# Exercise-1

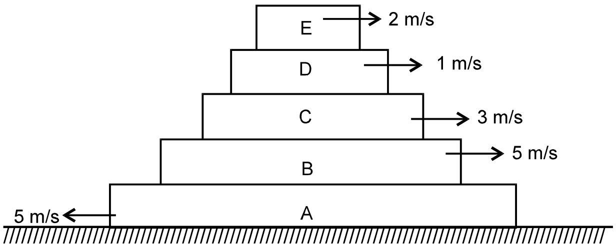
**Marked Questions can be used as Revision Questions.**

## PART - I : SUBJECTIVE QUESTIONS

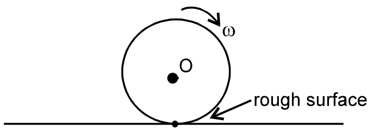
### Section (A) : Kinetic Friction

**A-1.** Suppose you are running fast in a field. When you suddenly find a snake in front of you, you stop quickly. Which force is responsible for your deacceleration ?

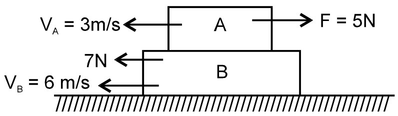
**A-2.** In the given diagram find the direction of friction forces on each block and on the ground (Assume all surfaces are rough and all velocities are with respect to ground).



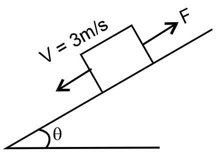

**A-3.** The wheel shown in the figure is fixed at 'O' and is in contact with a rough surface as shown. The wheel rotates with an angular velocity $\omega$. What is the direction and nature of friction force on the wheel and on the ground.




**A-4.** In the following figure, find the direction of friction on the blocks and ground.



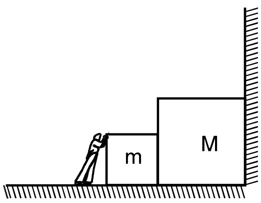

**A-5.** In the following figure, find the direction and nature of friction on the block.



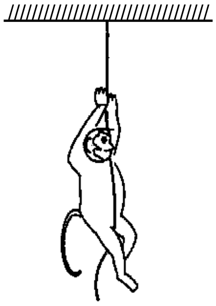

**A-6.** A block is shot with an initial velocity $5ms^{-1}$ on a rough horizontal plane. Find the distance covered by the block till it comes to rest. The coefficient of kinetic friction between the block and plane is 0.1.

### Section (B) : Static Friction

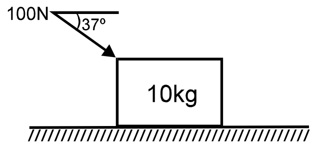
**B-1.** The person applies F force horizontally on the smaller block as shown in figure. The coefficient of static friction is $\mu$ between the blocks and the surface. Find the force exerted by the vertical wall on mass M. What is the value of action-reaction forces between m and M?



**B-2.** In the given figure a monkey of mass m is climbing up a rope hanging from the roof with acceleration a. The coefficient of static friction between the body of the monkey and the rope is $\mu$. Find the direction and value of friction force on the monkey.



**B-3.** In the figure shown calculate the angle of friction. The block is just about to slide. Take g = 10 m/s$^2$.




**B-4.** What is the minimum value of force (in following two cases) required to pull a block of mass m on a horizontal surface having coefficient of friction $\mu$? Also find the angle this force makes with the horizontal.

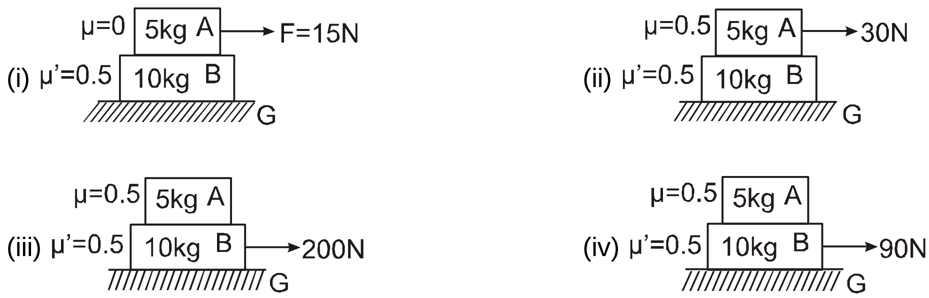
(a) If force is parallel to horizontal surface

(b) If force is in any direction (Also find the angle this force makes with the horizontal.)

### Section (C) : Miscellaneous Questions

**C-1.** A body of mass 5 kg is kept on a rough horizontal surface. It is found that the body does not slide if a horizontal force less than 30 N is applied to it. Also it is found that it takes 5 seconds to slide throughout the first 10 m if a horizontal force of 30 N is applied and the body is gently pushed to start the motion. Taking g= 10 m/s$^2$, calculate the coefficients of static and kinetic friction between the block and the surface.

**C-2.** In the given figures find the accelerations and the friction forces involved :



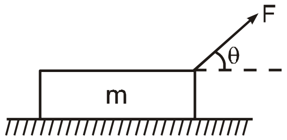

## PART - II : ONLY ONE OPTION CORRECT TYPE

### Section (A) : Kinetic Friction

**A-1.** Starting from rest a body slides down a 45º inclined plane in twice the time it takes to slide down the same distance in the absence of friction. The co-efficient of friction between the body and the inclined plane is:

(A) 0.75 (B) 0.33 (C) 0.25 (D) 0.80

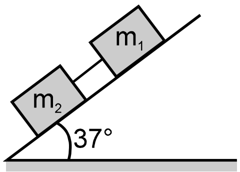
**A-2.** A wooden block of mass m resting on a rough horizontal table (coefficient of friction = $\mu$) is pulled by a force F as shown in figure. The acceleration of the block moving horizontally is :




(A) $\frac{F \cos \theta}{m}$ (B) $\frac{\mu F \sin \theta}{M}$

(C) $\frac{F}{m}(\cos \theta + \mu \sin \theta) - \mu g$ (D) none

**A-3.** Two blocks $m_1$ = 4kg and $m_2$ = 2kg, connected by a weightless rod on a plane having inclination of 37° as shown in figure. The coefficients of dynamic friction of $m_1$ and $m_2$ with the inclined plane are $\mu$ = 0.25. Then the common acceleration of the two blocks and the tension in the rod are : **[JEE 1979]**



