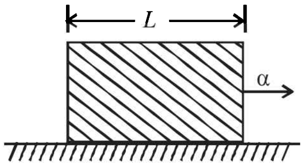
CHAPTER 3

Laws of Motion

Section-A JEE Advanced/ IIT-JEE

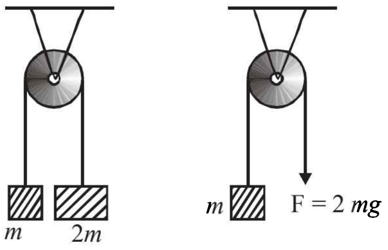
A Fill in the Blanks

1. A block of mass 1 kg lies on a horizontal surface in a truck. The coefficient of static friction between the block and the surface is 0.6. If the acceleration of the truck is 5 m/s^2, the frictional force acting on the block is ..... newtons. *(1984 - 2 Marks)*
2. A uniform rod of length L and density ρ is being pulled along a smooth floor with a horizontal acceleration α (see Fig.) The magnitude of the stress at the transverse cross-section through the mid- point of the rod is .... *(1993 - 1 Mark)*



B True/False

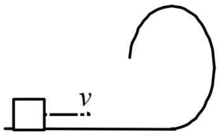
1. A rocket moves forward by pushing the surrounding air backwards. *(1980)*
2. When a person walks on a rough surface, the frictional force exerted by the surface on the person is opposite to the direction of his motion. *(1981 - 2 Marks)*
3. A simple pendulum with a bob of mass *m* swings with an angular amplitude of 40°. When its angular displacement is 20°, the tension in the string is greater than *mg* cos 20°. *(1984 - 2 Marks)*
4. The pulley arrangements of Figs. (a) and (b) are identical. The mass of the rope is negligible. In (a) the mass *m* is lifted up by attaching a mass 2*m* to the other end of the rope. In (b), *m* is lifted up by pulling the other end of the rope with a constant downward force $F = 2\,mg$. The acceleration of *m* is the same in both cases *(1984 - 2 Marks)*

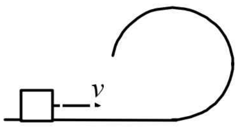


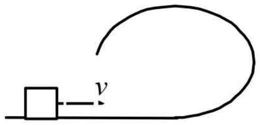
(a) (b)

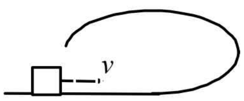
C MCQs with One Correct Answer

1. 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 *(1980)*
   (a) 1.5 m/sec. (b) 60 m/sec.
   (c) 0.1 m/sec. (d) 5 m/sec.
2. A block of mass 2 kg rests on a rough inclined plane making an angle of 30° 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) $0.7 \times 9.8 \times \sqrt{3}$N
   (c) $9.8 \times \sqrt{3}$N (d) 0.7×9.8 N *(1980)*
3. A block of mass 0.1 is held against a wall applying a horizontal force of 5 N on the block. If the coefficient of friction between the block and the wall is 0.5, the magnitude of the frictional force acting on the block is : *(1994 - 1 Mark)*
   (a) 2.5 N (b) 0.98 N
   (c) 4.9 N (d) 0.49 N
4. 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 *(2001S)*

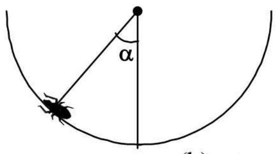
(a) 

(b) 

(c) 

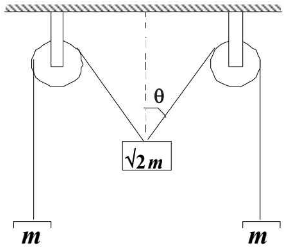
(d) 

5. 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 *(2001S)*



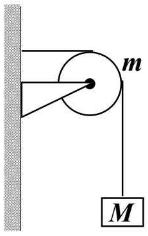
   (a) $\cot \alpha = 3$ (b) $\tan \alpha = 3$
   (c) $\sec \alpha = 3$ (d) $\text{cosec}\, \alpha = 3$

6. The pulleys and strings shown in the figure are smooth and of negligible mass. For the system to remain in equilibrium, the angle θ should be *(2001S)*



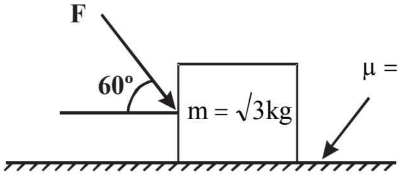
(a) 0°
(b) 30°
(c) 45°
(d) 60°

7. 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 *(2001S)*



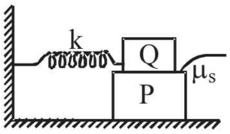
(a) $\sqrt{2}$ Mg (b) $\sqrt{2}$ mg
(c) $\sqrt{(M+m)^2+m^2}\ g$ (d) $\sqrt{(M+m)^2+M^2}\ g$

8. What is the maximum value of the force F such that the block shown in the arrangement, does not move? *(2003S)*



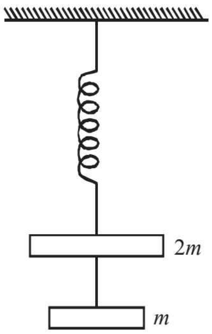
(a) 20N (b) 10N
(c) 12N (d) 15N

9. 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. *(2004S)*



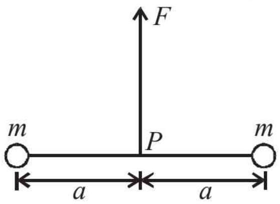
(a) $kA/2$ (b) kA
(c) $\mu_s$mg (d) zero

10. 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) *(2006 - 3M, –1)*



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

11. 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 *(2007)*



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

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

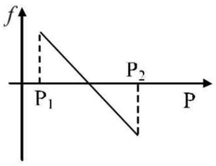
(c) $\frac{F}{2m}\frac{x}{a}$

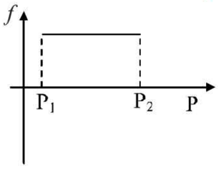
(d) $\frac{F}{2m}\frac{\sqrt{a^2-x^2}}{x}$

12. 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 *(2007)*
(a) 0° (b) 30°
(c) 45° (d) 90°

13. A block of base 10 cm × 10 cm and height 15 cm is kept on an inclined plane. The coefficient of friction between them is $\sqrt{3}$. The inclination θ of this inclined plane from the horizontal plane is gradually increased from 0°. Then *(2009)*
(a) at θ = 30°, the block will start sliding down the plane
(b) the block will remain at rest on the plane up to certain θ and then it will topple
(c) at θ = 60°, the block will start sliding down the plane and continue to do so at higher angles
(d) at θ = 60°, the block will start sliding down the plane and on further increasing θ, it will topple at certain θ.

14. A block of mass m is on an inclined plane of angle θ. The coefficient of friction between the block and the plane is μ and tan θ > μ. The block is held stationary by applying a force P parallel to the plane. The direction of force pointing up the plane is taken to be positive. As P is varied from P_1 = mg(sinθ – μ cosθ) to P_2 = mg(sinθ + μ cosθ), the frictional force f versus P graph will look like *(2010)*

(a)


(b)


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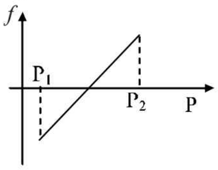

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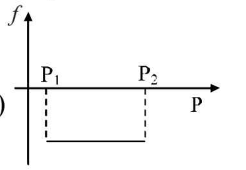
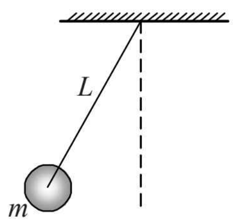


15. A ball of mass (m) 0.5 kg is attached to the end of a string having length (L) 0.5 m. The ball is rotated on a horizontal circular path about vertical axis. The maximum tension that the string can bear is 324 N. The maximum possible value of anguar velocity of ball (in radian/s) is *(2011)*

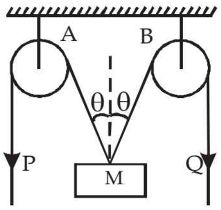


(a) 9 (b) 18
(c) 27 (d) 36

16. The image of an object, formed by a plano-convex lens at a distance of 8 m behind the lens, is real is one-third the size of the object. The wavelength of light inside the lens is $\frac{2}{3}$ times the wavelength in free space. The radius of the curved surface of the lens is *(JEE Adv. 2013)*
(a) 1m (b) 2m
(c) 3m (d) 6m

D MCQs with One or More than One Correct

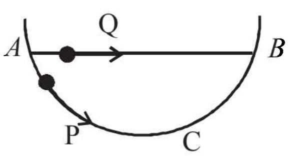
1. In the arrangement shown in the Fig, the ends *P* and *Q* of an unstretchable string move downwards with uniform speed *U*. Pulleys *A* and *B* are fixed. *(1982 -3 Marks)*
Mass *M* moves upwards with a speed
(a) $2U\cos\theta$
(b) $U/\cos\theta$
(c) $2U/\cos\theta$
(d) $U\cos\theta$



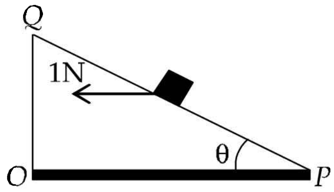
2. A reference frame attached to the earth *(1986 - 2 Marks)*
(a) is an inertial frame by definition.
(b) cannot be an inertial frame because the earth is revolving round the sun.
(c) is an inertial frame because Newton's laws are applicable in this frame.
(d) cannot be an inertial frame because the earth is rotating about its own axis.

3. 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 θ ($|\theta| < \phi$), 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 : *(1986 - 2 Marks)*
(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) $T = Mg\cos\theta$

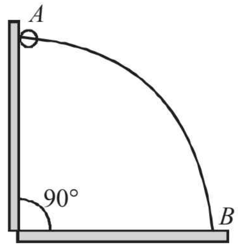
4. A particle *P* is sliding down a frictionless hemispherical bowl. It passes the point *A* at $t = 0$. At this instant of time, the horizontal component of its velocity is *v*. A bead *Q* of the same mass as *P* is ejected from *A* at $t = 0$ along the horizontal string *AB*, with the speed *v*. Friction 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 : *(1993-2 Marks)*
(a) $t_P < t_Q$
(b) $t_P = t_Q$
(c) $t_P > t_Q$
(d) $\dfrac{t_P}{t_Q} = \dfrac{\text{length of arc } ACB}{\text{length of arc } AB}$



5. A small block of mass of 0.1 kg lies on a fixed inclined plane PQ which makes an angle θ with the horizontal. A horizontal force of 1 N acts on the block through its centre of mass as shown in the figure. *(2012)*
The block remains stationary if (take $g = 10\ m/s^2$)
(a) $\theta = 45°$
(b) $\theta > 45°$ and a frictional force acts on the block towards P.
(c) $\theta > 45°$ and a frictional force acts on the block towards Q.
(d) $\theta < 45°$ and a frictional force acts on the block towards Q.

