the surface and directed so at to oppose the sliding. It is due to bonding between the body and the surface.

If the body does not slide, the frictional force is a **static frictional force f_s**. If there is sliding, the frictional force is a **kinetic frictional force f_k**.

Properties of friction

Property 1. If the body does not move, then the static frictional force $\mathbf{f_s}$ and the component of **F** that is parallel to the surface are equal in magnitude, and $\mathbf{f_s}$ is directed opposite that components. If that parallel component increases, $\mathbf{f_s}$ also increases.

Property 2. The magnitude of $\mathbf{f_s}$ has a maximum $f_{s,max}$ that is given by

$$f_{s,max} = \mu_s N,$$

where μ_s is the **coefficient of static friction** and N is the magnitude of the normal force. If the component of **F** that is parallel to the surface exceeds $f_{s,max}$, then the body slides on the surface.

Property 3. If the body begins to slide along the surface, the magnitude of the frictional force rapidly decreases to a constant value f_k given by

$$f_k = \mu_k N$$

where μ_k is the **coefficient of kinetic friction.**

<u>Practice Problems :</u>

1. **A body takes n times as much time to slide down at 45^0 rough incline as it takes to slide down a smooth 45^0 incline. The coefficient of friction is**

(a) $1-\frac{1}{n^2}$ **(b)** $\frac{1}{1-n^2}$ **(c)** $\sqrt{1-\frac{1}{n^2}}$ **(d)** $\frac{1}{\sqrt{1-n^2}}$

2. **A block of mass 2 kg rests on a rough inclined plane making an angle of 30^0 with the horizontal. The coefficient of static friction between the block and the plane is 0.7. The frictional force on the block is**

(a) **9.8 N** **(b)** **0.7 × 9.8 N**

(c) **9.8 × √3 N** **(d)** **0.7 × 9.8 × √3 N**

3. **A uniform chain of length L lies on a table. If the coefficient of friction is μ, then the maximum length of the chain which can hang from the edge of the table without the chain sliding down is**

(a) $\frac{L}{\mu}$ **(b)** $\frac{L}{\mu - 1}$ **(c)** $\frac{\mu L}{\mu + 1}$ **(d)** $\frac{\mu L}{\mu - 1}$

4. **A block placed on an inclined plane of slope angle θ slides down with a constant speed. The coefficient of kinetic friction is equal to**

(a) sin θ **(b)** cos θ **(c)** tan θ **(d)** cot θ

5. **A block of weight 5N is pushed against a wall by a force of 12N. The coefficient of friction between the wall and the block is 0.6. The magnitude of the force exerted by the wall on the block is**

(a) 5 N **(b)** 12 N **(c)** 13 N **(d)** 15.6 N

6. **In the previous problem, the angle made by the net contact force with normal reaction exerted by the wall on the block is**

(a) 37^0 **(b)** 53^0 **(c)** 75^0 **(d)** none of these

7. **A block of mass 1 kg lies on a horizontal surface in a truck, the coefficient of friction between the block and the surface is 0.6. The force of friction on the block if the acceleration of the truck is 5 m/s^2 is**

(a) 2 N **(b)** 3 N **(c)** 4 N **(d)** 5 N

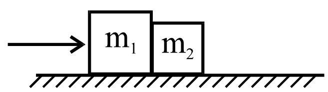
8. **A particle of mass m thrown up vertically reaches its highest point in time t_1 and returns to the ground in further time t_2. There is a constant air friction f on the particle opposite to its direction of motion. Let a = f/m, then t_1/t_2 equals to**

(a) $\sqrt{\frac{g+a}{g-a}}$ **(b)** $\sqrt{\frac{g-a}{g}}$ **(c)** $\sqrt{\frac{g-a}{g+a}}$ **(d)** $\sqrt{\frac{g}{g-a}}$

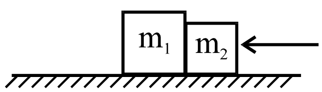
[Answers : (1) a (2) a (3) c (4) c (5) c (6) d (7) d (8) c]

SINGLE CORRECT CHOICE TYPE

1. Two blocks A and B, having masses m_1 and m_2 respectively, are placed in contact on a smooth horizontal suface. A force F is applied horizontally on A as shown in figure (I). Let the contact force between A and B is F_1. Now the same force is applied horizontally on B as shown in figure (II). Let the contact force between them is F_2 in this case. Then F_1/F_2 equals to