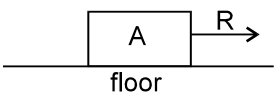

(A) 4 m/s², T = 0 (B) 2 m/s², T = 5 N (C) 10 m/s², T = 10 N (D) 15 m/s², T = 9N

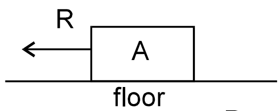
## Section (B) : Static Friction

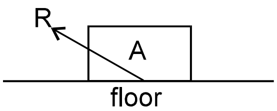
**B-1.** If the normal force is doubled, the co-efficient of friction is :

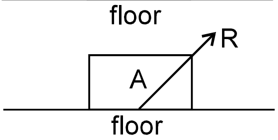
(A) halved (B) doubled (C) tripled (D) not changed

**B-2.** A box 'A' is lying on the horizontal floor of the compartment of a train running along horizontal rails from left to right. At time 't', it decelerates. Then the resultant contact force R by the floor on the box is given best by :

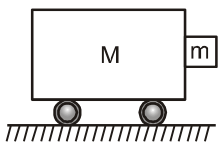
(A) 


(B) 


(C) 


(D) 


**B-3.** A cart of mass M has a block of mass m attached to it as shown in the figure. Co-efficient of friction between the block and cart is $\mu$. What is the minimum acceleration of the cart so that the block m does not fall?




(A) $\mu g$ (B) $\mu/g$ (C) $g/\mu$ (D) none

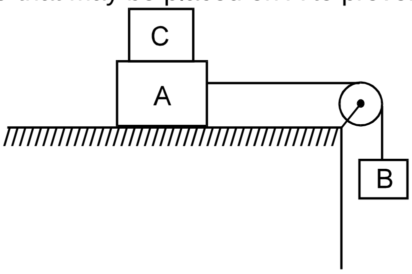
**B-4.** A block of mass 1 kg lies on a horizontal surface in a truck. The coefficient of static friction between the block and the surface is 0.6 If the acceleration of the truck is 5 m/s², the frictional force acting on the block is : **[JEE 1984]**

(A) 5 N (B) 6 N (C) 10 N (D) 15 N

**B-5.** 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 : **[IIT 1980]**

(A) 9.8 N (B) $0.7 \times 9.8\sqrt{3}$ N (C) 9.8 × 7 N (D) 0.8 × 9.8 N

**B-6.** Two masses A and B of 10 kg and 5 kg respectively are connected with a string passing over a frictionless pulley fixed at the corner of a table as shown. The coefficient of static friction of A with table is 0.2. The minimum mass of C that may be placed on A to prevent it from moving is

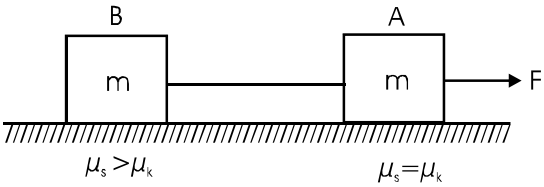


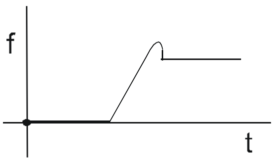

(A) 15 kg (B) 10 kg (C) 5 kg (D) 12 kg

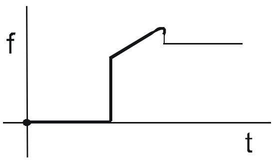
## Section (C) : Miscellaneous Questions

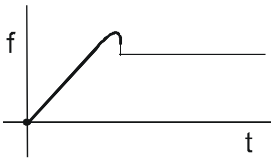
**C-1.** A 60 kg body is pushed horizontally with just enough force to start it moving across a floor and the same force continues to act afterwards. The coefficient of static friction and sliding friction are 0.5 and 0.4 respectively. The acceleration of the body is :
(A) 6 m/s$^2$ (B) 4.9 m/s$^2$ (C) 3.92 m/s$^2$ (D) 1 m/s$^2$

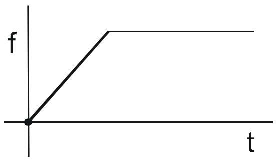
**C-2.** A force F = t is applied to block A as shown in figure. The force is applied at t = 0 seconds when the system was at rest and string is just straight without tension. Which of the following graphs gives the friction force between B and horizontal surface as a function of time 't'.



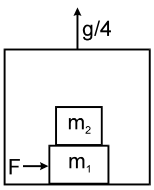

(A)



(B)



(C)



(D)



**C-3.** A plank of mass $m_1$ = 8 kg with a bar of mass $m_2$ = 2 kg placed on its rough surface, lie on a smooth floor of elevator ascending with an acceleration g/4. The coefficient of friction is $\mu$ = 1/5 between $m_1$ and $m_2$. A horizontal force F = 30 N is applied to the plank. Then the acceleration of bar and the plank in the reference frame of elevator are :

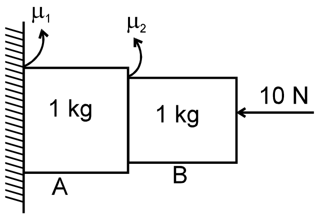



(A) 3.5 m/s$^2$, 5 m/s$^2$ (B) 5 m/s$^2$, $\frac{50}{8}$ m/s$^2$ (C) 2.5 m/s$^2$, $\frac{25}{8}$ m/s$^2$ (D) 4.5 m/s$^2$, 4.5m/s$^2$

**C-4.** A man of mass m is applying a horizontal force to slide a box of mass m′ on a rough horizontal surface. It is known that the man does not slide. The coefficient of friction between the shoes of the man and the floor is $\mu$ and between the box and the floor is $\mu'$. In which of the following cases it is certainly not possible to slide the box?
(A) $\mu > \mu'$, m < m′ (B) $\mu < \mu'$, m < m′ (C) $\mu < \mu'$, m > m′ (D) $\mu > \mu'$, m > m′

## PART - III : MATCH THE COLUMN

**1.** In the given figure find the accelerations of blocks A and B for the following cases ($g = 10\ m/s^2$)

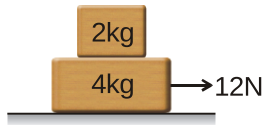



| Column-I | | Column-II | |
|---|---|---|---|
| (A) | $\mu_1 = 0$ and $\mu_2 = 0.1$ | (p) | $a_A = a_B = 9.5\ m/s^2$ |
| (B) | $\mu_2 = 0$ and $\mu_1 = 0.1$ | (q) | $a_A = 9\ m/s^2$, $a_B = 10\ m/s^2$ |
| (C) | $\mu_1 = 0.1$ and $\mu_2 = 1.0$ | (r) | $a_A = a_B = g = 10\ m/s^2$ |
| (D) | $\mu_1 = 1.0$ and $\mu_2 = 0.1$ | (s) | $a_A = 1$, $a_B = 9\ m/s^2$ |

