arride learning

FRICTION

Contents

Syllabus

Friction and its Application

Name : ______________________________ **Contact No.** ____________________

ARRIDE LEARNING ONLINE E-LEARNING ACADEMY

A-479 indra Vihar, Kota Rajasthan 324005

Contact No. 8033545007

FRICTION

When a force $\vec{f}$ tends to slide a body along a surface, a frictional force from the surface acts on the body. The frictional force is parallel to the surface and directed so as to oppose the sliding. It is due to bonding between the body and the surface. If the body does not slide the frictional force is a Static Frictional Force $\vec{f_S}$. If there is sliding the frictional force is kinetic frictional force $\vec{f_K}$.

THREE PROPERTIES OF FRICTION :

1. If the body does not move, then the static frictional force $\vec{f_S}$ and the component of $\vec{F}$ that is parallel to the surface are equal in magnitude, and $\vec{f_S}$ is directed opposite that component. If that parallel component increases, magnitude f_s also increases. If the applied parallel component exceeds a certain (maximum) value, the body slides on the surface.

2. The magnitude of $\vec{f_S}$ has a maximum value called **limiting value** $f_{s,max}$ or f_L that is given by $f_L = \mu_s N$ where μ_s is the coefficient of static friction and N is the magnitude of the normal force.

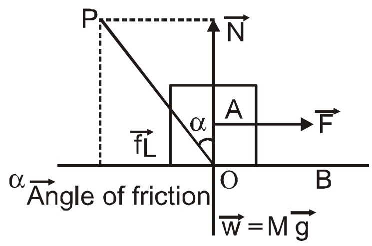
3. If the body begins to slide on the surface, the magnitude of the frictional force rapidly decreases to a constant value f_k given by $f_k = \mu_k N$
where μ_k is coefficient of kinetic friction.
The value of μ_s is greater or equal to μ_k.

NOTE : In problems if μ_s and μ_k are separately not given. But only μ is given. Then

$$\mu = \mu_s = \mu_k$$

ANGLE OF FRICTION :

As shown in fig, a body A is in contact with surface B. The forces acting on A is shown. Surface B applies two contact forces on body A.



$$\therefore \qquad \tan\alpha = \frac{f_L}{N} = \frac{\mu N}{N} = \mu \qquad \text{or} \qquad a = \tan^{-1}(\mu)$$

$$|\vec{OP}| = N\sqrt{1+\mu^2}$$

EXERCISE # 1

PART - I : OBJECTIVE QUESTIONS

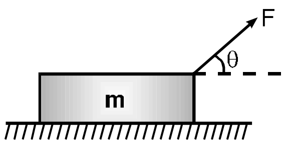
*** Marked Questions are having more than one correct option.**

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

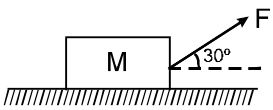
A-2. A wooden block of mass m resting on a rough horizontal table (coefficient of friction = μ) is pulled by a force F as shown in figure. The acceleration of the block moving horizontally is :



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

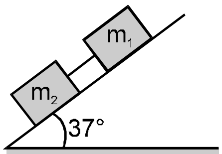
(C) $\frac{F}{m}(\cos\theta + \mu\sin\theta) - \mu g$ (D) none

A-3. A block of mass M = 5 kg is resting on a rough horizontal surface for which the coefficient of friction is 0.2. When a force F = 40 N is applied as shown in figure the acceleration of the block will be (g = 10 m/s^2) :



(A) 5.73 m/sec^2 (B) 8.0 m/sec^2 (C) 3.17 m/sec^2 (D) 10.0 m/sec^2

A-4. Two blocks m_1 = 4kg and m_2 = 2kg, connected by a weightless rod on a plane having inclination of 37^0 as shown in figure. The coefficients of dynamic friction of m_1 and m_2 with the inclined plane are μ = 0.25. Then the common acceleration of the two blocks and the tension in the rod are :



(A) 4 m/s^2, T = 0 (B) 2 m/s^2, T = 5 N

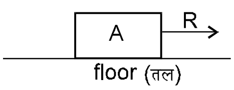
(C) 10 m/s^2 ,T = 10 N (D) 15 m/s^2, T = 9N

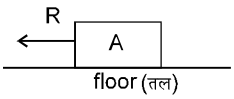
Section (B) : Static Friction

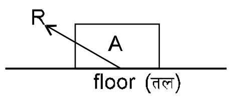
B-1. If the normal force is doubled, the co-efficient of friction is :

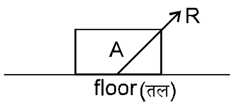
(A) halved (B) doubled (C) tripled (D) not changed

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 :

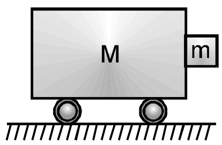
(A) 

(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 μ. What is the minimum acceleration of the cart so that the block m does not fall?