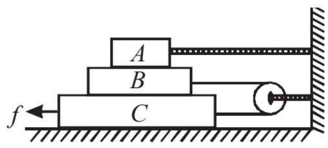


6. A wire, which passes through the hole in a small bead, is bent in the form of quarter of a circle. The wire is fixed vertically on ground as shown in the figure. The bead is released from near the top of the wire and it slides along the wire without friction. As the bead moves from *A* to *B*, the force it applies on the wire is *(JEE Adv. 2014)*
(a) always radially outwards
(b) always radially inwards
(c) radially outwards initially and radially inwards later
(d) radially inwards initially and radially outwards later

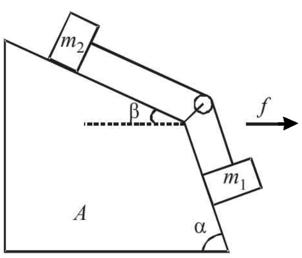


E Subjective Problems

1. In the diagram shown, the blocks *A*, *B* and *C* weight, 3 kg, 4 kg and 5 kg respectively. The coefficient of sliding friction between any two surface is 0.25. *A* is held at rest by a massless rigid rod fixed to the wall while *B* and *C* are connected by a light flexible cord passing around a frictionless pulley. Find the force *F* necessary to drag *C* along the horizontal surface to the left at constant speed. Assume that the arrangement shown in the diagram, *B* on *C* and *A* on *B*, is maintained all through. ($g = 9.8\ m/s^2$) *(1978)*

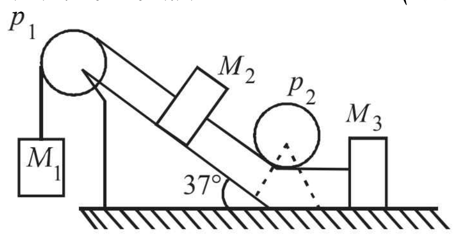


2. Two cubes of masses m_1 and m_2 be on two frictionless slopes of block *A* which rests on a horizontal table. The cubes are connected by a string which passes over a pulley as shown in the figure. To what horizontal acceleration *f* should the whole system (that is blocks and cubes) be subjected so that the cubes do not slide down the planes. What is the tension of the string in this situation? *(1978)*



3. A horizontal uniform rope of length *L*, resting on a frictionless horizontal surface, is pulled at one end by force *F*. What is the tension in the rope at a distance *l* from the end where the force is applied? *(1978)*

4. Masses M_1, M_2 and M_3 are connected by strings of negligible mass which pass over massless and friction less pulleys P_1 and P_2 as shown in fig The masses move such that the portion of the string between P_1 and P_2 in parallel to the inclined plane and the portion of the string between P_2 and M_3 is horizontal. The masses M_2 and M_3 are 4.0 kg each and the coefficient of kinetic friction between the masses and the surfaces is 0.25. The inclined plane makes an angle of 37° with the horizontal. *(1981- 6 Marks)*



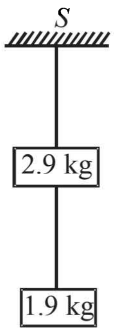
If the mass M_1 moves downwards with a uniform velocity, find

(i) the mass of M_1

(ii) The tension in the horizontal portion of the string ($g = 9.8$ m/sec², $\sin 37° \simeq 3/5$)

5. A particle of mass m rests on a horizontal floor with which it has a coefficient of static friction μ. It is desired to make the body move by applying the minimum possible force F. Find the maguitude of F and the direction in which it has to be applied. *(1987 - 7 Marks)*

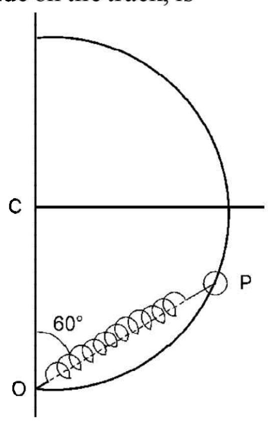
6. Two blocks of mass 2.9 kg and 1.9 kg are suspended from a rigid support S by two inextensible wires each of length 1 meter, see fig. The upper wire has negligible mass and the lower wire has a uniform mass of 0.2 kg/m. The whole system of blocks wires and support have an upward acceleration of 0.2 m/s². Acceleration due to gravity is 9.8 m/s². *(1989 - 6 Marks)*



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

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

7. A smooth semicircular wire-track of radius R is fixed in a vertical plane. One end of a massless spring of natural length $3R/4$ is attached to the lowest point O of the wire-track. A small ring of mass m, which can slide on the track, is attached to the other end of the spring. The ring is held stationary at point P such that the spring makes an angle of 60° with the vertical. The spring constant $K = mg/R$. Consider the instant when the ring is released, and (i) draw the free body diagram of the ring, (ii) determine the tangential acceleration of the ring and the normal reaction. *(1996 - 5 Marks)*

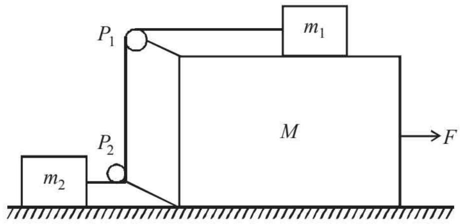


8. A particle of mass 10^{-2} kg is moving along the positive x axis under the influence of a force $F(x) = -K/(2x^2)$ where $K = 10^{-2}\ N m^2$. At time $t = 0$ it is at $x = 1.0$ m and its velocity is $v = 0$. *(1998 - 8 Marks)*

(a) Find its velocity when it reaches $x = 0.50$ m.

(b) Find the time at which it reaches $x = 0.25$ m.

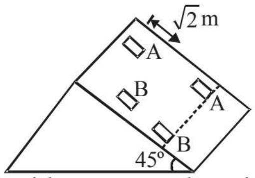
9. In the figure masses m_1, m_2 and M are 20 kg, 5 kg and 50 kg respectively. The coefficient of friction between M and ground is zero. The coefficient of friction between m_1 and M and that between m_2 and ground is 0.3. The pulleys and the strings are massless. The string is perfectly horizontal between 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/s². *(2000 - 10 Marks)*



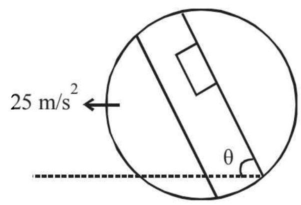
(a) Draw a free body diagram for mass M, clearly showing all the forces.

(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 F it is found that $f_1 = 2f_2$. Find f_1 and f_2. Write equations of motion of all the masses. Find F, tension in the string and acceleration of the masses.

10. Two block A and B of equal masses are placed on rough inclined plane as shown in figure. When and where 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. Co-efficient of kinetic friction for the blocks A and B are 0.2 and 0.3 respectively ($g = 10$ m/s²). *(2004 - Marks)*



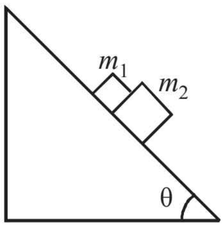
11. A circular disc with a groove along its diameter is placed horizontally on a rough surface. A block of mass 1 kg is placed as shown. The co-efficient of friction between the block and all surfaces of groove and horizontal surface in contact is $\mu = \dfrac{2}{5}$. The disc has an acceleration of 25 m/s² towards left. Find the acceleration of the block with respect to disc. Given $\cos\theta = \dfrac{4}{5}$, $\sin\theta = \dfrac{3}{5}$. *(2006 - 6M)*



F Match the Following

DIRECTIONS (Q. No. 1) : *Following question has matching lists. The codes for the lists have choices (a), (b), (c) and (d) out of which ONLY ONE is correct.*

1. A block of mass $m_1 = 1$ kg another mass $m_2 = 2$ kg, are placed together (see figure) on an inclined plane with angle of inclination θ. Various values of θ are given in List-I. The coefficient of friction between the block m_1 and plane is always zero. The coefficient of static and dynamic friction between the block m_2 and the plane are equal to $\mu = 0.3$. In List-II expressions for the friction on block m_2 are given. Match the correct expression of the friction in List-II with the angles given in List-I, and choose the correct option. The acceleration due to gravity is denoted by g.



[**Useful information:** $\tan(5.5°) \approx 0.1$; $\tan(11.5°) \approx 0.2$; $\tan(16.5°) \approx 0.3$] *(JEE Adv. 2014)*

	List-I		List-II
P.	$\theta = 5°$	**1.**	$m_2 g \sin\theta$
Q.	$\theta = 10°$	**2.**	$(m_1 + m_2) g \sin\theta$
R.	$\theta = 15°$	**3.**	$\mu m_2 g \cos\theta$
S.	$\theta = 20°$	**4.**	$\mu (m_1 + m_2) g \cos\theta$

Code:

(a) P-1, Q-1, R-1, S-3 (b) P-2, Q-2, R-2, S-3 (c) P-2, Q-2, R-2, S-4 (d) P-2, Q-2, R-3, S-3

G Comprehension Based Questions

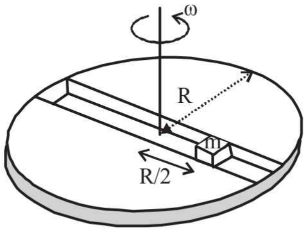
PARAGRAPH

A frame of reference that is accelerated with respect to an inertial frame of reference is called a non-inertial frame of reference. A coordinate system fixed on a circular disc rotating about a fixed axis with a constant angular velocity ω is an example of non-inertial frame of reference. The relationship between the force $\vec{F}_{rot}$ experienced by a particle of mass m moving on the rotating disc and the force $\vec{F}_{in}$ experienced by the particle in an inertial frame of reference is

$$\vec{F}_{rot} = \vec{F}_{in} + 2m\left(\vec{v}_{rot} \times \vec{\omega}\right) + m\left(\vec{\omega} \times \vec{r}\right) \times \vec{\omega}.$$

where $\vec{v}_{rot}$ is the velocity of the particle in the rotating frame of reference and $\vec{r}$ is the position vector of the particle with respect to the centre of the disc.

Now consider a smooth slot along a diameter of a disc of radius R rotating counter-clockwise with a constant angular speed ω about its vertical axis through its center. We assign a coordinate system with the origin at the center of the disc, the x-axis along the slot, the y-axis perpendicular to the slot and the z-axis along the rotation axis $\left(\vec{\omega} = \omega\hat{k}\right)$. A small block of mass m is gently placed in the slot at $\vec{r}(R/2)\hat{i}$ at $t = 0$ and is constrained to move only along the slot.



1. The distance r of the block at time t is *(JEE Adv. 2016)*

(a) $\frac{R}{4}\left(e^{\omega t} + e^{-\omega t}\right)$ (b) $\frac{R}{2}\cos\omega t$

(c) $\frac{R}{4}\left(e^{2\omega t} + e^{-2\omega t}\right)$ (d) $\frac{R}{2}\cos 2\omega t$

2. The net reaction of the disc on the block is *(JEE Adv. 2016)*

(a) $\frac{1}{2}m\omega^2 R\left(e^{2\omega t} - e^{-2\omega t}\right)\hat{j} + mg\hat{k}$

(b) $\frac{1}{2}m\omega^2 R\left(e^{\omega t} - e^{-\omega t}\right)\hat{j} + mg\hat{k}$

(c) $-m\omega^2 R\cos\omega t\,\hat{j} - mg\hat{k}$

(d) $m\omega^2 R\,\text{sins}\,\omega t\,\hat{j} - mg\hat{k}$

H Assertion & Reason Type Questions

1. **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.

STATEMENT-2 : For every action there is an equal and opposite reaction. *(2007)*

(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.

2. **STATEMENT-1 :** It is easier to pull a heavy object than to push it on a level ground and

STATEMENT-2 : The magnitude of frictional force depends on the nature of the two surfaces in contact. *(2008)*

(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

I Integer Value Correct Type

1. A block is moving on an inclined plane making an angle 45° with the horizontal and the coefficient of friction is μ. The force required to just push it up the inclined plane is 3 times the force required to just prevent it from sliding down. If we define $N = 10\,\mu$, then N is *(2011)*

Section-B JEE Main / AIEEE

1. If a body looses half of its velocity on penetrating 3 cm in a wooden block, then how much will it penetrate more before coming to rest? **[2002]**
(a) 1 cm (b) 2 cm
(c) 3 cm (d) 4 cm.