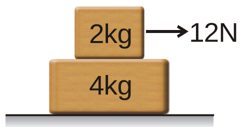
**2.** Column II gives certain situations involving two blocks of mass 2 kg and 4 kg. The 4 kg block lies on a smooth horizontal table. There is sufficient friction between both the blocks and there is no relative motion between the blocks in all situation. Horizontal forces act on one or both blocks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

**Column-I** | **Column-II**

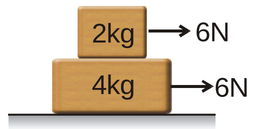
(A) Magnitude of frictional force is maximum. (p)



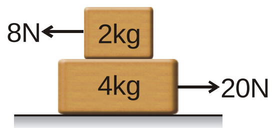

(B) Magnitude of friction force is least. (q)




(C) Friction force on 2 kg block is towards right. (r)




(D) Friction force on 2 kg block is towards left. (s)




# Exercise-2

**Marked Questions can be used as Revision Questions.**

## PART - I : ONLY ONE OPTION CORRECT TYPE

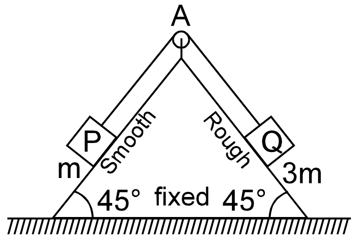
**1.** A body is projected up along a rough inclined plane from the bottom with some velocity. It travels up the incline and then returns back. If the time of ascent is $t_a$ and time of descent is $t_d$, then

(A) $t_a = t_d$ (B) $t_a > t_d$ (C) $t_a < t_d$ (D) data insufficient

**2.** The upper portion of an inclined plane of inclination $\alpha$ is smooth and the lower portion is rough. A particle slides down from rest from the top and just comes to rest at the foot. If the ratio of the smooth length to rough length is m : n, the coefficient of friction is :

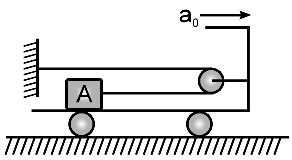
(A) $\left[\frac{m+n}{n}\right]\tan\alpha$  (B) $\left(\frac{m+n}{n}\right)\cot\alpha$  (C) $\left(\frac{m-n}{n}\right)\cot\alpha$  (D) $\frac{1}{2}$

**3.** A fixed wedge with both surface inclined at 45° to the horizontal as shown in the figure. A particle P of mass m is held on the smooth plane by a light string which passes over a smooth pulley A and attached to a particle Q of mass 3m which rests on the rough plane. The system is released from rest. Given that the acceleration of each particle is of magnitude $\frac{g}{5\sqrt{2}}$ then the tension in the string is :




(A) mg  (B) $\frac{6mg}{5\sqrt{2}}$  (C) $\frac{mg}{2}$  (D) $\frac{mg}{4}$

**4.** Starting from rest, A flat car is given a constant acceleration $a_0$ = 2 m/s². A cable is connected to a crate A of mass 50 kg as shown. Neglect the friction between floor and car wheels and mass of pulley. The cofficient of friction between crate & floor of the car is $\mu$ = 0.3. The tension in cable is –

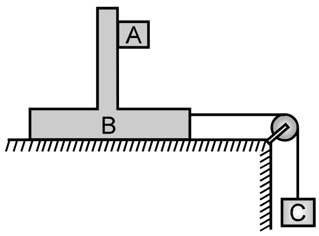



(A) 700 N  (B) 350 N  (C) 175 N  (D) 0

**5.** A uniform rope lies on a table with some portion hanging. The rope begins to slide when the length of hanging part is 25 % of entire length. The co-efficient of friction between rope and table is:

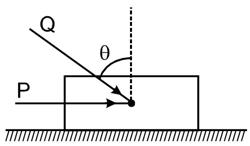
(A) 0.33  (B) 0.25  (C) 0.5  (D) 0.2

**6.** In the arrangement shown mass of the block B and A are 2 m and, 8 m respectively. Surface between B and floor is smooth. The block B is connected to block C by means of a pulley. If the whole system is released then the minimum value of mass of the block C so that the block A remains stationary with respect to B is : (Co-efficient of friction between A and B is $\mu$ and pulley is ideal)



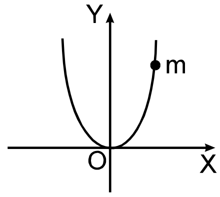

(A) $\frac{m}{\mu}$  (B) $\frac{2m}{\mu+1}$  (C) $\frac{10\ m}{1-\mu}$  (D) $\frac{10m}{\mu-1}$

**7.** A block of mass m lying on a rough horizontal plane is acted upon by a horizontal force P and another force Q inclined at an angle $\theta$ to the vertical. The minimum value of coefficient of friction between the block and the surface for which the block will remain in equilibrium is:



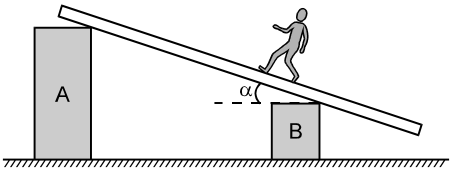

(A) $\frac{P+Q\sin\theta}{mg+Q\cos\theta}$  (B) $\frac{P\cos\theta+Q}{mg-Q\sin\theta}$  (C) $\frac{P+Q\cos\theta}{mg+Q\sin\theta}$  (D) $\frac{P\sin\theta-Q}{mg-Q\cos\theta}$

**8.** A bead of mass m is located on a parabolic wire (equation $x^2 = ay$) with its axis vertical and vertex directed downward as in figure. If the coefficient of friction is μ, the highest distance above the x-axis at which the particle will be in equilibrium is




(A) $\mu a$ (B) $\mu^2 a$ (C) $\frac{1}{4}\mu^2 a$ (D) $\frac{1}{2}\mu a$

**9.** A plank is held at an angle $\alpha$ to the horizontal (Fig.) on two fixed supports A and B. The plank can slide against the supports (without friction) because of its weight Mg. With what acceleration and in what direction, a man of mass m should move so that the plank does not move.