(A) μg (B) μ/g (C) g/μ (D) none

B-4. A uniform rope so lies on a table that part of it lays over. 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

B-5. A block of mass 1 kg lies on a horizontal surface in a truck. The coefficient of static friction between the block and the surface is 0.6 If the acceleration of the truck is 5 m/s^2, the frictional force acting on the block is :
(A) 5 N (B) 6 N (C) 10 N (D) 15 N

B-6.* A contact force exerted by one body on horizontal surface is equal to the normal force ($\neq 0$) between them. It can be said that :

(A) the contact surfaces must be frictionless

(B) the force of friction between the contact surfaces is zero

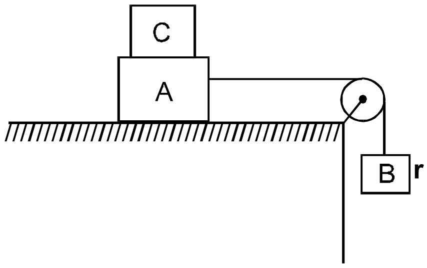
(C) the magnitude of normal force equals that of friction

(D) It is possible that the bodies are rough and they do not slip on each other.

B-7. A block of mass 2 kg rests on a rough inclined plane making an angle of 30^0 with the horizontal. The coefficient of static friction between the block and the plane is 0.7. The frictional force on the block is :

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

B-8. 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

B-9.* 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 :

Here ϕ = Limiting angle of repose

θ = angle of inclined plane

w = weight of the body

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

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

Section (C) : Miscellaneous Questions

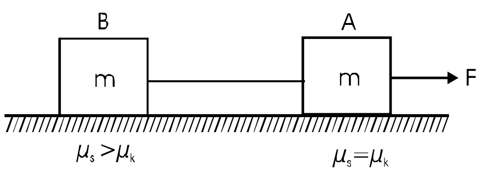
C-1. A block of mass 5 kg and surface area 2 m^2 just begins to slide down an inclined plane when the angle of inclination is 30°. Keeping mass same, the surface area of the block is doubled. The angle at which this starts sliding down is :

(A) 30° (B) 60° (C) 15° (D) none

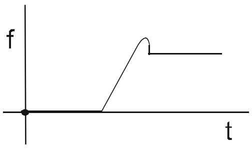
C-2. A 60 kg body is pushed horizontally with just enough force to start it moving across a floor and the same force continues to act afterwards. The coefficient of static friction and sliding friction are 0.5 and 0.4 respectively. The acceleration of the body is :

(A) 6 m/s^2 (B) 4.9 m/s^2 (C) 3.92 m/s^2 (D) 1 m/s^2

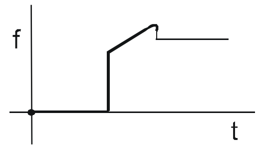
C-3. A force F = t is applied to block A as shown in figure. The force is applied at t = 0 seconds when the system was at rest and string is just straight without tension. Which of the following graphs gives the friction force between B and horizontal surface as a function of time 't'.



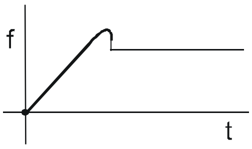
(A)



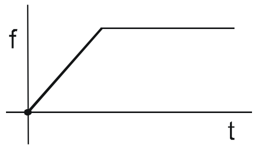
(B)



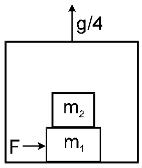
(C)



(D)



C-4. 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 μ = 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/s², 5 m/s² (B) 5 m/s², $\frac{50}{8}$ m/s² (C) 2.5 m/s², $\frac{25}{8}$ m/s² (D)4.5 m/s², 4.5m/s²

C-5. 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 μ and between the box and the floor is μ'. on which of the following cases it is certainly not possible to slide the box?