(I)



(II)

(a) 1 : 1 (b) $\frac{m_2}{m_1}$

(c) $\frac{m_1}{m_2}$ (d) $\frac{m_2}{m_1+m_2}$

2. A monkey of mass 40 kg climbs on a massless rope of breaking strength 600 N. The rope will break if the monkey (g = 10 m/s^2)

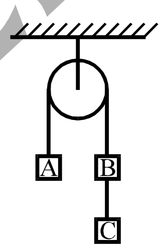
(a) climbs up with a uniform speed of 5 m/s

(b) climbs up with an acceleration of 6 m/s^2

(c) climbs down with an acceleration of 4 m/s^2

(d) climbs down with a uniform speed of 5 m/s.

3. Three blocks A, B and C, each of mass m, are hanging over a fixed pulley as shown in figure. The tension in the string connecting B and C is



(a) zero (b) mg/3

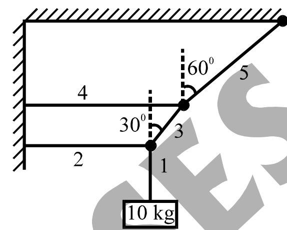
(c) 2mg/3 (d) mg

4. In the pervious problem the force exerted by the string connected to the ceiling on the pulley is

(a) zero (b) mg/3

(c) 2mg/3 (d) 8mg/3

5. The tension in the fifth string is



(a) 200 N (b) 100√3 N

(c) 100 N (d) 200√3 N

6. A homogenous rod with a length L is acted upon by two collinear forces F_1 and F_2 applied to its ends and directed opposite. The magnitude of the pulling force F at the cross-section distant l from F_1 end ($F_1 > F_2$) is

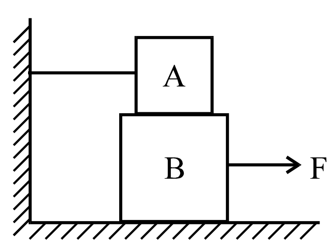
(a) $F_1 + \frac{l}{L}(F_2 - F_1)$

(b) $F_1 + \frac{l}{L}(F_1 - F_2)$

(c) $F_2 + \frac{l}{L}(F_1 - F_2)$

(d) $F_2 + \frac{l}{L}(F_2 - F_1)$

7. A block A of mass 200 kg rests on a block B of mass 300 kg. A is tied with a horizontal string to a wall. Coefficient of friction between A and B is 0.25 and between B and floor is 0.2, The horizontal force F needed to move the block B is (g = 10 m/s^2)



(a) 550 N (b) 1100 N

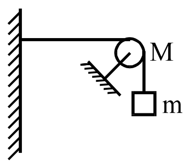
(c) 1500 N (d) 2200 N

8. If the coefficient of friction between an insect and bowl surface is μ and the radius of bowl is r, the maximum height to which the insect can drawn in the bowl is

(a) $\frac{r}{\sqrt{1+\mu^2}}$ (b) $r\left[1-\frac{1}{\sqrt{1+\mu^2}}\right]$

(c) $r\sqrt{1+\mu^2}$ (d) $r\left[\sqrt{1+\mu^2}-1\right]$

9. In the situation shown in figure the block suspended from the light rope. The mass of block and pulley are m and M respectively. The force exerted by the clamp on the pulley is



(a) $\sqrt{(Mg+mg)^2+(mg)^2}$

(b) $\sqrt{(Mg+mg)^2+(Mg)^2}$

(c) $\sqrt{(Mg-mg)^2+(mg)^2}$

(d) $\sqrt{(Mg+mg)^2-(mg)^2}$

10. A block of mass m is sliding on an inclined right angle trough which is inclined at an angle of θ with the horizontal. If μ is the coefficient of kinetic friction, the acceleration of the block is

(a) $g[\sin\theta - \sqrt{2}\,\mu\cos\theta]$

(b) $g[\sin\theta + \sqrt{2}\,\mu\cos\theta]$

(c) $g[\sin\theta - \mu\cos\theta]$

(d) $g[\sin\theta + \mu\cos\theta]$

11. A cart weighing 200 N can roll without friction along a horizontal path. The cart carries a block weighing 20 N. The coefficient of friction between the block and the cart is 0.25 and g = 10 m/s^2. A force of 2 N is applied on the block along the horizontal direction. The acceleration of the block is