(A) $g \sin\alpha\left(1+\frac{m}{M}\right)$ down the incline (B) $g \sin\alpha\left(1+\frac{M}{m}\right)$ down the incline

(C) $g \sin\alpha\left(1+\frac{m}{M}\right)$ up the incline (D) $g \sin\alpha\left(1+\frac{M}{m}\right)$ up the incline

**10.** A 1.5 kg box is initially at rest on a horizontal surface when at t = 0 a horizontal force $\vec{F} = (1.8t)\hat{i}$ N (with t in seconds) is applied to the box. The acceleration of the box as a function of time t is given by : (g = 10m/s²)

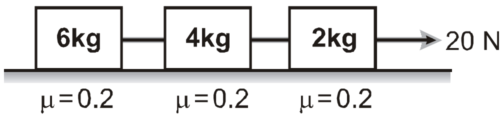
$\vec{a} = 0$ for $0 \le t \le 2.85$

$\vec{a} = (1.2t - 2.4)\hat{i}$ m/s² for $t > 2.85$

The coefficient of kinetic friction between the box and the surface is :

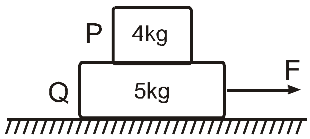
(A) 0.12 (B) 0.24 (C) 0.36 (D) 0.48

**11.** In the arrangement shown tension in the string connecting 4kg and 6kg masses is



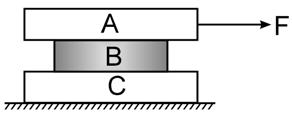

(A) 8N (B) 12N (C) 6N (D) 4N

**12.** In the given figure the coefficient of friction between 4kg and 5 kg blocks is 0.2 and between 5 kg block and ground is 0.1. Choose the correct statements



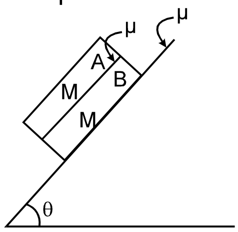

(A) Minimum force needed to cause system to move is 17 N
(B) When force is 4N static friction at all surfaces is 4N to keep system at rest
(C) Maximum acceleration of 4kg block is 2m/s²
(D) Slipping between 4kg and 5 kg blocks starts when F is > 17N

**13.** Given $m_A$ = 30 kg, $m_B$ = 10 kg, $m_C$ = 20 kg. Between A and B friction coefficient $\mu_1$ = 0.3, between B and C friction coefficient $\mu_2$ = 0.2 and between C and ground $\mu_3$ = 0.1. The least horizontal force F to start the motion of any part of the system of three blocks resting upon one another as shown in figure is (g = 10 m/s²)



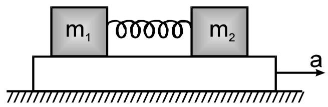

(A) 60 N (B) 90 N (C) 80 N (D) 150 N

**14.** Two identical blocks of same masses are placed on a fixed wedge as shown in figure. Coefficient of friction between all the contact surfaces is μ. Choose the correct alternative




(A) For motion at any surface, $\theta \le \tan^{-1}(\mu)$.
(B) Acceleration of block A will be more than acceleration of block B in downward direction.
(C) Acceleration of block A will be less than acceleration of block B in down ward direction.
(D) Two blocks A and B move with same acceleration.

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

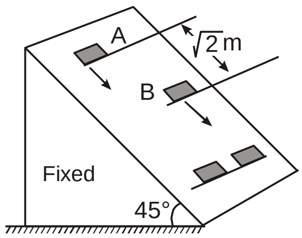



(A) spring will be stretched if $a > \mu g$
(B) spring will be compressed if $a \le \mu g$
(C) spring will neither be compressed nor be stretched only if $a \le \mu g$
(D) spring will be in its natural length under all conditions only if initial velocities of blocks are same

## PART - II : SINGLE AND DOUBLE VALUE INTEGER TYPE

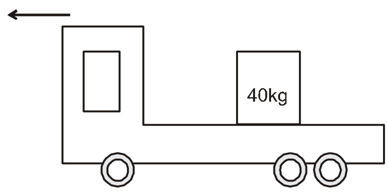
**1.** Two blocks A and B of equal masses are sliding down along straight parallel lines on an inclined plane of 45°. Their coefficients of kinetic friction are $\mu_A = 0.2$ and $\mu_B = 0.3$ respectively. At t = 0, both the blocks are at rest and block A is $\sqrt{2}$ meter behind block B. The time (in second) from the initial position where the front faces of the blocks come in line on the inclined plane as shown in figure. (Use g = 10 $ms^{-2}$.)

**[JEE 2004 (Scr.) 3/84]**

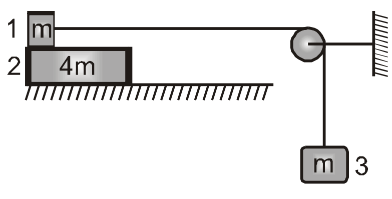



**2.** A block of mass 2 kg is pushed against a rough vertical wall with a force of 30 N, coefficient of static friction being 0.5. Another horizontal force of 15 N is applied on the block in a direction parallel to the wall. What is the acceleration of block (in $m/s^2$) ?

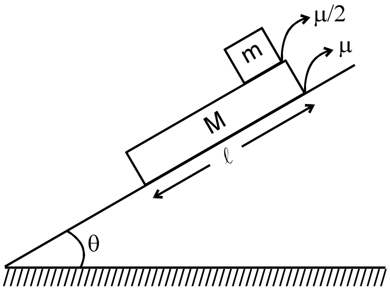
**3.** The rear side of a truck is open and a box of 40 kg mass is placed 5 m away from the open end as shown in figure. The coefficient of friction between the box and the surface below it is 0.15. On a straight road, the truck starts from rest and accelerates with 2 $ms^{-2}$. Find the distance (in m) travelled by the truck by the time box falls from the truck. (Ignore the size of the box).



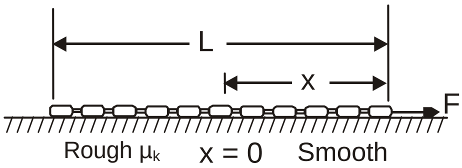

**4.** In figure block 1 has one fourth mass and one fourth length of block 2 (mass 4m and length ℓ). No friction exists between block 2 and surface on which it rests. Coefficient of friction is $\mu_k$ between 1 & 2. The distance block 2 moves when only half of block 1 is still on block 2 is $\frac{n\mu_k \ell}{8(2-3\mu_k)}$. Then find value of n.