(A) μ > μ', m < m' (B) μ < μ', m < m' (C) μ < μ', m > m' (D) μ > μ', m > m

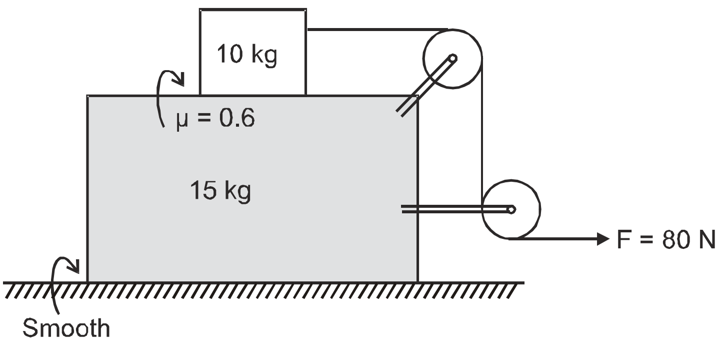
---

PART - II : MISLLANEOUS QUESTIONS

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/s²)



1. The magnitude of acceleration of the 10 kg block is :

(A) 3.2 m/s² (B) 2.0 m/s² (C) 1.6 m/s² (D) 0.8 m/s²

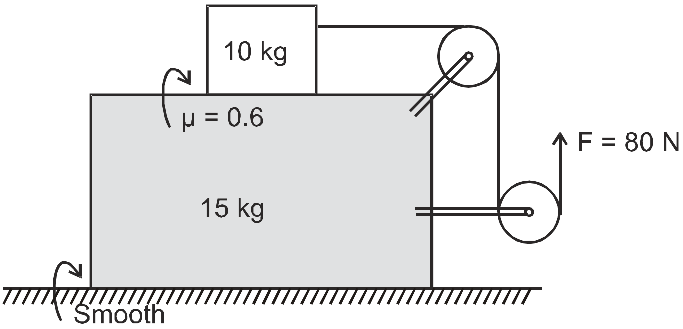
2. The magnitude of acceleration of the 15 kg block is :

(A) 4.2 m/s² (B) 3.2 m/s² (C) 16/3 m/s² (D) 2.0 m/s²

3. 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

4. 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

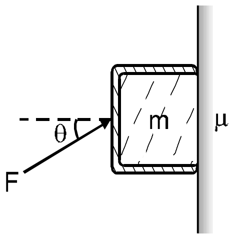
5. In the situation of the previous question, acceleration of the 15 kg block will be :

(A) 4 m/s^2, towards right (B) 16/5 m/s^2, towards right

(C) 2/3 m/s^2, towards right (D) 4/3 m/s^2, towards left

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 μ_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.



6. 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) $\frac{mg}{\mu\tan\theta}$

7. 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) $\frac{mg}{\tan\theta}$

8. 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

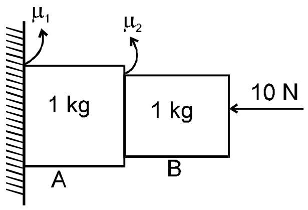
(B) If $F = F_{min}$; the block slides upward

(C) In each case (for any value of F) the friction force $f \leq mg$

(D) All the above

Match The Column :

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



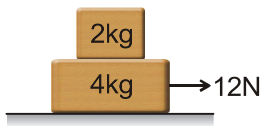
Column - I	Column - II
(A) $\mu_1 = 0$ and $\mu_2 = 0.1$	(p) $a_A = a_B = 9.5\ m/s^2$
(B) $\mu_2 = 0$ and $\mu_1 = 0.1$	(q) $a_A = 9\ m/s^2$, $a_B = 10\ m/s^2$
(C) $\mu_1 = 0.1$ and $\mu_2 = 1.0$	(r) $a_A = a_B = g = 10\ m/s^2$
(D) $\mu_1 = 1.0$ and $\mu_2 = 0.1$	(s) $a_A = 1$, $a_B = 9\ m/s^2$

10. 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 block and there is no relative motion between both the blocks in all situations. 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**

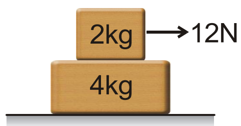
(A) Magnitude of frictional force is maximum.