(a) 0.09 m/s^2 (b) 0.25 m/s^2

(c) 0.50 m/s^2 (d) 7.5 m/s^2

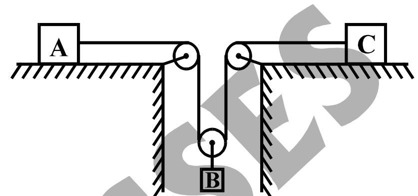
12. Two particles, each of mass m are connected by a light string of length 2L. A continuous force F is applied at the mid point of the string (x = 0) at right angles to the initial position of the string. The acceleration of m in the direction at right angles to F is given by

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

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

where x is the perpendicular distance of one of the particle from the line of action of F.

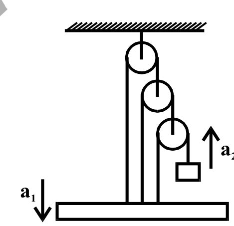
13. Blocks A and C starts from rest and move to the right with acceleration $a_A = 12t$ m/s^2 and $a_c = 3$ m/s^2. The time when block B again comes to rest is



(a) 2 sec (b) 1 sec

(c) 3/2 sec (d) 1/2 sec

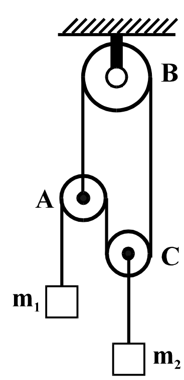
14. The relation between a_1 & a_2 is



(a) $3a_1 = a_2$ (b) $a_1 = 7a_2$

(c) $7a_1 = a_2$ (d) $3a_1 = 7a_2$

15. Consider the system as shown in figure. Neglect the masses of the pulleys and string and also neglect the friction. Let $m_1/m_2 = 1 : 2$.



Then the acceleration of block of mass m_1 is

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

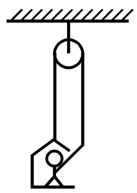
(c) g (d) 2g/3

EXCERCISE BASED ON NEW PATTERN

COMPREHENSION TYPE

Comprehension-1

A man of mass M stands on a trolly of mass m in the figure. A rope attached to the trolley and passing over an overhead pulley allows the man to raise him and the trolley by pulling the rope downward.



1. The minimum force should the man pull the rope so as to prevent himself falling down

(a) $(M + m)g$ (b) $\frac{(M+m)g}{2}$

(c) $\frac{(M+m)g}{3}$ (d) $\frac{(M+m)g}{4}$

2. If the man pull the rope with a force F greater than the minimum force, the acceleration of the (man + trolly) system is

(a) $\frac{2F}{M+m}-g$ (b) $\frac{4F}{M+m}-g$

(c) $\frac{F}{M+m}-g$ (d) $\frac{3F}{M+m}-g$

3. The normal reaction between the man and the trolley is

(a) $\left[\frac{M-m}{M}\right]F$ (b) $\left[\frac{M-m}{m}\right]F$

(c) $\left[\frac{M}{M+m}\right]F$ (d) $\left[\frac{M-m}{M+m}\right]F$

Comprehension-2

A particle of mass 10^{-2} kg is moving along the x-axis under the influence of a force $F(x) = -\frac{K}{2x^2}$, where $K = 10^{-2}$ Nm². At time t = 0, it is at x = 1.0 m and its velocity is v = 0.

4. The velocity of the particle when its reaches x = 0.50 m

(a) 1 m/s towards negative x-axis

(b) 1 m/s towards positive x-axis

(c) zero

(d) 2 m/s towards negative x-axis

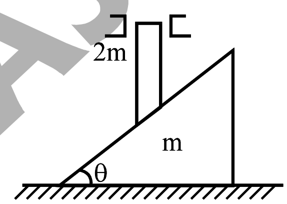
5. The time at which it reaches x = 0.25 m.

(a) $\left(\frac{\pi}{4}+\frac{\sqrt{3}}{4}\right)$sec (b) $\left(\frac{\pi}{4}+\frac{\sqrt{3}}{5}\right)$sec

(c) $\left(\frac{\pi}{4}+\frac{\sqrt{3}}{6}\right)$sec (d) $\left(\frac{\pi}{3}+\frac{\sqrt{3}}{4}\right)$sec

Comprehension-3

The figure shows a rod of mass 2m restricted horizontal by two vertical supports rests on a wedge of mass m. All the surfaces are frictionless. Let the acceleration of rod is a_1 and acceleration of wedge is a_2.