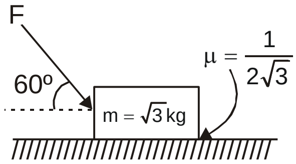
**5.** In the given situation it is known that when released the blocks slide. Find the time (in second) when the small block will fall off from the larger block. (The size of m is very –very small then M, see figure). If m = 1 kg, M = 4 kg, $\ell$ = 4 m, $\theta$ = 37°, $\mu$ = 0.4.



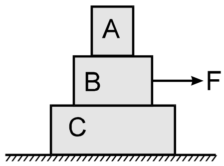

**6.** A heavy chain with mass per unit length '$\rho$' is pulled by the constant force F along a horizontal surface consisting of a smooth section and a rough section. The chain is initially at rest on the rough surface with x = 0. If the coefficient of kinetic friction between the chain and the rough surface is $\mu_k$, then what is the velocity v (in m/s) of the chain when x = L, if the force F is greater than $\mu_k \rho g L$ in order to initiate the motion. : If F = 21N, $\mu$ = 0.5, L = 1 m, $\rho$ = 2 kg/m




**7.** What is the maximum value of the force F (in newton) such that the block shown in the arrangement, does not move :



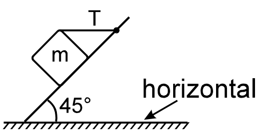

**8.** In the figure shown, the coefficient of static friction between C and ground is 0.5, coefficient of static friction between A and B is 0.25, coefficient of static friction between B and C is zero. Find the minimum value of force 'F' (in newton), to cause sliding between A and B. Masses of A, B and C are respectively 2 kg, 4 kg and 5 kg.




**9.** A small body was launched up an inclined plane set at an angle $\alpha$ = 15° against the horizontal. The coefficient of friction is k, if the time of the ascent of the body is $\eta$ = 2.0 times less than the time of its descent. Find value of 100 k

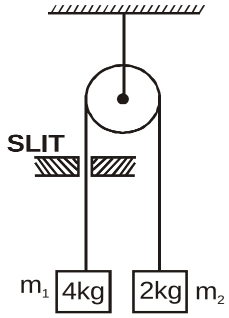
## PART - III : ONE OR MORE THAN ONE OPTIONS CORRECT TYPE

**1.** A block of mass 15 kg is resting on a rough inclined plane as shown in figure. The block is tied up by a horizontal string which has a tension of 50 N. The coefficient of friction between the surfaces of contact may be (g = 10 m/s$^2$)




(A) 1/2 (B) 2/3 (C) 3/4 (D) 1/4

**2.** Two masses $m_1$ = 4 kg and $m_2$ = 2kg are connected with an inextensible, massless string that passes over a frictionless pulley and through a slit, as shown. The string is vertical on both sides and the string on the left is acted upon by a constant friction force 10 N by the slit as it moves. (use g = 10 m/s²)



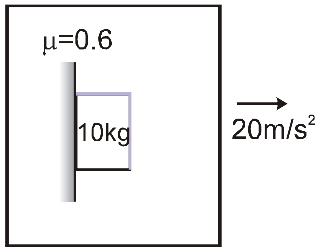

(A) Acceleration of mass $m_1$ is $\frac{5}{3}$ m/s², downwards.

(B) Tension in the string is same throughout.

(C) Force exerted by the string on mass $m_2$ is $\frac{70}{3}$ N.

(D) If positions of both the masses are interchanged, then 2kg mass moves up with an acceleration $\frac{10}{3}$ m/s².

**3.** Car is accelerating with acceleration = 20 m/s². A box of mass m = 10 kg that is placed inside the car, it is put in contact with the vertical wall of car as shown. The friction coefficient between the box and the wall is $\mu$ = 0.6.



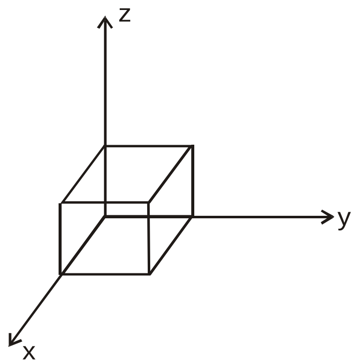

(A) The acceleration of the box will be 20 m/sec²

(B) The friction force acting on the box will be 100 N

(C) The contact force between the vertical wall and the box will be $100\sqrt{5}$ N

(D) The net contact force between the vertical wall and the box is only of electromagnetic in nature.

**4.** A solid cube of mass 5 kg is placed on a rough horizontal surface, in xy-plane as shown. The friction coefficient between the surface and the cube is 0.4. An external force $\vec{F} = 6\hat{i} + 8\hat{j} + 20\hat{k}$ N is applied on the cube. (use g = 10 m/s²)




(A) The block starts slipping over the surface

(B) The friction force on the cube by the surface is 10 N.

(C) The friction force acts in xy-plane at angle 127° with the positive x-axis in clockwise direction.

(D) The contact force exerted by the surface on the cube is $10\sqrt{10}$ N.

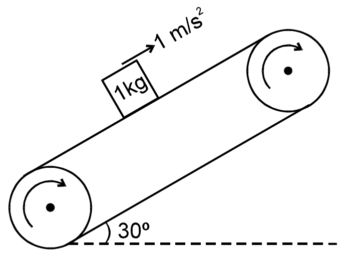
**5.** The force $F_1$ parallel to inclined plane that is necessary to move a body up an inclined plane is double the force $F_2$ that is necessary to just prevent it from sliding down, then :

(A) $F_2 = w \sin(\theta - \phi) \sec\phi$ (B) $F_1 = w \sin(\theta - \phi) \sec\phi$

(C) $\tan\phi = 3\tan\theta$ (D) $\tan\theta = 3\tan\phi$

Where $\phi$ = Limiting angle of repose, $\theta$ = angle of inclined plane, w = weight of the body

**6.** A block of mass 1 kg is stationary with respect to a conveyer belt that is accelerating with 1 m/s² upwards at an angle of 30º as shown in figure. Which of the following is/are correct?



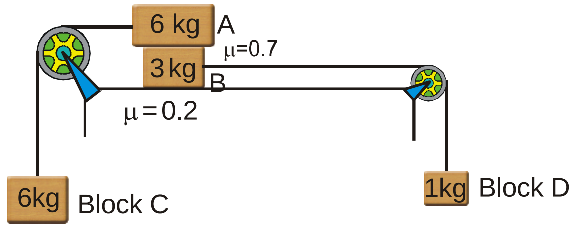

(A) Force of friction on block is 6 N upwards along the inclined plane.

(B) Force of friction on block is 1.5 N upwards along the inclined plane.

(C) Contact force between the block & belt is 10.5 N.