2. A lift is moving down with acceleration a. A man in the lift drops a ball inside the lift. The acceleration of the ball as observed by the man in the lift and a man standing stationary on the ground are respectively **[2002]**
(a) g, g (b) $g-a, g-a$
(c) $g-a, g$ (d) a, g

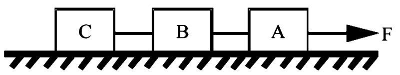
3. When forces F_1, F_2, F_3 are acting on a particle of mass m such that F_2 and F_3 are mutually perpendicular, then the particle remains stationary. If the force F_1 is now removed then the acceleration of the particle is **[2002]**
(a) F_1/m (b) F_2F_3/mF_1
(c) $(F_2-F_3)/m$ (d) F_2/m.

4. Two forces are such that the sum of their magnitudes is 18 N and their resultant is 12 N which is perpendicular to the smaller force. Then the magnitudes of the forces are **[2002]**
(a) 12 N, 6 N (b) 13 N, 5 N
(c) 10 N, 8 N (d) 16N, 2N.

5. Speeds of two identical cars are u and $4u$ at the specific instant. The ratio of the respective distances in which the two cars are stopped from that instant is **[2002]**
(a) 1 : 1 (b) 1 : 4
(c) 1 : 8 (d) 1 : 16.

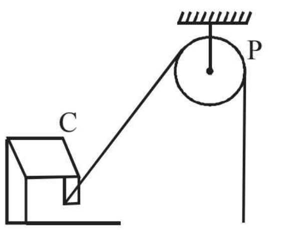
6. A light string passing over a smooth light pulley connects two blocks of masses m_1 and m_2 (vertically). If the acceleration of the system is $g/8$, then the ratio of the masses is **[2002]**
(a) 8 : 1 (b) 9 : 7
(c) 4 : 3 (d) 5 : 3.

7. Three identical blocks of masses $m = 2$ kg are drawn by a force $F = 10.2$ N with an acceleration of $0.6\ \text{ms}^{-2}$ on a frictionless surface, then what is the tension (in N) in the string between the blocks B and C? **[2002]**



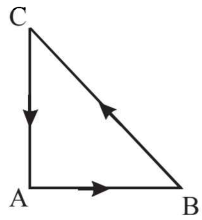
(a) 9.2 (b) 3.4
(c) 4 (d) 9.8

8. One end of a massless rope, which passes over a massless and frictionless pulley P is tied to a hook C while the other end is free. Maximum tension that the rope can bear is 360 N. With what value of maximum safe acceleration (in ms^{-2}) can a man of 60 kg climb on the rope? **[2002]**
(a) 16
(b) 6
(c) 4
(d) 8.



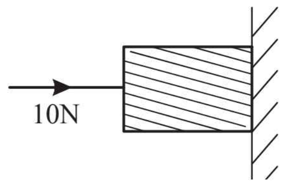
9. A spring balance is attached to the ceiling of a lift. A man hangs his bag on the spring and the spring reads 49 N, when the lift is stationary. If the lift moves downward with an acceleration of $5\ \text{m/s}^2$, the reading of the spring balance will be **[2003]**
(a) 24 N (b) 74 N
(c) 15 N (d) 49 N

10. Three forces start acting simultaneously on a particle moving with velocity, $\vec{v}$. These forces are represented in magnitude and direction by the three sides of a triangle ABC. The particle will now move with velocity **[2003]**



(a) less than $\vec{v}$
(b) greater than $\vec{v}$
(c) $|v|$ in the direction of the largest force BC
(d) $\vec{v}$, remaining unchanged

11. A horizontal force of 10 N 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) 20 N (b) 50 N **[2003]**
(c) 100 N (d) 2 N

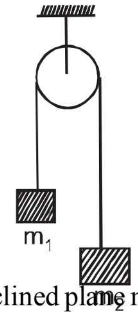
12. A marble block of mass 2 kg lying on ice when given a velocity of 6 m/s is stopped by friction in 10 s. Then the coefficient of friction is **[2003]**
(a) 0.02 (b) 0.03
(c) 0.04 (d) 0.06

13. A block of mass M is pulled along a horizontal frictionless surface by a rope of mass m. If a force P is applied at the free end of the rope, the force exerted by the rope on the block is
(a) $\dfrac{Pm}{M+m}$ (b) $\dfrac{Pm}{M-m}$ **[2003]**
(c) P (d) $\dfrac{PM}{M+m}$

14. A light spring balance hangs from the hook of the other light spring balance and a block of mass M kg hangs from the former one. Then the true statement about the scale reading is **[2003]**
(a) Both the scales read M kg each
(b) The scale of the lower one reads M kg and of the upper one zero
(c) The reading of the two scales can be anything but the sum of the reading will be M kg
(d) Both the scales read $M/2$ kg each

15. A rocket with a lift-off mass 3.5×10^4 kg is blasted upwards with an initial acceleration of 10m/s^2. Then the initial thrust of the blast is **[2003]**
(a) 3.5×10^5 N (b) 7.0×10^5 N
(c) 14.0×10^5 N (d) 1.75×10^5 N

16. Two masses $m_1 = 5$kg and $m_2 = 4.8$ kg tied to a string are hanging over a light frictionless pulley. What is the acceleration of the masses when left free to move ? $(g = 9.8 m/s^2)$ [2004]



(a) $5\ m/s^2$
(b) $9.8\ m/s^2$
(c) $0.2\ m/s^2$
(d) $4.8\ m/s^2$

17. A block rests on a rough inclined plane making an angle of 30° with the horizontal. The coefficient of static friction between the block and the plane is 0.8. If the frictional force on the block is 10 N, the mass of the block (in kg) is (take $g = 10\ m/s^2$) [2004]
(a) 1.6 (b) 4.0
(c) 2.0 (d) 2.5

18. A smooth block is released at rest on a 45° incline and then slides a distance 'd'. The time taken to slide is 'n' times as much to slide on rough incline than on a smooth incline. The coefficient of friction is [2005]
(a) $\mu_k = \sqrt{1-\frac{1}{n^2}}$ (b) $\mu_k = 1-\frac{1}{n^2}$
(c) $\mu_s = \sqrt{1-\frac{1}{n^2}}$ (d) $\mu_s = 1-\frac{1}{n^2}$

19. A parachutist after bailing out falls 50 m without friction. When parachute opens, it decelerates at $2\ m/s^2$. He reaches the ground with a speed of 3 m/s. At what height, did he bail out ? [2005]
(a) 182 m (b) 91 m
(c) 111 m (d) 293 m

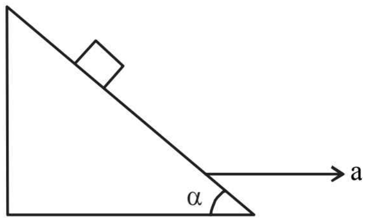
20. A bullet fired into a fixed target loses half of its velocity after penetrating 3 cm. How much further it will penetrate before coming to rest assuming that it faces constant resistance to motion ? [2005]
(a) 2.0 cm (b) 3.0 cm
(c) 1.0 cm (d) 1.5 cm

21. An annular ring with inner and outer radii R_1 and R_2 is rolling without slipping with a uniform angular speed. The ratio of the forces experienced by the two particles situated on the inner and outer parts of the ring, $\frac{F_1}{F_2}$ is [2005]
(a) $\left(\frac{R_1}{R_2}\right)^2$ (b) $\frac{R_2}{R_1}$ (c) $\frac{R_1}{R_2}$ (d) 1

22. The upper half of an inclined plane with inclination ϕ is perfectly smooth while the lower half is rough. A body starting from rest at the top will again come to rest at the bottom if the coefficient of friction for the lower half is given by [2005]
(a) $2 \cos \phi$ (b) $2 \sin \phi$
(c) $\tan \phi$ (d) $2 \tan \phi$

23. A particle of mass 0.3 kg subject to a force $F = -kx$ with $k = 15$ N/m. What will be its initial acceleration if it is released from a point 20 cm away from the origin ? [2005]
(a) $15\ m/s^2$ (b) $3\ m/s^2$
(c) $10\ m/s^2$ (d) $5\ m/s^2$

24. A block is kept on a frictionless inclined surface with angle of inclination 'α'. The incline is given an acceleration 'a' to keep the block stationary. Then a is equal to [2005]



(a) g cosec α (b) $g / \tan \alpha$
(c) $g \tan \alpha$ (d) g

25. Consider a car moving on a straight road with a speed of 100 m/s. The distance at which car can be stopped is $[\mu_k = 0.5]$ [2005]
(a) 1000 m (b) 800 m
(c) 400 m (d) 100 m

26. A mass of M kg is suspended by a weightless string. The horizontal force that is required to displace it until the string makes an angle of 45° with the initial vertical direction is [2006]
(a) $Mg(\sqrt{2}+1)$ (b) $Mg\sqrt{2}$
(c) $\frac{Mg}{\sqrt{2}}$ (d) $Mg(\sqrt{2}-1)$

27. A ball of mass 0.2 kg is thrown vertically upwards by applying a force by hand. If the hand moves 0.2 m while applying the force and the ball goes upto 2 m height further, find the magnitude of the force. (Consider g = 10 m/s^2). [2006]
(a) 4 N (b) 16 N
(c) 20 N (d) 22 N

28. A player caught a cricket ball of mass 150 g moving at a rate of 20 m/s. If the catching process is completed in 0.1s, the force of the blow exerted by the ball on the hand of the player is equal to [2006]
(a) 150 N (b) 3 N
(c) 30 N (d) 300 N

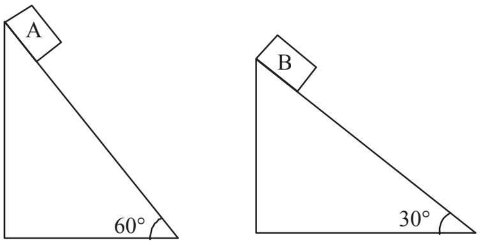
29. A coin is placed on a horizontal platform which undergoes vertical simple harmonic motion of angular frequency ω. The amplitude of oscillation is gradually increased. The coin will leave contact with the platform for the first time [2006]
(a) at the mean position of the platform
(b) for an amplitude of $\frac{g}{\omega^2}$
(c) for an amplitude of $\frac{g^2}{\omega^2}$
(d) at the highest position of the platform

30. A block of mass m is connected to another block of mass M by a spring (massless) of spring constant k. The block are kept on a smooth horizontal plane. Initially the blocks are at rest and the spring is unstretched. Then a constant force F starts acting on the block of mass M to pull it. Find the force of the block of mass m. **[2007]**

(a) $\frac{MF}{(m+M)}$ (b) $\frac{mF}{M}$

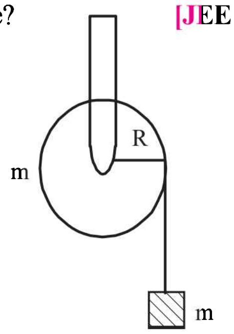
(c) $\frac{(M+m)F}{m}$ (d) $\frac{mF}{(m+M)}$

31. Two fixed frictionless inclined planes making an angle 30° and 60° with the vertical are shown in the figure. Two blocks A and B are placed on the two planes. What is the relative vertical acceleration of A with respect to B ? **[2010]**



(a) 4.9 ms^{-2} in horizontal direction
(b) 9.8 ms^{-2} in vertical direction
(c) Zero
(d) 4.9 ms^{-2} in vertical direction

32. A mass 'm' is supported by a massless string wound around a uniform hollow cylinder of mass m and radius R. If the string does not slip on the cylinder, with what acceleration will the mass fall or release? **[JEE Main 2014]**



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

(b) $\frac{g}{2}$

(c) $\frac{5g}{6}$

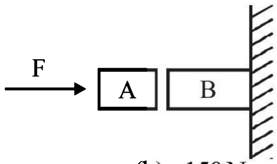
(d) g

33. A block of mass m is placed on a surface with a vertical cross section given by $y = \frac{x^3}{6}$. If the coefficient of friction is 0.5, the maximum height above the ground at which the block can be placed without slipping is: **[JEE Main 2014]**