6. The relation between a_1 and a_2 is

(a) $a_1 = a_2 \tan\theta$ (b) $a_1 = a_2 \sin\theta$

(c) $a_1 = a_2 \cos\theta$ (d) $a_1 = a_2$

7. The value of a_1 is

(a) $\frac{g}{2+\cot^2\theta}$ (b) $\frac{g}{1+\cot^2\theta}$

(c) $\frac{2g}{2\tan\theta+\cot\theta}$ (d) $\frac{2g}{2+\cot^2\theta}$

MATRIX-MATCH TYPE

Matching-1

	Column - A		Column - B
(A)	Newton's first law	(P)	Inertial frame
(B)	Accelerated frame	(Q)	non-inertial frame
(C)	Earth	(R)	non-conservative force
(D)	Frictional force	(S)	Electromagnetic force
		(T)	conservative force

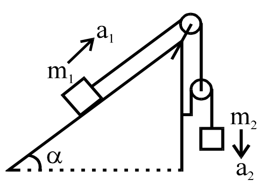
Matching-2

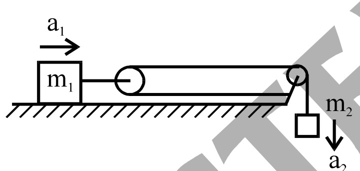
Two blocks of masses 2.9 kg and 1.9 kg are suspended from a rigid support S by two inextensible wires each of length 1 m. The upper wire has negligible mass and the lower wire has uniform mass of 0.2 kg/m. The whose system of blocks, wires and support have an upward acceleration of 0.2 m/s^2. Acceleration due to gravity is 9.8 m/s^2. The tension in the massless wire is T_1, the force exerted by the heavier rope on 1.9 kg is T_2, the force exerted by the heavier rope on 2.9 kg is T_3, the tension at the mid-point at the heavier rope is T_4.

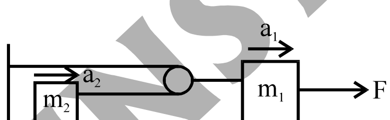
	Column - A	Column - B	
(A)	T_1	(P)	50 N
(B)	T_2	(Q)	30 N
(C)	T_3	(R)	31 N
(D)	T_4	(S)	29 N
		(T)	19 N

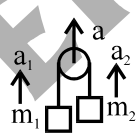
Matching-3

Column - A

(A) 

(B) 

(C) 

(D) 

Column - B

(P) $a = a_1 + a_2$

(Q) $a = \dfrac{a_1 + a_2}{2}$

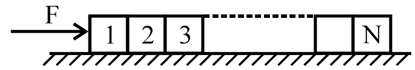
(R) $a_1 = 2a_2$

(S) $2a_1 = a_2$

(T) $a = \dfrac{a_1 - a_2}{2}$

MULTIPLE CORRECT CHOICE TYPE

1. **There are N identical blocks each of mass m are placed as shown in figure. Assume that the surface is smooth and a force F is applied on the block 1.**



Choose the correct statement from the following

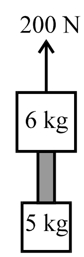
(a) **The acceleration of any block is F/mN**

(b) **The interaction force between second and third block is $\left(1-\dfrac{2}{N}\right)F$**

(c) **The force exerted by (N – 1)th block on Nth block is $\dfrac{F}{N}$**

(d) **If the same force will be applied on the Nth block then the intraction force between first block and second block will change**

2. **Two blocks in figure are connected by uniform rope of mass 4 kg. An upward force of 200 N is applied. Choose the correct statements**



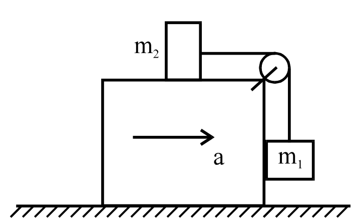
(a) **The net force on the rope is 13.3 N**