(D) Contact force between the block & belt is $5\sqrt{3}$ N.

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

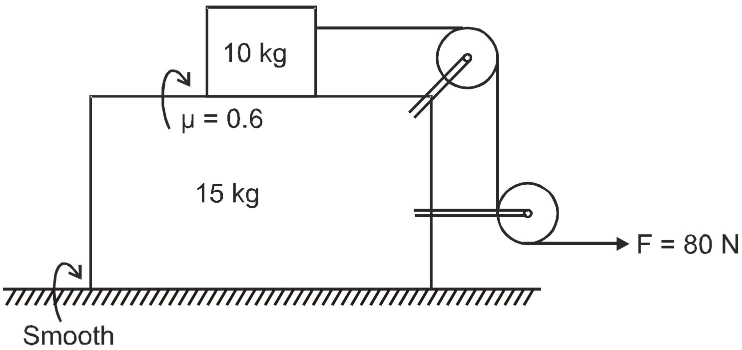



(A) The magnitude of acceleration of the system is $2\ m/s^2$ and there is no slipping between block A and block B.
(B) The magnitude of friction force between block A and block B is 42 N.
(C) Acceleration of block C is $1\ m/s^2$ downwards.
(D) Tension in the string connecting block B and block D is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

## PART - IV : COMPREHENSION

**Comprehension-1**

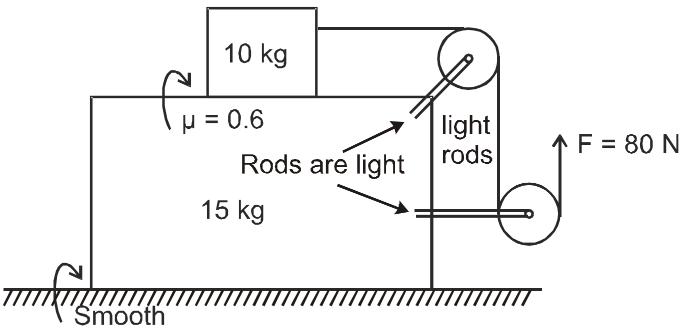
A block of mass 15 kg is placed over a frictionless horizontal surface. Another block of mass 10 kg is placed over it, that is connected with a light string passing over two pulleys fastened to the 15 kg block. A force F = 80 N is applied horizontally to the free end of the string. Friction coefficient between two blocks is 0.6. The portion of the string between 10 kg block and the upper pulley is horizontal as shown in figure Pulley string & connecting rods are massless. (Take $g = 10\ m/s^2$)




**1.** The magnitude of acceleration of the 10 kg block is :
(A) $3.2\ m/s^2$ (B) $2.0\ m/s^2$ (C) $1.6\ m/s^2$ (D) $0.8\ m/s^2$

**2.** If applied force F = 120 N, then magnitude of acceleration of 15 kg block will be :
(A) $8\ m/s^2$ (B) $4\ m/s^2$ (C) $3.2\ m/s^2$ (D) $4.8\ m/s^2$

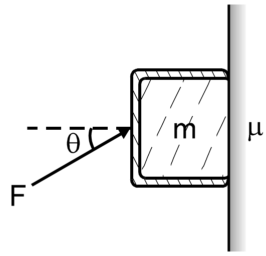
**3.** Continuing with the situation, if the force F = 80 N is directed vertically as shown, the acceleration of the 10 kg block will be :



(A) 2 m/s$^2$, towards right (B) 2 m/s$^2$, towards left
(C) 6 m/s$^2$, towards left (D) 16/5 m/s$^2$, towards right

**Comprehension-2**

Impending state of motion is a critical border line between static and dynamic states of a body. A block of mass m is supported on a rough vertical wall by applying a force F as shown in figure. Coefficient of static friction between block and wall is $\mu_S$. The block under the influence of F $\sin\theta$ may have a tendency to move upward or it may be assumed that F $\sin\theta$ just prevents downward fall of the block. Read the above passage carefully and answer the following questions.




**4.** The minimum value of force F required to keep the block stationary is :

(A) $\frac{mg}{\mu\cos\theta}$ (B) $\frac{mg}{\sin\theta+\mu\cos\theta}$ (C) $\frac{mg}{\sin\theta-\mu\cos\theta}$ (D) $\frac{mg}{\mu\tan\theta}$

**5.** The value of F for which friction force between the block and the wall is zero.

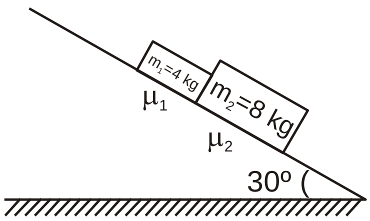
(A) mg (B) $\frac{mg}{\sin\theta}$ (C) $\frac{mg}{\cos\theta}$ (D) $\frac{mg}{\tan\theta}$

**6.** If F is the force applied on the block as shown and $F_{min}$ is the minimum value of force required to keep the block stationary. Then choose the correct alternative.

(A) If F < $F_{min}$ ; the block slides downward
(B) If F = $F_{min}$ ; the block slides upward
(C) In each case (for any value of F) the friction force f < mg
(D) All the above

**Comprehension-3**

In the figure shown below the friction between the 4 kg block and the incline as $\mu_1$ and between 8 kg and incline is $\mu_2$. (Take g = 10 m/s$^2$)




**7.** If $\mu_1$ = 0.2 and $\mu_2$ = 0.3 then find acceleration of $m_1$ and $m_2$ ?

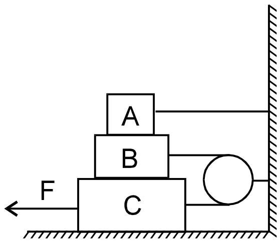
(A) $a_1 = a_2 = 2.7$ m/s$^2$ (B) $a_1 = 3.2$ m/s$^2$ $a_2 = 2.4$ m/s$^2$
(C) $a_1 = a_2 = 3.2$ m/s$^2$ (D) $a_1 = 2.4$ m/s$^2$ $a_2 = 3.2$ m/s$^2$

**8.** If $\mu_1$ = 0.3 and $\mu_2$ = 0.2 then find acceleration of $m_1$ and $m_2$ ?

(A) $a_1 = a_2 = 2.7$ m/s$^2$ (B) $a_1 = 3.2$ m/s$^2$ $a_2 = 2.4$ m/s$^2$
(C) $a_1 = a_2 = 3.2$ m/s$^2$ (D) $a_1 = 2.4$ m/s$^2$ $a_2 = 3.2$ m/s$^2$