(a) $\frac{1}{6}$m (b) $\frac{2}{3}$m

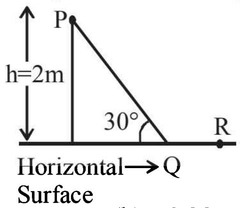
(c) $\frac{1}{3}$m (d) $\frac{1}{2}$m

34. Given in the figure are two blocks A and B of weight 20 N and 100 N, respectively. These are being pressed against a wall by a force F as shown. If the coefficient of friction between the blocks is 0.1 and between block B and the wall is 0.15, the frictional force applied by the wall on block B is: **[JEE Main 2015]**



(a) 120 N (b) 150 N
(c) 100 N (d) 80 N

35. A point particle of mass m, moves long the uniformly rough track PQR as shown in the figure. The coefficient of friction, between the particle and the rough track equals μ. The particle is released, from rest from the point P and it comes to rest at a point R. The energies, lost by the ball, over the parts, PQ and QR, of the track, are equal to each other, and no energy is lost when particle changes direction from PQ to QR.
The value of the coefficient of friction μ and the distance x (= QR), are, respectively close to : **[JEE Main 2016]**



(a) 0.29 and 3.5 m (b) 0.29 and 6.5 m
(c) 0.2 and 6.5 m (d) 0.2 and 3.5 m

3 Laws of Motion

Section-A : JEE Advanced/ IIT-JEE

A	**1.** 5	**2.** $\rho L\alpha/2$				
B	**1.** F	**2.** F	**3.** T	**4.** F		
C	**1.** (c)	**2.** (a)	**3.** (b)	**4.** (a)	**5.** (a)	
	6. (c)	**7.** (d)	**8.** (a)	**9.** (a)	**10.** (c)	
	11. (b)	**12.** (d)	**13.** (b)	**14.** (a)	**15.** (d)	
	16. (c)					
D	**1.** (b)	**2.** (b, d)	**3.** (b, c)	**4.** (a)	**5.** (a, c)	**6.** (d)

E

1. 71.05 N

2. $f=\dfrac{(m_1\sin\alpha+m_2\sin\beta)\,g}{m_1\cos\alpha+m_2\cos\beta};\ T=\dfrac{m_1m_2\,g\sin(\alpha-\beta)}{m_1\cos\alpha+m_2\cos\beta}$

3. $T=F\left(1-\dfrac{\ell}{L}\right)$

4. 4.2 Kg, 9.8 N

5. $mg\sin\theta,\ \tan^{-1}\mu$

6. 20N, 50N

7. $\dfrac{5\sqrt{3}}{8}g,\ \dfrac{3mg}{8}$

8. **(a)** $-1\,\text{m/s}$ **(b)** $\left(\dfrac{\pi}{3}+\dfrac{\sqrt{3}}{4}\right)$ sec

9. **(b)** F = 60 N; T = 18 N

$a=\dfrac{3}{5}\,\text{m/s}^2,\ f_1=15\,\text{N},\ f_2=30\,\text{N}$

10. $8\sqrt{2}\,\text{m},\ 7\sqrt{2}\,\text{m},\ 2\text{ sec}.$

11. $10\,\text{m/s}^2$

F	**1.** (d)	
G	**1.** (a)	**2.** (b)
H	**1.** (b)	**2.** (b)
I	**1.** 5	

Section-B : JEE Main/ AIEEE

1. (a)	**2.** (c)	**3.** (a)	**4.** (b)	**5.** (d)	**6.** (b)
7. (b)	**8.** (c)	**9.** (a)	**10.** (d)	**11.** (d)	**12.** (d)
13. (d)	**14.** (a)	**15.** (b)	**16.** (c)	**17.** (c)	**18.** (b)
19. (d)	**20.** (c)	**21.** (c)	**22.** (d)	**23.** (c)	**24.** (c)
25. (a)	**26.** (d)	**27.** (d)	**28.** (c)	**29.** (b)	**30.** (d)
31. (a)	**32.** (b)	**33.** (a)	**34.** (a)	**35.** (a)	

Section-A JEE Advanced/ IIT-JEE

A. Fill in the Blanks

1. As seen by the observer on the ground, the frictional force is responsible to move the mass with an acceleration of $5\,\text{m/s}^2$.

Therefore, frictional force $= m\times a = 1\times 5 = 5\,N$.

2. Let A be the area of cross-section of the rod.

Consider the back half portion of the rod.

Mass of half portion of the rod $=\dfrac{\rho AL}{2}$

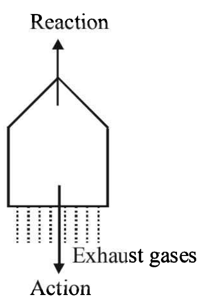
The force responsible for its acceleration is

$f=\dfrac{\rho AL}{2}\times\alpha \quad \therefore\ \text{Stress}=\dfrac{f}{A}=\dfrac{\rho L\alpha}{2}$

B. True/ False

1. **KEY CONCEPT :** The rocket moves forward when the exhaust gases are thrown backward.

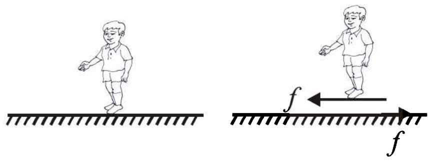
Here exhaust gases thrown backwards is action and rocket moving forward is reaction.



Note : This phenomenon takes place in the absence of air as well.

2. **KEY CONCEPT :** Friction force opposes the relative motion of the surface of contact.

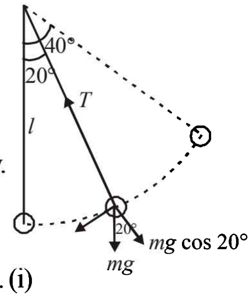
When a person walks on a rough surface, the foot is the surface of contact. When he pushes the foot backward, the motion of surface of contact tends to be backwards. Therefore the frictional force will act forward (in the direction of motion of the person)



3. As the angular amplitude of the pendulum is 40°, the bob will be in the mid of the equilibrium position and the extreme position as shown in the figure

Note : For equilibrium of the bob, $T - mg\cos 20° = \frac{mv^2}{l}$,

where l is the length of the pendulum and is the velocity of the bob.



$\therefore \quad T = mg\cos 20° + \frac{mv^2}{l}$

$\frac{mv^2}{l}$ is always a positive quantity.

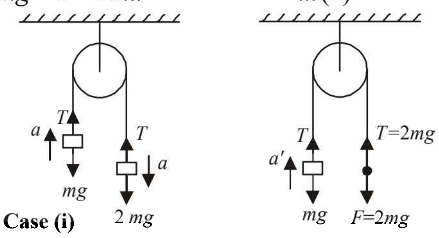
Hence, $T > mg\cos 20°$.

4. **Case (i)** For mass m

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

For mass $2m$

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



Case (i) **Case (ii)**

From (i) and (ii)

$a = g/3$

Case (ii) $T - mg = ma'$

$2mg - mg = ma'$ $[\because T = 2mg]$

$\therefore \quad a' = g$

Hence, $a < a'$

C. MCQs with ONE Correct Answer

1. (c) $F = ma$

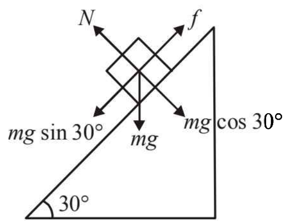
$\Rightarrow \quad a = \frac{F}{m} = \frac{5\times10^4}{3\times10^7} = \frac{5}{3}\times10^{-3}\,\text{ms}^{-2}$

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

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

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

2. (a) The force acting on the block along the incline to shift the block downwards



$= mg\sin\theta = 2\times9.8\sin30° = 9.8\,N$

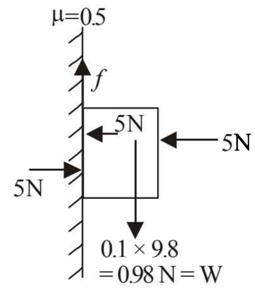
The limiting frictional force

$f_l = \mu_s mg\cos\theta = 0.7\times2\times9.8\times\frac{\sqrt{3}}{2} = 11.8\,N$

Note : The frictional force is never greater than the force tending to produce relative motion.

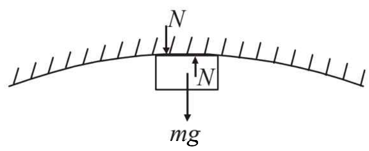
Therefore the frictional force is 9.8 N

3. (b) Limiting frictional force, $f_l = \mu_s N = 0.5\times5 = 2.5\,N$. But force tending to produce relative motion is the weight (W) of the block which is less than f_l. Therefore, the frictional force is equal to the weight, the magnitude of the frictional force f has to balance the weight 0.98 N acting downwards.



Therefore the frictional force = 0.98 N.

4. (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 $(mg + N)$.

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

where r is the radius of curvature at the top.

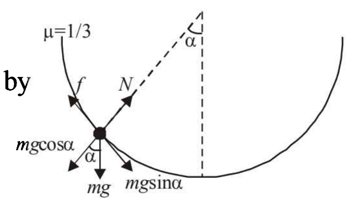
If the surface is smooth then on applying conservation of mechanical energy, the velocity of the body is always same at the top most point. Hence, N and r have inverse relationship. From the figure it is clear that r is minimum for first figure, therefore N will be maximum.

Note : If we do not assume the surface to be smooth, we cannot reach to a conclusion.

5. (a) **KEY CONCEPT :**

For the maximum possible value of α, $mg\sin\alpha$ will also be maximum and equal to the frictional force.

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.

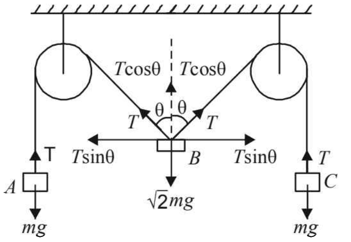
$\therefore \quad N = mg\cos\alpha$

$f = mg\sin\alpha$

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

$\therefore \quad \mu\, mg\cos\alpha = mg\sin\alpha \Rightarrow \cot\alpha = \frac{1}{\mu} \Rightarrow \cot\alpha = 3$

6. (c) The tension in both strings will be same due to symmetry.



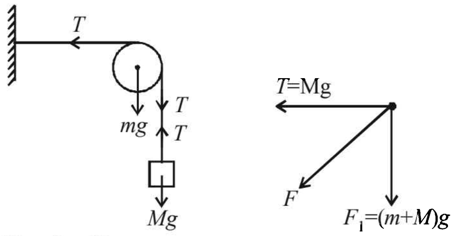
For equilibrium in vertical direction for body B we have

$$\sqrt{2}\,mg = 2T\cos\theta$$

$\therefore \quad \sqrt{2}\,mg = 2(mg)\cos\theta \qquad [\because T = mg, \text{(at equilibrium)}]$

$\therefore \quad \cos\theta = \dfrac{1}{\sqrt{2}} \Rightarrow \theta = 45°$

7. (d) At equilibrium $T = Mg$



F.B.D. of pulley

$F_1 = (m+M)g$

The resultant force on pulley is

$F = \sqrt{F_1^2 + T^2} = [\sqrt{(m+M)^2 + M^2}\,]g$

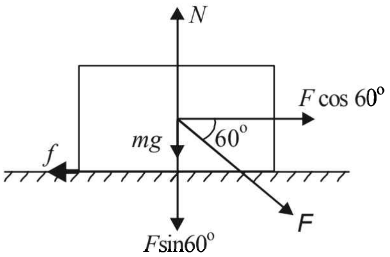
8. (a) The forces acting on the block are shown. Since the block is not moving forward for the maximum force F applied, therefore

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

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

and $F\sin 60° + mg = N$... (ii)

From (i) and (ii)



$$F\cos 60° = \mu\,[F\sin 60° + mg]$$

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

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

9. (a) Let ω be the angular frequency of the system.