(b) **The tension at the mid-point of the rope is 93.3 N**

(c) **The force exerted by the rope on lower block is 66.6 N**

(d) **The force exerted by the rope on upper block is 120 N**

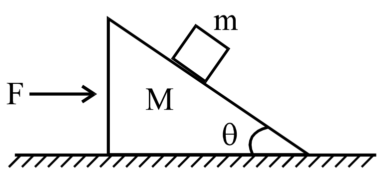
3. **In the figure shown, all the surface are smooth. The bigger block has given an acceleration *a* towards right such that m_1 and m_2 are stationary with respect to bigger block. Let the force exerted by the bigger block on m_1 and m_2 are N and R respectively and the force exerted by the clamp on the pulley is F. Then :**



(a) $a = \frac{m_1 g}{m_2}$ (b) $R = m_2 g$

(c) $F = \sqrt{2}\, m_1 g$ (d) $N = \frac{m_1^2 g}{m_2}$

4. A smaller block of mass m is placed on the wedge of mass M. All the surfaces are smooth. Let the magnitude of the horizontal force F required to keep the block at rest with respect to wedge and the force exerted by the wedge on the smaller block is R. Then :



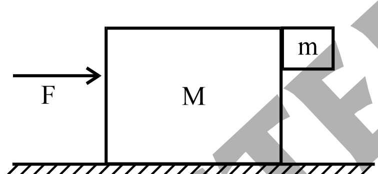
(a) $F = (M + m)g \sin\theta$

(b) $R = mg \sec\theta$

(c) $R = (M + m)g \cot\theta$

(d) $F = (M + m)g \tan\theta$

5. Figure shows two blocks m and M, which are pushed together on a smooth horizontal surface. If the coefficient of friction between the blocks is μ then the possible values of the horizontal force to hold the blocks together is



(a) $\frac{(M+m)g}{\mu}$ (b) $\frac{3(M+m)g}{2\mu}$

(c) $\frac{(M+m)g}{3\mu}$ (d) $\frac{5(M+m)g}{4\mu}$

6. A block of mass *m* is placed on another block of mass *M* lying on a smooth horizontal surface.The coefficient of static friction between *m* and *M* is *μ*. The possible force that can be applied to *m* so that the blocks remains at rest relative to each other is

(a) $\frac{\mu(m+M)mg}{2M}$ (b) $\frac{\mu(m+M)mg}{3M}$

(c) $\frac{\mu(m+M)mg}{M}$ (d) $\frac{\mu(m+M)mg}{4M}$

7. The total mass of an elevator, with an 80 kg man in it, is 1000 kg. It is moving upwards with a speed of 8 m/s. If it is brought to rest over a distance of 16 m, then during retardation, the tension in the supporting cable and the force exerted by the man on the floor are T and N respectively. Then :

(a) T = 8000 N (b) N = 640 N

(c) T = 4000 N (d) N = 320 N

8. A small block starts sliding down an inclined plane subtending an angle θ with the horizontal. The coefficient of friction between the block and plane depends on the distance covered from rest along the plane as $\mu = \mu_0 x$ where μ_0 is a constant. Let the distance covered by the block down the plane till it stops sliding is x_0 and the maximum velocity is v_0. Then :

(a) $x_0 = \frac{2\tan\theta}{\mu_0}$

(b) $x_0 = \frac{\tan\theta}{\mu_0}$

(c) $v_0 = \sin\theta\sqrt{\frac{g}{\mu_0\cos\theta}}$

(d) $v_0 = \sqrt{\frac{g}{\mu_0\cos\theta}}$

9. A ball is projected vertically upward. Consider the air friction. Choose the correct statements

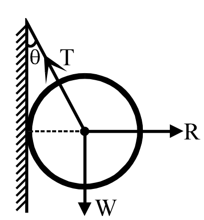
(a) the time of flight of the ball depends upon the mass of the ball.

(b) the time of ascent is greater than the time of descent

(c) the time of ascent is less than the time of descent

(d) $\frac{\text{Time of ascent}}{\text{Time of descent}} = \sqrt{\frac{\text{Acceleration of descent}}{\text{Acceleration of ascent}}}$

10. A metal sphere is hung by a string fixed to a wall. The forces acting on the sphere are shown in figure. Which of the following statements is correct



(a) $\vec{R} + \vec{T} + \vec{W} = 0$ (b) $T^2 = R^2 + W^2$

(c) $T = R + W$ (d) $R = W \tan\theta$

Assertion-Reason Type

Each question contains STATEMENT-1 (Assertion) and STATEMENT-2 (Reason). Each question has 4 choices (A), (B), (C) and (D) out of which ONLY ONE is correct.