**Comprehension-4**

$M_A$ = 3 kg, $M_B$ = 4 kg and $M_C$ = 8 kg. Friction cofficient between any two surfaces is 0.25. Pulley is frictionless and string is massless. Block, A is connected to the wall through a horizontal massless rigid rod as shown in figure. (g = 10 m/s$^2$)




**9.** Find the value of F to keep C moving with constant speed

(A) 60 N (B) 40 N (C) 80 N (D) 100 N

**10.** If F is 200 N then find acceleration of B

(A) 5 m/s$^2$ (B) 10 m/s$^2$ (C) 4 m/s$^2$ (D) zero

## Exercise-3

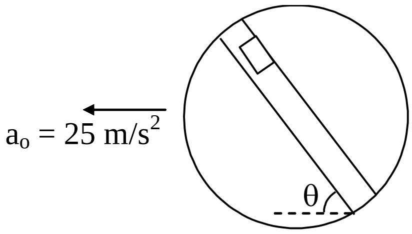
**✍ Marked Questions may have for Revision Questions.**

*** Marked Questions may have more than one correct option.**

## PART - I : JEE (ADVANCED) / IIT-JEE PROBLEMS (PREVIOUS YEARS)

**1.** A disc is kept on a smooth horizontal plane with its plane parallel to horizontal plane. A groove is made in the disc as shown in the figure. The coefficient of friction between mass m and surface of the groove is 2/5 and sin θ = 3/5. Find the acceleration of mass with respect to the frame of reference of the disc.

**[JEE 2006, 6/184]**




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

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

**[JEE 2008, 3/163, –1]**

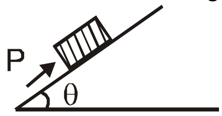
(A) STATEMENT-1 is True, STATEMENT-2 is True; STATEMENT-2 **is** a correct explanation for STATEMENT-1

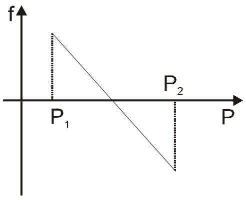
(B) STATEMENT-1 is True, STATEMENT-2 is True; STATEMENT-2 **is NOT** a correct explanation for STATEMENT-1

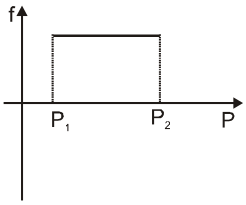
(C) STATEMENT-1 is True, STATEMENT-2 is False

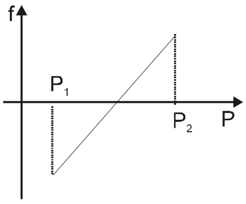
(D) STATEMENT-1 is False, STATEMENT-2 is True.

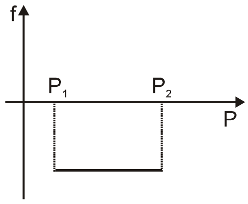
**3.** A block of mass m is on inclined plane of angle θ. The coefficient of friction between the block and the plane is μ and tanθ > μ. The block is held stationary by applying a force P parallel to the plane. The direction of force pointing up the plane is taken to be positive. As P is varied from $P_1 = mg(\sin\theta - \mu\cos\theta)$ to $P_2 = mg(\sin\theta + \mu\cos\theta)$, the frictional force f versus P graph will look like : **[JEE 2010, 3/163, –1]**




(A)


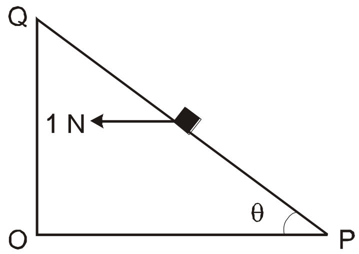

(B)



(C)



(D)


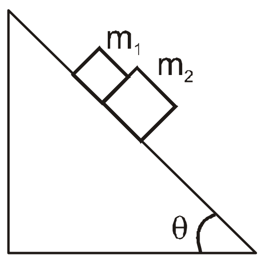

**4.** A block is moving on an inclined plane making an angle 45° with the horizontal and the coefficient of friction is μ. The force required to just push it up the inclined plane is 3 times the force required to just prevent it from sliding down. If we define k = 10 μ, then value of k is **[JEE 2011, 4/160]**

**5*.** A small block of mass 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 center of mass as shown in the figure. The block remains stationary if (take g = 10 m/s$^2$) **[IIT-JEE-2012, Paper-1; 4/70]**




(A) θ = 45°
(B) θ > 45° and a frictional force acts on the block towards P.
(C) θ > 45° and a frictional force acts on the block towards Q.
(D) θ < 45° and a frictional force acts on the block towards Q.

**6.** A block of mass $m_1$ = 1 kg and 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 the plane is always zero. The coefficient of static and dynamic friction between the block $m_2$ and the plane are equal to μ = 0.3. In List II expression for the friction on block $m_2$ 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. **[JEE (Advanced) 2014, 3/60, –1]**




[**Useful information** : tan(5.5°) ≈ 0.1 ; tan (11.5°) ≈ 0.2 ; tan(16.5° ≈ 0.3)]

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

## PART - II : JEE (MAIN) / AIEEE PROBLEMS (PREVIOUS YEARS)

**1.** A smooth block is released from rest on a 45º 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 **[AIEEE-2005; 4/300]**

(1) $\mu_s = 1 - \frac{1}{n^2}$ (2) $\mu_s = \sqrt{1 - \frac{1}{n^2}}$ (3) $\mu_k = 1 - \frac{1}{n^2}$ (4) $\mu_k = \sqrt{1 - \frac{1}{n^2}}$

**2.** The upper half of an incline plane with inclination $\phi$ is perfectly smooth while the lower half is rough. A body starting from rest at the top will again come to rest at the the bottom if the coefficient of friction for the lower half is given by **[AIEEE-2005; 4/300]**

(1) 2 tan $\phi$ (2) tan $\phi$ (3) 2 sin $\phi$ (4) 2 cos $\phi$

**3.** 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] **[AIEEE-2005; 4/300]**

(1) 100 m (2) 400 m (3) 800 m (4) 1000 m

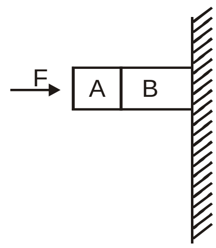
**4.** The minimum force required to start pushing a body up a rough (friction coefficient $\mu$) inclined plane is $F_1$ while the minimum force needed to prevent it from sliding down is $F_2$. If the inclined plane makes an angle $\theta$ from the horizontal such that tan $\theta$ = 2$\mu$ then the ratio $\frac{F_1}{F_2}$ is : **[AIEEE 2011, 11 May; 4/120, –1]**