The maximum acceleration of the system,

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

The force of friction provides this acceleration.

$$\therefore \quad f = ma = m\left(\frac{kA}{2m}\right) = \frac{kA}{2}$$

10. (c) 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.

$$\therefore \quad 3mg - 2mg = 2m \times a \quad \therefore \quad \frac{g}{2} = a$$

11. (b) The acceleration of mass m is due to the force $T\cos\theta$

$$\therefore \quad T\cos\theta = ma \quad \Rightarrow \quad a = \frac{T\cos\theta}{m} \qquad \text{... (i)}$$

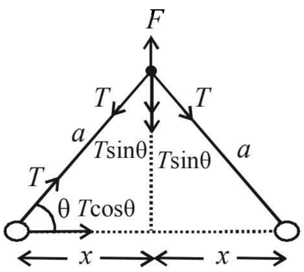
also, $F = 2T\sin\theta \quad \Rightarrow \quad T = \dfrac{F}{2\sin\theta}$ ... (ii)

From (i) and (ii)

$$a = \left(\frac{F}{2\sin\theta}\right)\frac{\cos\theta}{m}$$

$$= \frac{F}{2m\tan\theta} = \frac{F}{2m}\frac{x}{\sqrt{a^2 - x^2}}$$

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



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

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

Here, $\vec{F}.\vec{P} = 0$ But $\vec{F}.\vec{p} = Fp\cos\theta$

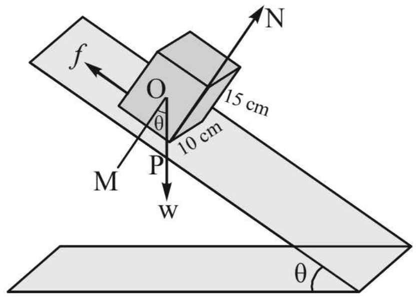
$\therefore \quad \cos\theta = 0 \Rightarrow \theta = 90°$.

13. (b) For the block to slide, the angle of inclination should be equal to the angle of repose, i.e.,

$\tan^{-1}\mu = \tan^{-1}\sqrt{3} = 60°$.

Therefore, option (a) is wrong.

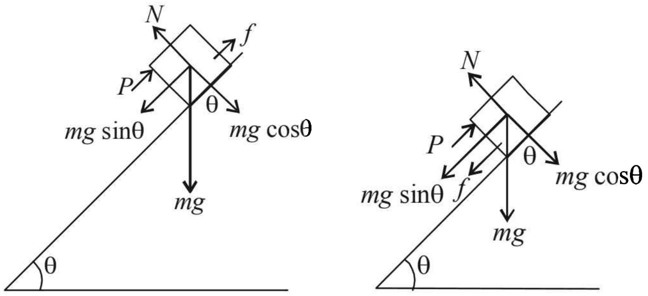
For the block to topple, the condition of the block will be as shown in the figure.



In ΔPOM, $\tan\theta = \dfrac{PM}{OM} = \dfrac{5\,\text{cm}}{7.5\,\text{cm}} = \dfrac{2}{3}$

For this, $\theta < 60°$. From this we can conclude that the block will topple at lesser angle of inclination. Thus the block will remain at rest on the plane up to a certain anlgle θ and then it will topple.

14. **(a)** As $\tan\theta > \mu$, the block has a tendency to move down the incline. Therfore a force P is applied upwards along the incline. Here, at equilibrium $P + f = mg\sin\theta \Rightarrow f = mg\sin\theta - P$



Now as P increases, f decreases linearly with respect to P.

When $P = mg\sin\theta, f = 0$.

When P is increased further, the block has a tendency to move upwards along the incline.

Therefore the frictional force acts downwards along the incline.

Here, at equilibrium $P = f + mg\sin\theta$

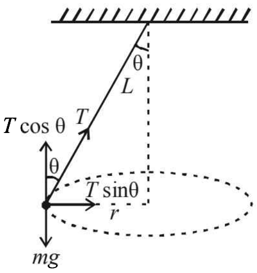
$\therefore \quad f = P - mg\sin\theta$

Now as P increases, f increases linearly w.r.t P.

This is represented by graph (a) .

15. **(d)** Here, the horizontal component of tension provides the necessary centripetal force.

$\therefore T\sin\theta = mr\omega^2$



From (i) and (ii)

$T \times \frac{r}{L} = mr\omega^2 \left[\because \sin\theta = \frac{r}{L}\right]$

$\therefore \omega = \sqrt{\frac{T}{mL}} = \sqrt{\frac{324}{0.5 \times 0.5}}$

$= \frac{18}{0.5} = 36\text{ rad/s}$

16. **(c)** For a plano convex lens

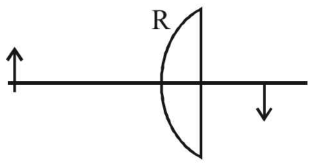
$\frac{1}{f} = \frac{(\mu - 1)}{R} = \frac{1}{v} - \frac{1}{u}$ ...(i)

Here $\mu = \frac{\lambda_a}{\lambda_m} = \frac{\lambda_a}{\frac{2}{3}\lambda_a} = \frac{3}{2} = 1.5$

Where λ_a = wavelength of light in air

λ_m = wavelength of light in water

v = 8m



Also $m = \frac{v}{u} = -\frac{1}{3}$

$\therefore u = -24$ cm.

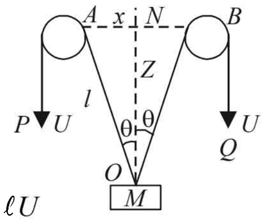
From (i) $\frac{1.5 - 1}{R} = \frac{1}{8} - \left(\frac{1}{-24}\right) = \frac{1}{8} + \frac{1}{24} = \frac{1}{6}$

$\therefore R = 3m$ option (c) is correct

D. MCQs with ONE or MORE THAN ONE Correct

1. **(b)** This is a problem based on constraint motion. The motion of mass M is constraint with the motion of P and Q. Let $AN = x$, $NO = z$. Then velocity of mass is $\frac{dz}{dt}$. Also, let $OA = \ell$. then $\frac{d\ell}{dt} = U$

From ΔANO, using pythagorous theorem



$\therefore \quad x^2 + z^2 = \ell^2$

Here x is a constant.

Differentiating the above equation w.r.t to t

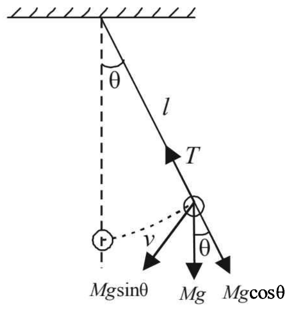
$0 + 2z\frac{dz}{dt} = 2\ell\frac{d\ell}{dt} \Rightarrow zv_M = \ell U$

$\Rightarrow v_M = \frac{\ell}{z}U = \frac{U}{z/\ell} = \frac{U}{\cos\theta} \quad \left(\because \cos\theta = \frac{z}{\ell}\right)$

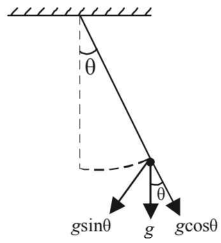
2. **(b, d)** Since earth is an accelerated frame and hence, cannot be an inertial frame.

Note : 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.

3. **(b, c)** Since the body is moving in a circular path therefore it needs centripetal force $\left(\frac{Mv^2}{\ell}\right)$.

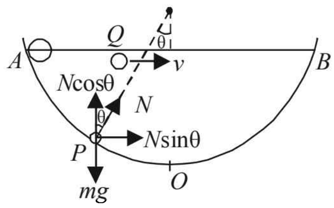


$\therefore \quad T - Mg\cos\theta = \frac{Mv^2}{\ell}$

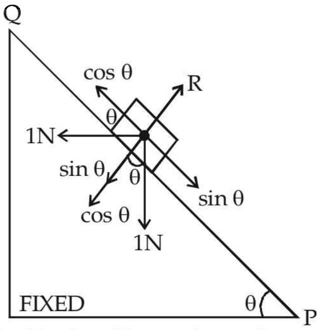


Also, the tangential acceleration acting on the mass is $g\sin\theta$.

4. **(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 $t_P < t_Q$.



5. **(a, c)** The forces are resolved as shown in the figure. When $\theta = 45°$, $\sin\theta = \cos\theta$

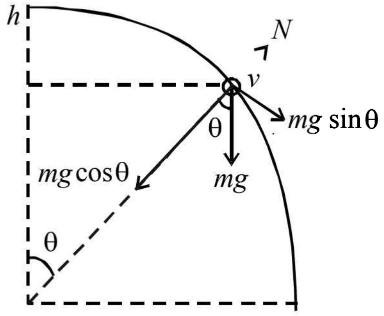


The block will remain stationary and the frictional force is zero.

When $\theta > 45°$, $\sin\theta > \cos\theta$

Therefore a frictional force acts towards Q.

6. **(d)**



As the bead is moving in the circular path

$$\therefore\ mg\cos\theta - N = \frac{mv^2}{R}$$

$$\therefore\ N = mg\cos\theta - \frac{mv^2}{R} \qquad ...(1)$$

By energy conservation, $\frac{1}{2}mv^2 = mg\left[R - R\cos\theta\right]$

$$\therefore\ \frac{v^2}{R} = 2g(1-\cos\theta) \qquad ..(2)$$

From (1) and (2)

$$N = mg\cos\theta - m\left[2g - 2g\cos\theta\right]$$

$$N = mg\cos\theta - 2mg + 2mg\cos\theta$$

$$N = 3mg\cos\theta - 2mg$$

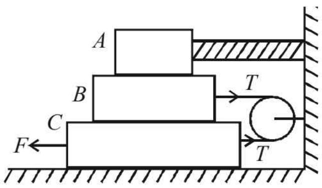
$$\Rightarrow\quad N = mg(3\cos\theta - 2)$$

Clearly N is positive (acts radially outwards) when $\cos\theta > \frac{2}{3}$

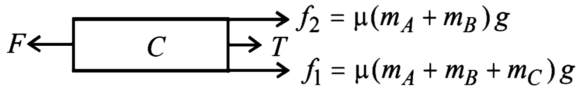
Similarly, N acts radially inwards if $\cos\theta < \frac{2}{3}$

E. Subjective Problems

1. When force F is applied on C, the block C will move towards left.

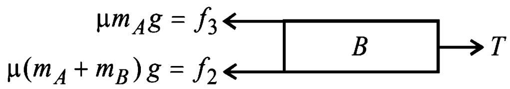


The F.B.D. for mass C is



As C is moving with constant speed $F = f_1 + f_2 + T$ ... (i)

F.B.D. for mass B is



As B is moving with constant speed $f_2 + f_3 = T$ (ii)

Subtracting (ii) from (i)

$$F - (f_2 + f_3) = f_1 + f_2 + T - T = f_1 + f_2$$

$$\Rightarrow\quad F = f_1 + 2f_2 + f_3 = \mu(m_A + m_B + m_C)g + 2\mu(m_A + m_B)g + \mu m_A g$$

$$F = \mu(4m_A + 3m_B + m_C)g$$

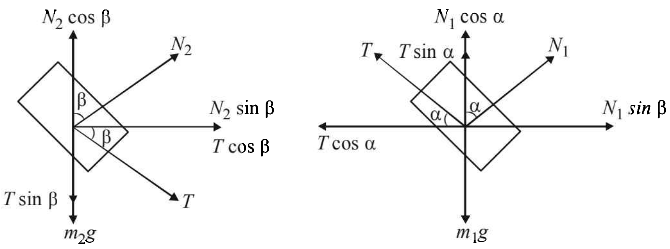
$$= 0.25\,[4\times 3 + 3\times 4 + 5]\times 9.8 = 71.05\,N$$

2. **Without Pseudo Force**

F.B.D for mass m_2

$$N_2\cos\beta = T\sin\beta + m_2 g \qquad ...(i)$$

and $(N_2\sin\beta + T\cos\beta) = m_2 f$ ...(ii)



FBD for mass m_1

$$N_1\cos\alpha + T\sin\alpha = m_1 g \qquad ...(iii)$$

and $(N_1\sin\alpha - T\cos\alpha) = m_1 f$ ... (iv)

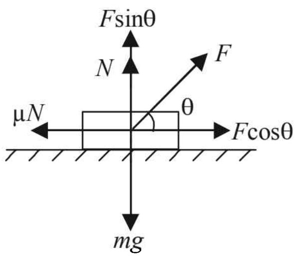
On solving the four equations, we get the above results.