(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1

(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1

(C) Statement-1 is True, Statement-2 is False

(D) Statement-1 is False, Statement-2 is True

1. STATEMENT-1 : It is easier to pull than to push a lawn roller.

   STATEMENT-2 : In case of pulling the frictional force will reduced.

2. STATEMENT-1 : Two persons are pulling, the ends of a string in such a way so that the string is stretched horizontally. When a weight of 10 kg is suspended in the middle of the string, the string does not remain horizontal. The persons make it horizontal again by pulling it with a greater force.

   STATEMENT-2 : The tension in the string is non-zero

3. STATEMENT-1 : When a person walks on a rough surface the frictional force exerted by the surface on the person in opposite to the direction of his motion.

   STATEMENT-2 : The origin of frictional force is electromagnet.

4. STATEMENT-1 : The frictional force on a body cannot be zero on the rough surface.

   STATEMENT-2 : The frictional force is acting at the point of contact along the tangent.

5. 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.

6. STATEMENT-1 : A block of mass M is suspended by a light cord C from the ceiling and another stronger cord D is attached to the bottom of the block. The cord D is pulled down by a force T. If the tension T in D is increased steadily, the cord C breaks.

   STATEMENT-2 : When the string B is pulled steadily the force applied to it will be transmitted from string B to A through the mass M and as tension in A will be greater than in B by Mg, the string A will break.

7. STATEMENT-1 : A massless rope is strung over a frictionless pulley. A monkey holds on to one end of the rope, and a mirror, having the same weight as the monkey, is attached to the other end of the rope at the monkey's level. The monkey get away from the image seen in the mirror by climbing down the rope.

   STATEMENT-2 : The force on mirror and monkey remain identical.

8. STATEMENT-1 : Two bodies of mass M and m are allowed to fall from the same height. If the air resistance for each be the same, then both the bodies reach the earth simultaneously.

   STATEMENT-2 : The acceleration of the body depends on their mass.

(Answers) EXCERCISE BASED ON NEW PATTERN

COMPREHENSION TYPE

1. b 2. a 3. d 4. a 5. d 6. a
7. d

MATRIX-MATCH TYPE

1. [A-P ; B-Q ; C-Q ; D-R, S] 2. [A-P ; B-R ; C-S ; D-Q]
3. [A-S, B-S, C-S, D-Q]

MULTIPLE CORRECT CHOICE TYPE

1. a, b, c, d 2. a, b, c, d 3. a, b, c, d 4. b, d 5. a, b, d
6. a, b, c, d 7. a, b 8. a, c 9. a, c, d 10. a, b, d

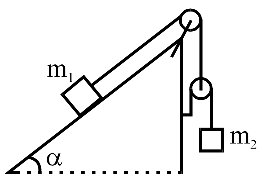
ASSERTION-REASON TYPE

1. A 2. D 3. D 4. D 5. A 6. A
7. D 8. C

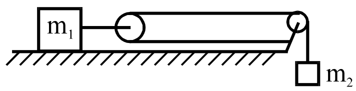
INITIAL STEP EXERCISE (SUBJECTIVE)

1. Consider the following system. Find the acceleration of each body and tension in the string ? Assume that the strings are massless and pulleys are smooth and massless. Assume that surfaces are frictionless.

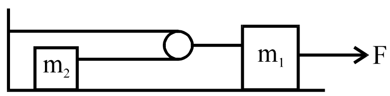
(a)



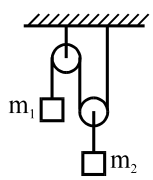
(b)



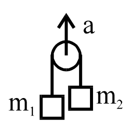
(c)



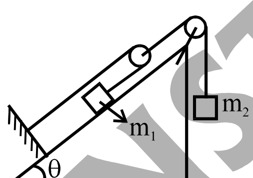
(d)



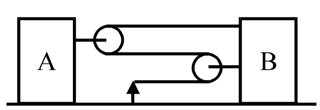
(e)



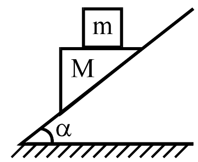
(f)



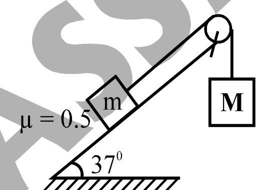
2. In the arrangement shown in figure the block B starts from rest and move towards right with a constant acceleration. After time t the velocity of A with respect to B becomes v. Find the acceleration of A.