(1) 1 (2) 2 (3) 3 (4) 4

**5.** 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, 4/120, –1]**

(1) $\frac{1}{6}$m (2) $\frac{2}{3}$m (3) $\frac{1}{3}$m (4) $\frac{1}{2}$m

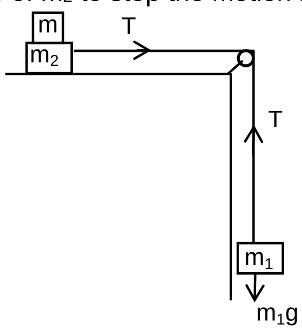
**6.** Given in the figure are two blocks A and B of weight 20 N and 100 N, respectively. These are being pressed against a wall by a force F as shown. If the coefficient of friction between the blocks is 0.1 and between block B and the wall is 0.15, the frictional force applied by the wall on block B is (Assume system in equilibrium): **[JEE (Main) 2015; 4/120, –1]**




(1) 100N (2) 80N

(3) 120N (4) 150N

**7.** Two masses $m_1$ = 5kg and $m_2$ = 10kg connected by an inextensible string over a frictionless pulley are moving as shown in the figure. The coefficient of friction of horizontal surface is 0.15. The minimum weight m that should be put on top of $m_2$ to stop the motion is : **[JEE (Main) 2018; 4/120, –1]**




(1) 43.3 kg (2) 10.3 kg (3) 18.3 kg (4) 27.3 kg

# Answers

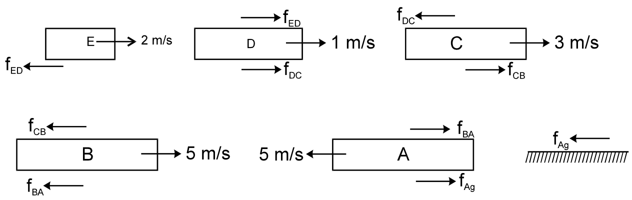
## EXERCISE-1

### PART - I

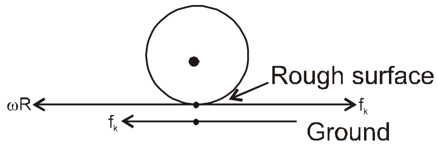
**Section (A) :**

**A-1.** Frictional force, which is a type of electromagnetic force.

**A–2**

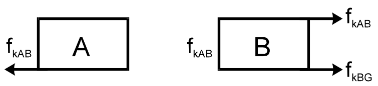



**A–3**




Kinetic friction is involved.

**A-4.**




**A-5.** Up the incline, kinetic friction.

**A-6.** 12.5 m

**Section (B) :**

**B-1.** action-reaction force between M and vertical wall

$N = 0$ for $F\mu \le (M+m)g$

$N = F - \mu(M+m)g$ for $F > \mu(M+m)g$

action-reaction force between m and M

$N = F - \mu mg$ for $F > \mu mg$

and $N = 0$ for $F < \mu mg$

**B-2.** Upwards, $f = m(g+a)$ **B-3.** $\theta = \tan^{-1}\frac{1}{2}$

**B-4.** (a) $\mu mg$ (b) $\frac{\mu mg}{\sqrt{1+\mu^2}}$, $\tan^{-1}\mu$.

**Section (C) :**

**C-1.** $\mu_s = 0.60$, $\mu_k = 0.52$

**C-2.** (i) $a_A = 3\ m/s^2$, $a_B = 0$, $f_{AB} = 0$, $f_{BG} = 0$

(ii) $a_A = 1\ m/s^2$, $a_B = 0$, $f_{AB} = 25N$, $f_{BG} = 25N$

(iii) $a_A = 5\ m/s^2$ ; $a_B = 10\ m/s^2$ ; $f_{AB} = 25N$ ; $f_{BG} = 75N$

(iv) $a_A = 1m/s^2$ ; $a_B = 1m/s^2$ ; $f_{AB} = 5N$ ; $f_{BG} = 75N$

### PART - II

**Section (A)**

| | | | | | |
|---|---|---|---|---|---|
| **A-1.** | (A) | **A-2.** | (C) | **A-3.** | (A) |

**Section (B)**

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

**Section (C)**

| | | | | | |
|---|---|---|---|---|---|
| **C-1.** | (D) | **C-2.** | (A) | **C-3.** | (C) |
| **C-4.** | (B) | | | | |

### PART - III

**1.** (A) – r ; (B) – q ; (C) – p ; (D) – s

**2.** (A) – s ; (B) – r ; (C) – p, s ; (D) – q, r

## EXERCISE-2

### PART - I

| | | | | | |
|---|---|---|---|---|---|
| **1.** | (C) | **2.** | (A) | **3.** | (B) |
| **4.** | (B) | **5.** | (A) | **6.** | (D) |
| **7.** | (A) | **8.** | (C) | **9.** | (B) |
| **10.** | (B) | **11.** | (A) | **12.** | (C) |
| **13.** | (A) | **14.** | (D) | **15.** | (D) |

### PART - II

| | | | | | |
|---|---|---|---|---|---|
| **1.** | 2 | **2.** | 5 | **3.** | 20 |
| **4.** | 7 | **5.** | 2 | **6.** | 4 |
| **7.** | 20 | **8.** | 15 | **9.** | 16 |

### PART - III

| | | | | | |
|---|---|---|---|---|---|
| **1.** | (ABC) | **2.** | (AC) | **3.** | (ABCD) |
| **4.** | (BCD) | **5.** | (AD) | **6.** | (AC) |
| **7.** | (AD) | | | | |

### PART - IV

| | | | | | |
|---|---|---|---|---|---|
| **1.** | (A) | **2.** | (B) | **3.** | (A) |
| **4.** | (B) | **5.** | (B) | **6.** | (A) |
| **7.** | (A) | **8.** | (D) | **9.** | (C) |
| **10.** | (B) | | | | |

## EXERCISE-3

### PART - I

| | | | | | |
|---|---|---|---|---|---|
| **1.** | 10 | **2.** | (B) | **3.** | (A) |
| **4.** | 5 | **5.** | (AC) | **6.** | (D) |

### PART - II

| | | | | | |
|---|---|---|---|---|---|
| **1.** | (3) | **2.** | (1) | **3.** | (4) |
| **4.** | (3) | **5.** | (1) | **6.** | (3) |
| **7.** | (4) | | | | |