3. From equation (i) $T = \frac{M}{L}(L-\ell)a$

Also, $F = Ma$ $\quad\therefore\ \frac{T}{F} = \left(\frac{L-\ell}{L}\right) \Rightarrow T = F\left(1 - \frac{\ell}{L}\right)$

4. **(a)** If M_1, M_2 and M_3 are considered as a system, then the force responsible to more them is M_1g and the retarding force is $(M_2g\sin\theta + \mu M_2 g\cos\theta + \mu M_3 g)$. These two should be equal as the system is moving with constant velocity.

5. Let F be the force applied to move the body at an angle θ to the horizontal.



The body will move when

$$F\cos\theta = \mu N \quad ...(i)$$

Applying equilibrium of forces in the vertical direction we get

$$F\sin\theta + N = mg$$

$$\Rightarrow\quad N = mg - F\sin\theta \quad ...(ii)$$

$\Rightarrow$ From (i) and (ii)

$$F = \frac{\mu mg}{\cos\theta + \mu\sin\theta} \quad ...(iii)$$

Differentiating the above equation w.r.t. θ , we get

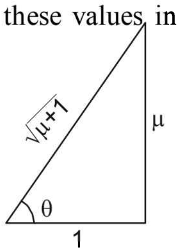
$$\frac{dF}{d\theta}=\frac{\mu mg}{(\cos\theta+\mu\sin\theta)^2}[-\sin\theta+\mu\cos\theta]=0$$

$\Rightarrow \quad \theta=\tan^{-1}\mu$

This is the angle for minimum force.

To find the minimum force substituting these values in equation (iii)

$$\sin\theta=\frac{\mu}{\sqrt{\mu^2+1}},\quad \cos\theta=\frac{1}{\sqrt{\mu^2+1}}$$



$$F=\frac{\mu mg}{\frac{1}{\sqrt{\mu^2+1}}+\frac{\mu}{\sqrt{\mu^2+1}}\times\mu}$$

$$\Rightarrow \quad F=\frac{\mu mg(\sqrt{\mu^2+1})}{\mu^2+1}=\frac{\mu mg}{\sqrt{\mu^2+1}}$$

$\Rightarrow \quad F=mg\sin\theta$

6. Let λ be the mass per unit length of lower wire.

Let us consider the dotted portion as a system and the tension T accelerates the system upwards

$\therefore \quad T-(m_1+\lambda\ell)g=(m_1+\lambda\ell)a$

$\therefore \quad T=(m_1+\lambda\ell)(a+g)$

$=(1.9+0.2\times0.5)(9.8+0.2)=2\times10=20\,N$

To find tension T' Let us consider the dotted portion given in figure (2)

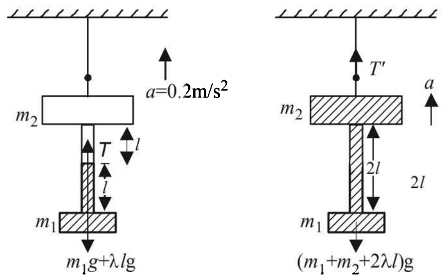


Fig. (1) Fig. (2)

$T'-(m_2g+\lambda\times2\ell g+m_1g)=(m_1+\lambda2\ell+m_2)a$

$\therefore \quad T'=(m_1+\lambda2\ell+m_2)(a+g)$

$=(1.9+0.2\times1+2.9)(10)=5\times10=50\,N.$

Alternatively considering m_1, m_2 and lower wire as a system

$T'-5g=5a$

7.

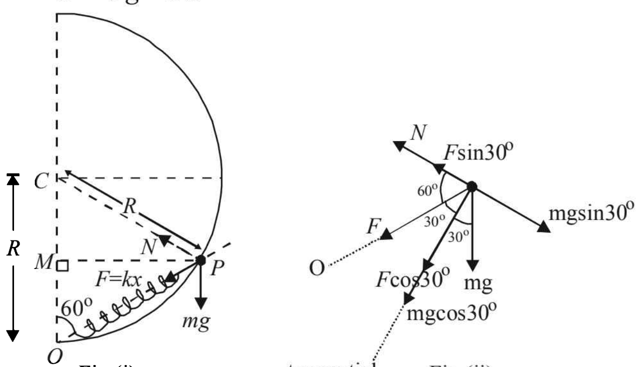


Fig (i) Fig (ii)

In ΔOCP, $OC=CP=R$

$\therefore \quad \angle COP=\angle CPO=60^\circ \Rightarrow \angle OCP=60^\circ$

$\therefore \quad \Delta OCP$ is an equilateral triangle $\Rightarrow OP=R$

$\therefore \quad$ Extension of string $=R-\frac{3R}{4}=\frac{R}{4}=x$

The forces acting are shown in the figure (i)

The free body diagram of the ring is shown in fig. (ii)

Force in the tangential direction

$=F\cos30^\circ+mg\cos30$

$=[kx+mg]\cos30^\circ$

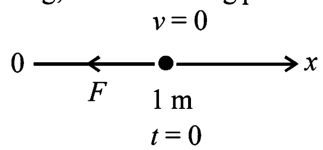
$F_t=\frac{5mg}{8}\sqrt{3} \quad \therefore F_t=ma_t \quad \Rightarrow \quad a_t=\frac{5\sqrt{3}}{8}g$

Also, when the ring is just released

$N+F\sin30^\circ=mg\sin30^\circ$

$\Rightarrow \quad N=(mg-F)\sin30^\circ=\left(mg-\frac{mg}{4}\right)\times\frac{1}{2}=\frac{3mg}{8}$

8. $m=10^{-2}$ kg, motion is along positive X-axis



$F(x)=-\frac{K}{2x^2}$, $K=10^{-2}\,Nm^2$; At $t=0, x=1.0$ m

and $V=0$

(a) $F(x)=\frac{-K}{2x^2}$ or $m\left(\frac{dV}{dx}\right)V=-\frac{K}{2x^2}$

or $\quad m\int_0^v VdV=-\int_1^x\frac{K}{2x^2}dx$

or $\quad \frac{mV^2}{2}=\left[\frac{K}{2x}\right]_1^x=\frac{K}{2}\left(\frac{1}{x}-1\right)$

or $\quad V^2=\frac{K}{m}\left(\frac{1}{x}-1\right)$ or $|\vec{V}|=\pm\sqrt{\frac{K}{m}\left(\frac{1}{x}-1\right)}$ ... (i)

Initially the particle was moving in $+X$ direction at $x=1$. When the particle is at $x=0.5$, obviously its velocity will be in $-X$ direction. The force acting in $-X$ direction first decreases the speed of the particle, bring it momentarily at rest and then changes the direction of motion of the particle.

When x = 0.5 m : $|\vec{V}|=-\sqrt{\frac{K}{m}\left(\frac{1}{0.5}-1\right)}$

$$=-\sqrt{\frac{K}{m}}=-\sqrt{\frac{10^{-2}}{10^{-2}}}=-1\,m/s$$

(b) As $\frac{K}{m}=1$ m/s, hence from (i)

$$V=\frac{dx}{dt}=-\sqrt{\frac{1-x}{x}}$$

Note : We have chosen –ve sign because force tends to decrease the displacement with time

$$\sqrt{\frac{x}{1-x}}dx=-dt;\int_1^{0.25}\sqrt{\frac{x}{1-x}}dx=\int_0^t-dt$$

Put $x = \sin^2\theta$, $dx = 2\sin\theta\cos\theta\, d\theta$

So, $\int_{\pi/2}^{\pi/6} 2\sin^2\theta\, d\theta = -t$

$\cos 2\theta = 1 - 2\sin^2\theta;\quad 2\sin^2\theta = 1 - \cos 2\theta$

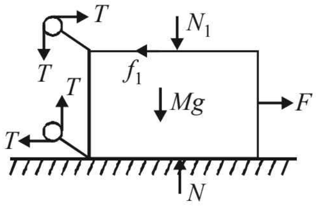
$\int_{\pi/2}^{\pi/6} (1-\cos 2\theta)\, d\theta = -t; \left[\theta - \sin\frac{2\theta}{2}\right]_{\pi/2}^{\pi/6} = -t$

$\frac{\pi}{6} - \frac{1}{2}\sin\frac{\pi}{3} - \frac{\pi}{2} - \frac{1}{2}\sin\pi = -t$

$\therefore \quad t = \left(\frac{\pi}{3} + \frac{\sqrt{3}}{4}\right)\text{sec}.$

9. 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



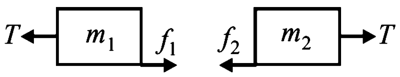
(B) The maximum value of f_1 is

$(f_1)_{max} = (0.3)(20)(10) = 60\,N$

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 :



Note : 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.

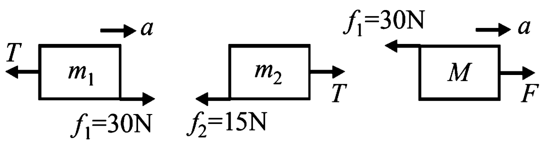
In the second case, when m_1 and m_2 both move

$f_2 = (f_2)\max = 15\,N$

Therefore, $f_1 = 2f_2 = 30\,N$

Note : Since $f_1 < (f_1)_{max}$, there is no relative motion between m_1 and M, i.e., all the masses move with same acceleration, say 'a'.

Free body diagrams and equations of motion are as follows:



For m_1 : $30 - T = 20\,a$ ... (i)

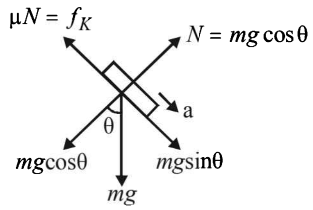
For m_2 : $T - 15 = 5\,a$ ... (ii)

For M : $F - 30 = 50\,a$ ... (iii)

Solving these three equations, we get,

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

10.



$a = \frac{mg\sin\theta - \mu_k mg\cos\theta}{m}$

$\therefore \quad a_A = g\sin\theta - \mu_{k,A}\, g\cos\theta$ ... (i)

and $a_B = g\sin\theta - \mu_{k,B}\, g\cos\theta$ ... (ii)

Putting values we get

$a_A = 4\sqrt{2}\,m/s^2$ and $a_B = 3.5\sqrt{2}\,m/s^2$

Let a_{AB} is relative acceleration of A w.r.t. B. Then

$a_{AB} = a_A - a_B$

$L = \sqrt{2}\,m$

[where L is the relative distance between A and B]

Then $L = \frac{1}{2}a_{AB}t^2$

or $t^2 = \frac{2L}{a_{AB}} = \frac{2L}{a_A - a_B}$

Putting values we get, $t^2 = 4$ or $t = 2s$.

Distance moved by B during that time is given by

$S = \frac{1}{2}a_B t^2 = \frac{1}{2}\times 3.5\sqrt{2}\times 4 = 7\sqrt{2}\,m$

Similarly for $A = 8\sqrt{2}$ m.