3. Block M with another block m over it is placed on a fixed inclined plane of angle α. Find the acceleration of M.

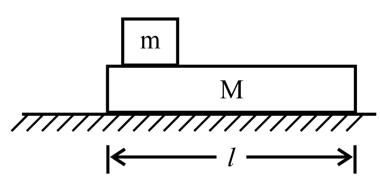


4. In the arrangement shown in the figure if M = 20 kg then determine the minimum and maximum values of mass of the block m to keep the block of mass M stationary.



5. A plank of mass m_1 with a bar of mass m_2 placed on it lies on a smooth horizontal plane. A horizontal force growing with time t as F = αt (α is cosntant) is applied to the bar. Find how the accelerations of the plank a_1 and of the bar a_2 depend on t, if the coefficient of friction between the plank and the bar is μ. Draw the approximate plots of these dependences.

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

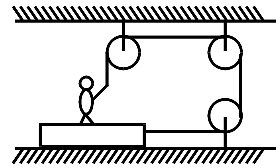


7. A block of mass 2.5 kg is kept on a rough horizontal surface. It is found that the block does not slide if a horizontal force less than 15 N is applied to it. Also it is found that it takes 5 seconds to slide through the first 10 m if a horizontal force of 15 N is applied and the block is gently pushed to start the motion. Taking g = 10 m/s^2, find the coefficient of static friction and kinetic friction between the block and the surface.

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

9. A rod of length l and mass M is fixed to one end of a string. The string passes over a massless, frictionless pulley. A small ball of mass m (<M) is attached to other side of the string. The ball has an opening through which the string passes and the ball can slide along the string with some friction. Initially, the ball is held at level with the lower end of the rod. When set free, both the masses move with constant acceleration. What is the force of friction, if the ball rises to the level of the upper end of the rod in time t ?

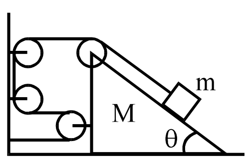
10. The friction coefficient between the board and the floor shown in the figure is μ. Find the maximum force that the man can exert on the rope so that the board does not slip on the floor.



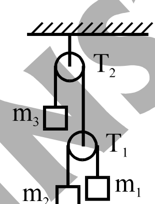
The mass of the man is M and mass of body is m.

FINAL STEP EXERCISE (SUBJECTIVE)

1. Assuming all surfaces to be frictionless and the string to be light and inextensible. Find the acceleration of the wedge.

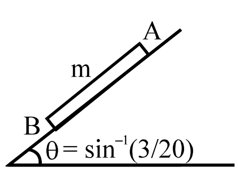


2. A system of three masses m_1, m_2 and m_3 are shown in figure. The pulleys are smooth and massless; the string are massless and inextensible. (a) Find the tension in the strings. (b) Find the acceleration of each mass.



3. A plank of mass m kept on a smooth inclined plane. A man of mass η times the mass of plank moves on the plank, starts from A, such that the plank is at rest, w.r.t. the inclined plane. If he reaches the other end B of the plank in t = 5 sec.

Then find the acceleration & the value of η, if the length of the plank is 50 m.

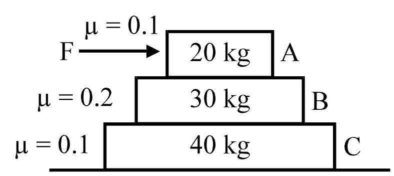


4. A system of masses is shown in fig. with masses and coefficients of friction indicated. Calculate

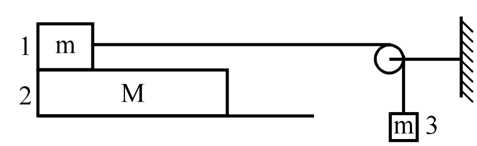
(a) the maximum value of F for which there is no slipping anywhere

(b) The minimum value of F for which B slides on C.

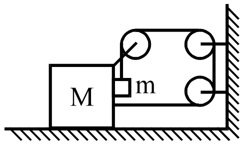
(c) The minimum value of F for which A slips on B.