11. Applying pseudo force ma and resolving it.

Applying $F_{net} = ma_r$

$ma\cos\theta - (f_1 + f_2) = ma_r$

$ma\cos\theta - \mu N_1 - \mu N_2 = ma_r$

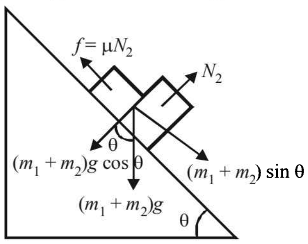
$ma\cos\theta - \mu ma\sin\theta - \mu\, mg = ma_r$

$\Rightarrow \quad a_r = a\cos\theta - \mu a\sin\theta - \mu g$

$= 25\times\frac{4}{5} - \frac{2}{5}\times 25\times\frac{3}{5} - \frac{2}{5}\times 10 = 10\,m/s^2$

F. Match the Following

1. **(d)** If $(m_1 + m_2)\sin\theta < \mu N_2$ the bodies will be at rest i.e., $(m_1 + m_2)g\sin\theta < \mu m_2\, g\cos\theta$



$\tan\theta < \frac{\mu m_2 g}{(m_1 + m_2)g}$

$\Rightarrow \quad \tan\theta < \frac{\mu m_2}{m_1 + m_2}$

$\Rightarrow \quad \tan\theta < \frac{0.3\times 2}{1+2}$

$\Rightarrow \quad \tan\theta < 0.2$

i.e., If the angle $\theta < 11.5°$ the frictional force is less than

$\mu N_2 = \mu m_2 g = 0.3 \times 2 \times g = 0.6\,g$

and is equal to $(m_1 + m_2)g\sin\theta$

At $\theta = 11.5°$ the bodies are on the verge of moving, $f = 0.6\,g$

At $\theta > 11.5°$ the bodies start moving and $f = 0.6\,g$

The above relationship is true for (d).

G. Comprehension Based Questions

1. (a) Force on the block along slat $= m r\omega^2 = m v\dfrac{dv}{dr}$

$$\therefore \int_0^v V dv = \int_{R/2}^{r} \omega^2 r dr \Rightarrow V = \omega\sqrt{r^2 - \frac{R^2}{4}} = \frac{dr}{dt}$$

$$\therefore \int_{R/4}^{r} \frac{dr}{\sqrt{r^2 - \frac{R^2}{4}}} = \int_0^t \omega\, dt$$

On solving we get

$$r + \sqrt{r^2 - \frac{R^2}{4}} = \frac{R}{2} e^{wt}$$

$$\text{or } r^2 - \frac{R^2}{4} = \frac{R^2}{4} e^{2wt} + r^2 - 2r\frac{R}{2} e^{wt}$$

$$\therefore \quad r = \frac{R}{4}\left(e^{wt} + e^{-wt}\right)$$

2. (b) $\vec{F}_{rot} = \vec{F}_{in} + 2m\left(V_{rot}\hat{i}\right) \times w\hat{k} + m\left(w\hat{k} \times r\hat{i}\right) \times w\hat{k}$

$$\therefore m r\omega^2 \hat{i} = \vec{F}_{in} + 2m\, V_{rot}\,\omega\left(-\hat{j}\right) + m\omega^2 r\hat{i}$$

$$\vec{F}_{in} = mrV_{rot}\,\omega\,\hat{j} \qquad -(i)$$

$$\text{But } r = \frac{R}{4}\left[e^{wt} + e^{-wt}\right]$$

$$\therefore \frac{dr}{dt} = V_r = \frac{R}{4}\left[\omega e^{wt} - \omega e^{-wt}\right] - (ii)$$

From (i) and (ii)

$$\vec{F}_{in} = 2m\frac{R\omega}{4}\left(e^{wt} - e^{-wt}\right)\omega\hat{j}$$

$$\therefore \vec{F}_{in} = \frac{mR\omega^2}{2}\left(e^{wt} - e^{-wt}\right)\hat{j}$$

$$\therefore \vec{F}_{reaction} = \frac{mR\omega^2}{2}\left(e^{wt} - e^{-wt}\right)\hat{j} + mg\,\hat{K}$$

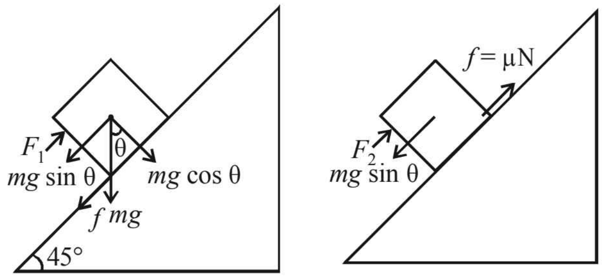
H. Assertion & Reason Type Questions

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

2. (b) It is easier to pull a heavy object than to push it on a level ground. Statement-1 is true. This is because the normal reaction in the case of pulling is less as compared by pushing. ($f = \mu N$). Therefore the frictional force is small in case of pulling.
statement-2 is true but is not the correct explanation of statement-1.

I. Integer Value Correct Type

1. 5



The pushing force $F_1 = mg\sin\theta + f$

$\therefore F_1 = mg\sin\theta + \mu\, mg\cos\theta = mg(\sin\theta + \mu\cos\theta)$

The force required to just prevent it from sliding down

$F_2 = mg\sin\theta - \mu N = mg(\sin\theta - \mu\cos\theta)$

Given, $F_1 = 3F_2$

$\therefore \quad \sin\theta + \mu\cos\theta = 3(\sin\theta - \mu\cos\theta)$

$\therefore \quad 1 + \mu = 3(1 - \mu) \quad [\because \sin\theta = \cos\theta]$

$\therefore \quad 4\mu = 2 \qquad \therefore \quad \mu = 0.5$

$\therefore \quad N = 10\,\mu = 5$

Section-B JEE Main/ AIEEE

1. (a) $W = \Delta K = FS$

$$\frac{1}{2}mv^2 - \frac{1}{2}m\left(\frac{v}{2}\right)^2 = F \times 3 \quad \ldots(i)$$

$$\frac{1}{2}m\left(\frac{v}{2}\right)^2 - 0 = F \times S \quad \ldots(ii)$$

On dividing

$$\frac{1/4}{3/4} = S/3$$

$\therefore S = 1$ cm

2. (c)
- For the man standing in the left, the acceleration of the ball

  $\vec{a}_{bm} = \vec{a}_b - \vec{a}_m \Rightarrow a_{bm} = g - a$

  Where 'a' is the acceleration of the mass (because the acceleration of the lift is 'a')
- For the man standing on the ground, the acceleration of the ball

  $\vec{a}_{bm} = \vec{a}_b - \vec{a}_m \Rightarrow a_{bm} = g - 0 = g$

3. (a) When F_1, F_2 and F_3 are acting on a particle then the particle remains stationary. This means that the resultant of F_1 F_2 and F_3 is zero. When F_1 is removed, F_2 and F_3 will remain. But the resultant of F_2 and F_3 should be equal and opposite to F_1. i.e. $|\vec{F}_2 + \vec{F}_3| = |\vec{F}_1|$

$$\therefore \quad a = \frac{|\vec{F}_2 + \vec{F}_3|}{m} \Rightarrow a = \frac{F_1}{m}$$

4. **(b)** Let the two forces be F_1 and F_2 and let $F_2 < F_1$. R is the resultant force.

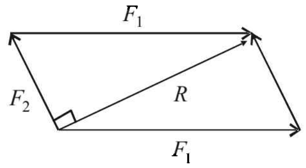
Given $F_1 + F_2 = 18$ ...(i)

From the figure $F_2^2 + R^2 = F_1^2$

$$F_1^2 - F_2^2 = R^2$$

$$\therefore \quad F_1^2 - F_2^2 = 144 \qquad \text{...(ii)}$$

Only option (b) follows equation (i) and (ii).



5. **(d)** $\Delta K = FS$

$$\frac{1}{2}mu^2 = F \times S_1 \qquad \text{...(i)}$$

$$\frac{1}{2}m(4u)_2 = FS_2 \qquad \text{...(ii)}$$

Dividing (i) and (ii),

$$\frac{u^2}{16u^2} = \frac{2as_1}{2as_2} \Rightarrow \frac{1}{16} = \frac{s_1}{s_2}$$

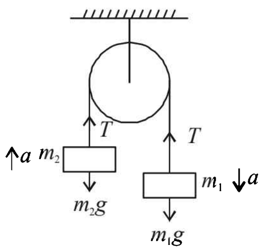
6. **(b)** **For mass m_1**

$m_1 g - T = m_1 a$

For mass m_2

$T - m_2 g = m_2 a$

Adding the equations we get

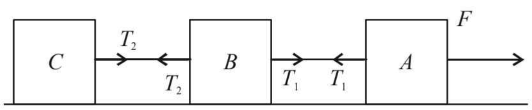


$$a = \frac{(m_1 - m_2)g}{m_1 + m_2}$$

$$\therefore \quad \frac{1}{8} = \frac{\frac{m_1}{m_2} - 1}{\frac{m_1}{m_2} + 1} \Rightarrow \frac{m_1}{m_2} + 1 = 8\frac{m_1}{m_2} - 8 \Rightarrow \frac{m_1}{m_2} = \frac{9}{7}$$

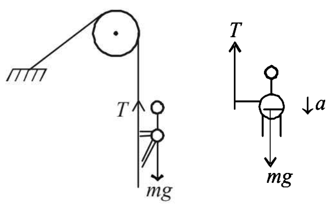
7. **(b)** $F = (m + m + m) \times a \qquad \therefore a = \frac{10.2}{6} m/s^2$

$$\therefore \; T_2 = ma = 2 \times \frac{10.2}{6} = 3.4\text{N}$$



8. **(c)** $mg - T = ma$

$$\therefore \quad a = g - \frac{T}{m} = 10 - \frac{360}{60} = 4m/s^2$$

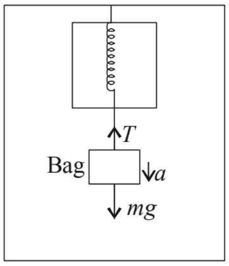


9. **(a)** For the bag accelerating down

$mg - T = ma$

$\therefore \; T = m(g - a)$

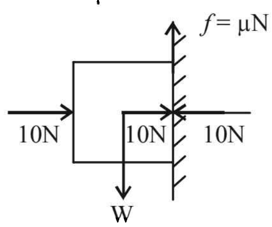
$$= \frac{49}{10}(10 - 5) = 24.5\text{ N}$$



10. **(d)** As shown in the figure, the three forces are represented by the sides of a triangle taken in the same order. Therefore the resultant force is zero. $\vec{F}_{net} = m\vec{a}$. Therefore acceleration is also zero ie velocity remains unchanged.

11. **(d)** For the block to remain stationary with the wall

$f = W \quad \therefore \; \mu N = W$



$0.2 \times 10 = W \Rightarrow W = 2N$

12. **(d)** $u = 6$ m/s, $v = 0$, $t = 10s$,

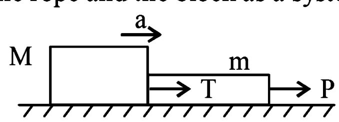
$$a = -\frac{f}{m} = \frac{-\mu mg}{m} = -\mu g = -10\mu$$

$v = u + at$

$0 = 6 - 10\mu \times 10$

$\therefore \; \mu = 0.06$

13. **(d)** Taking the rope and the block as a system



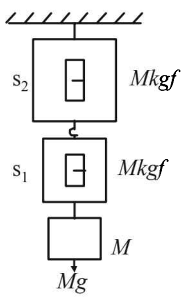
we get $P = (m + M)\,a \qquad \therefore a = \frac{P}{m + M}$

Taking the block as a system, we get $T = Ma$

$$\therefore \; T = \frac{MP}{m + M}$$

14. **(a)** The Earth pulls the block by a force Mg. The block in turn exerts a force Mg on the spring of spring balance S_1 which therefore shows a reading of M kgf.

The spring S_1 is massless. Therefore it exerts a force of Mg on the spring of spring balance S_2 which shows the reading of M kgf.

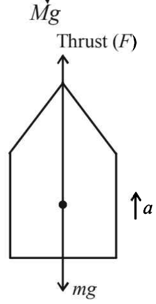


15. **(b)** As shown in the figure $F - mg = ma$

$\therefore \; F = m(g + a)$

$= 3.5 \times 10^4 (10 + 10)$

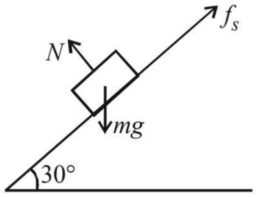
$= 7 \times 10^5$N



16. **(c)** Acceleration $a = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) g$

$$= \frac{(5-4.8)\times 9.8}{(5+4.8)} \text{m/s}^2 = 0.2 \text{ m/s}^2$$

17. **(c)**

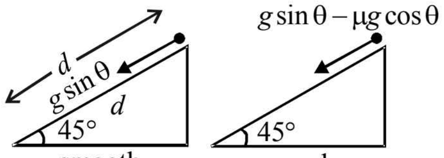


mg sinθ = f_s (for body to be at rest)

$\Rightarrow m \times 10 \times \sin 30° = 10$

$\Rightarrow m \times 5 = 10 \Rightarrow m = 2.0$ kg

18. **(b)**



When surface is smooth	When surface is rough
$d = \frac{1}{2}(g \sin\theta)t_1^2$,	$d = \frac{1}{2}(g\sin\theta - \mu g\cos\theta)t_2^2$
$t_1 = \sqrt{\frac{2d}{g\sin\theta}}$,	$t_2 = \sqrt{\frac{2d}{g\sin\theta - \mu g\cos\theta}}$

According to question, $t_2 = nt_1$

$$n\sqrt{\frac{2d}{g\sin\theta}} = \sqrt{\frac{2d}{g\sin\theta - \mu g\cos\theta}}$$

$$n = \frac{1}{\sqrt{1-\mu_k}} \qquad \left(\because \cos 45° = \sin 45° = \frac{1}{\sqrt{2}}\right)$$

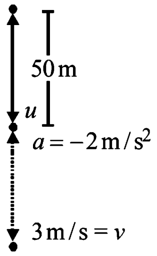
$$n^2 = \frac{1}{1-\mu_k} \text{ or } 1-\mu_k = \frac{1}{n^2} \text{ or } \mu_k = 1 - \frac{1}{n^2}$$

19. **(d)** The velocity of parachutist when parachute opens is

$u = \sqrt{2gh} = \sqrt{2\times 9.8 \times 50} = \sqrt{980}$

The velocity at ground, $v = 3$ m/s

$$\therefore S = \frac{v^2 - u^2}{2\times(-2)} = \frac{3^2 - 980}{-4} \approx 243 \text{ m}$$



Initially he has fallen 50 m.

∴ Total height from where he bailed out = 243 + 50 = 293 m

20. **(c)** Let K be the initial kinetic energy and F be the resistive force. Then according to work-energy theorem,

$W = \Delta K$

i.e., $3F = \frac{1}{2}mv^2 - \frac{1}{2}m\left(\frac{v}{2}\right)^2$ ...(1)

For *B* to *C*:

$Fx = \frac{1}{2}m\left(\frac{v}{2}\right)^2 - \frac{1}{2}m(0)^2$ ... (2)

Dividing eqns. (1) and (2) we get $\frac{x}{3} = \frac{1}{3}$

or $x = 1$ cm

21. **(c)** Force experienced by the particle, $F = m\omega^2 R$

$$\therefore \frac{F_1}{F_2} = \frac{R_1}{R_2}$$

22. **(d)** According to work-energy theorem, $W = \Delta K = 0$

(Since initial and final speeds are zero)

∴ Workdone by friction + Work done by gravity = 0

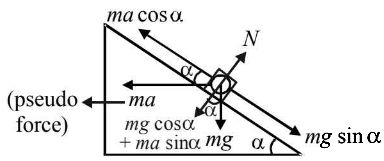
i.e., $-(\mu\, mg \cos\phi)\frac{\ell}{2} + mg\ell \sin\phi = 0$

or $\frac{\mu}{2}\cos\phi = \sin\phi$ or $\mu = 2\tan\phi$

23. **(c)** Mass $(m) = 0.3$ kg $\Rightarrow F = m.a = 15x$

$$a = -\frac{15}{0.3}x = \frac{150}{3}x = 50x \quad a = 50 \times 0.2 = 10\,\text{m/s}^2$$

24. **(c)** From diagram,



For block to remain stationary,

$mg \sin\alpha = ma\cos\alpha \Rightarrow a = g\tan\alpha$

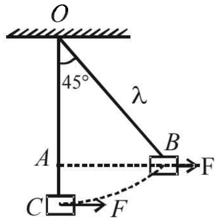
25. **(a)** $v^2 - u^2 = 2as$ or $0^2 - u^2 = 2(-\mu_k g)s$

$$-100^2 = 2 \times -\frac{1}{2} \times 10 \times s \Rightarrow s = 1000 \text{ m}$$

26. **(d)** Work done by tension + Work done by force (applied) + Work done by gravitational force = change in kinetic energy

Work done by tension is zero

$\Rightarrow 0 + F \times AB - Mg \times AC = 0$



$$\Rightarrow \text{F} = \text{Mg}\left(\frac{\text{AC}}{\text{AB}}\right) = \text{Mg}\left[\frac{1-\frac{1}{\sqrt{2}}}{\frac{1}{\sqrt{2}}}\right]$$

$[\because AB = \ell \sin 45° = \frac{\ell}{\sqrt{2}}$

and $AC = OC - OA = \ell - \ell\cos 45° = \ell\left(1 - \frac{1}{\sqrt{2}}\right)$

where ℓ = length of the string.]

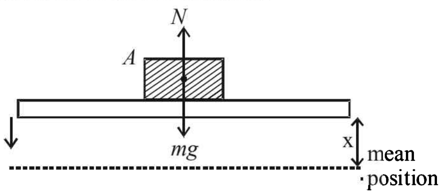
$\Rightarrow F = Mg(\sqrt{2} - 1)$

27. **(d)** $W_{hand} + W_{gravity} = \Delta K$

$\Rightarrow F(0.2) - (0.2)(10)(2.2) = 0 \Rightarrow F = 22\ N$

28. **(c)** $F = \frac{m(v-u)}{t} = \frac{0.15(0-20)}{0.1} = 30\ N$

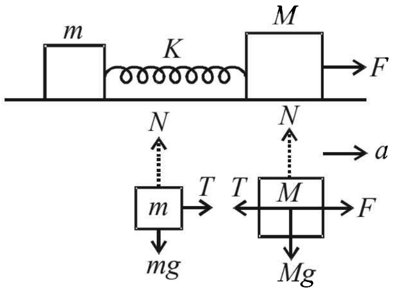
29. **(b)** For block *A* to move in *SHM*.



$mg - N = m\omega^2 x$
where x is the distance from mean position
For block to leave contact $N = 0$

$$\Rightarrow mg = m\omega^2 x \Rightarrow x = \frac{g}{\omega^2}$$

30. (d) Drawing free body-diagrams for m & M,



we get $T = ma$ and $F - T = Ma$
where T is force due to spring
$\Rightarrow F - ma = Ma$ or, $F = Ma + ma$

$$\therefore \; a = \frac{F}{M+m}.$$

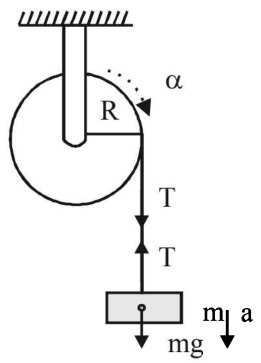
Now, force acting on the block of mass m is

$$ma = m\left(\frac{F}{M+m}\right) = \frac{mF}{m+M}.$$

31. (a) $mg \sin\theta = ma \quad \therefore a = g\sin\theta$
where a is along the inclined plane
$\therefore$ vertical component of acceleration is $g \sin^2\theta$
$\therefore$ relative vertical acceleration of A with respect to B is

$g(\sin^2 60 - \sin^2 30] = \frac{g}{2} = 4.9$ m/s² in vertical direction

32. (b) From figure,
Acceleration $a = R\alpha$ ...(i)
and $mg - T = ma$ ...(ii)
From equation (i) and (ii)



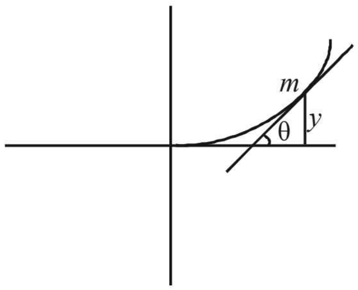
$$T \times R = mR^2\alpha = mR^2\left(\frac{a}{R}\right)$$

or $T = ma$
$\Rightarrow mg - ma = ma$

$$\Rightarrow \; a = \frac{g}{2}$$

33. (a) At limiting equilibrium, $\mu = \tan\theta$

$$\tan\theta = \mu = \frac{dy}{dx} = \frac{x^2}{2} \text{ (from question)}$$



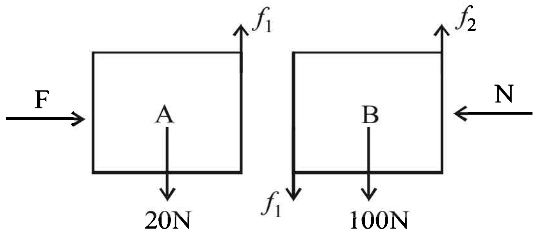
$\because$ Coefficient of friction $\mu = 0.5$

$$\therefore \; 0.5 = \frac{x^2}{2}$$

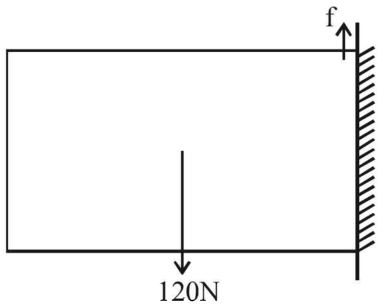
$\Rightarrow \; x = \pm 1$

$$\text{Now, } y = \frac{x^3}{6} = \frac{1}{6} m$$

34. (a)



Assuming both the blocks are stationary
N = F
$f_1 = 20$ N
$f_2 = 100 + 20 = 120$N



Considering the two blocks as one system and due to equilibrium f = 120N

35. (a) Loss in P.E. = Work done against friction from $p \to Q$ + work done against friction from $Q \to R$
$mgh = \mu(mg\cos\theta)\,PQ + \mu mg\,(QR)$
$h = \mu\cos\theta \times PQ + \mu(QR)$

$$2 = \mu \times \frac{\sqrt{3}}{2} \times \frac{2}{\sin 30°} + \mu x$$

$2 = 2\sqrt{3}\,\mu + \mu x$ ---(i)

$$[\sin 30° = \frac{2}{PQ}]$$

Also work done $P \to Q$ = work done $Q \to R$
$\therefore \; 2\sqrt{3}\,\mu = \mu x$
$\therefore \; x \approx 3.5$m
From (i) $2 = 2\sqrt{3}\,\mu + 2\sqrt{3}\,\mu = 4\sqrt{3}\,\mu$

$$\mu = \frac{2}{4\sqrt{3}} = \frac{1}{2 \times 1.732} = 0.29$$