5. In figure block 1 is one fourth of length l of block 2 of mass also one fourth. No friction exist between block 2 and surface on which it rests. Coefficient of friction is μ_k between 1 and 2. Find the distance block 2 moves when only half of block 1 is still on block 2. Block 1 and block 3 have same mass.

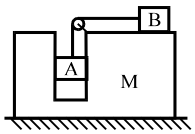


6. Find the acceleration of the block of mass M in the situation of figure.



The coefficient of friction between the two blocks is μ_1 and that between the bigger block and the ground is μ_2.

7. A block of mass M rests on a smooth horizontal surface. Two blocks A and B of masses m and m′ respectively are connected by a string passing over a smooth pulley fixed to M. B rests on the smooth horizontal top surface of M and A can move along a frictionless vertical slot in block M.

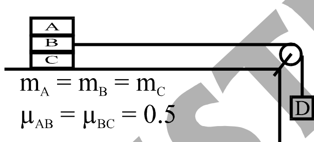


Find the acceleration of M.

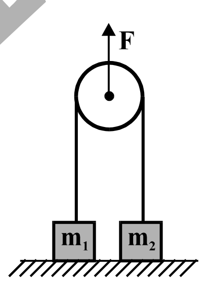
8. (a) Find the maximum mass M_D of the block D so that blocks A, B & C move without slipping over each other.

(b) If the mass of block D is just greater then M_D which block would slip with respect to B.

(c) For what value of M_D will both A & C start slipping.

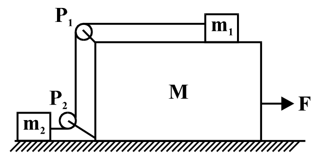


9. At t = 0, both masses m_1 = 1 kg and m_2 = 2 kg touch the ground and the string is taut which passes over a movable pulley. A vertically upward, time dependent force F = 2t (F in N, t in s) is applied to the pulley.



Calculate (i) the time when m_1 is lifted off the ground and (ii) m_2 is lifted off the ground (iii) when t = 25 s, what is the acceleration of the masses as seen by an observer outside.

10. 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_2 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 $g = 10 m/s^2$)

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

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

ANSWERS (SINGLE CORRECT CHOICE TYPE)

1.	b	9.	a
2.	b	10.	a
3.	c	11.	a
4.	d	12.	a
5.	a	13.	d
6.	a	14.	c
7.	c	15.	c
8.	b		

ANSWERS SUBJECTIVE (INITIAL STEP EXERCISE)

1. (d) $a_1 = \frac{2(2m_1 - m_2)g}{4m_1 + m_2}$

2. $\frac{3v}{t}$

3. $\frac{(M + m)g \sin\alpha}{M + m\sin^2\alpha}$

4. 20 kg ≤ m ≤ 100 kg

5. $a_1 = a_2 = \frac{\alpha t}{m_1 + m_2}$ $t < t_0$, where, $t_0 = \frac{\mu m_2(m_1 + m_2)g}{m_1\alpha}$,

for $t \geq t_0$, $a_1 = \frac{\mu m_2 g}{m_1}$, $a_2 = \frac{\alpha t - \mu m_2 g}{m_2}$ $t \geq t_0$

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

7. $\mu_s = 0.6$, $\mu_k = 0.52$

8. $\mu mg/(1 + \mu^2)^{1/2}$, $\theta = \tan^{-1}\mu$

9. $\frac{2lmM}{(M - m)t^2}$

10. $\frac{\mu(m + M)g}{(1 + \mu)}$

ANSWERS SUBJECTIVE (FINAL STEP EXERCISE)

1. $\frac{3mg\sin\theta}{2m(5 - 3\cos\theta) + M}$

2. $a_1 = \left[\frac{4m_1m_2 + m_1m_3 - 3m_2m_3}{4m_1m_2 + m_3(m_1 + m_2)}\right]g$

3. (a) $\eta = 3/5$; (b) acceleration = 4m/s^2

4. (a) 20 N, (b) never, (c) 20 N

5. $\frac{7\mu_k l}{8(2 - 3\mu_k)}$

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

7. $a_A = \frac{mm'g}{M(m + m') + m^2 + 2mm'}$

8. (a) M = 3m, (b) A, (c) never

9. (i) 10 s (ii) 20 s (iii) 15 m/s^2, 2.5m/s^2

10. $f_1 = 30$ N, $f_2 = 5$N, F = 60 N, T = 18 N, a = $\frac{3}{5}$ m/s^2