(p)



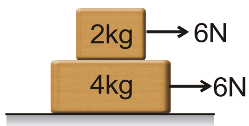
(B) Magnitude of friction force is least.

(q)



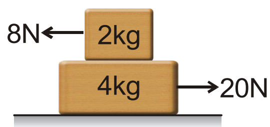
(C) Friction force on 2 kg block is towards right.

(r)



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

(s)



Assertion / Reasoning :

11. **STATEMENT-1 :** While drawing a line on a paper by pencil, friction force acts on paper in the same direction along which line is drawn on the paper.

STATEMENT-2 : Friction always opposes motion.

(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

12. **STATEMENT-1 :** A body is lying at rest on a rough horizontal surface. A person accelerating with acceleration $a\hat{i}$ (where a is positive constant and $\hat{i}$ is a unit vector in horizontal direction) observes the body. With respect to him, the block experiences a kinetic friction.

STATEMENT-2 : Whenever there is relative motion between the contact surfaces then kinetic friction acts.

(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

13. **STATEMENT-1 :** A block of mass m = 10 kg lies on rough horizontal surface. The coefficient of friction between block and horizontal surface is $\mu = \frac{3}{4}$. Initially the only force acting on block are its weight and normal reaction due to horizontal surface. An additional force of magnitude 70 N can move the block on horizontal surface.

STATEMENT-2 : The magnitude of minimum force required to move a block of mass m placed on rough horizontal surface is μN. (Where μ is co-efficient of friction and N is normal reaction acting on the block).

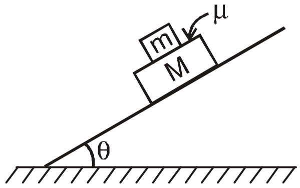
(A) Statement-1 is True, Statement-2 is True; Statement-2 **is** a correct explanation for Statement-1

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

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

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

14. **STATEMENT–1 :** A block of mass m is placed on a block of mass M, which in turn is placed on smooth fixed inclined plane. The two block system is released from rest as shown. Whatever be the coefficient of friction between both the blocks, the magnitude of friction force between the both the blocks will be zero (As long as they are on inclined surface).



STATEMENT–2 : In the situation of statement-1, there is no tendency of relative motion between the blocks.

(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.

True / False :

15. State True or False :

(i) 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.

(ii) The contact force on spherical body is always in radial direction.

(iii) Whenever a small block is placed (free to move) on the inclined surface of a fixed wedge, the contact force between block and wedge surface is always less than or equal to the weight of the block.

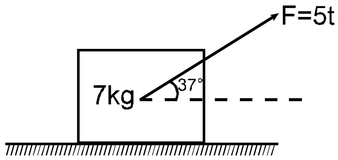
Fill in the Blanks :

16. Fill in the blanks :

(i) A block can move over a rough horizontal x-y plane. At the moment when the block is moving with a negligible velocity along the positive x-axis, three forces $\vec{F}_1 = (2\hat{i} + 3\hat{j})$ N, $\vec{F}_2 = (-4\hat{i} + \hat{j})$ N and $\vec{F}_3 = (3\hat{i} - 5\hat{j})$ N start acting on the block. The direction of the friction force on the block at the moment when the forces started acting is .... (Mention the answer in vector form)

(ii) 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.

(iii) A block of 7 kg is placed on a rough horizontal surface and is pulled through a variable force F(in N) = 5t, where 't' is time in second, at an angle of 37° with the horizontal as shown in figure. The coefficient of static friction of the block with the surface is one. If the force starts acting at t = 0 s, Find the time at which the block starts to slide .... (Take g = 10 m/s^2) :



(iv) A lift is moving downwards with an acceleration equal to the acceleration due to gravity. A body of mass M kept on the lift is pulled horizontally. If the co-efficient of friction is 'μ' then the frictional resistance offered by the body is ....

EXERCISE # 2

PART - I : MIXED OBJECTIVE

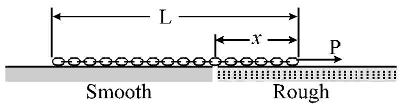
* ***Marked Questions are having more than one correct option.***

Single Choice Type :

1. A body is projected up along the 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. A chain of length L is placed on a horizontal surface as shown in figure. At any instant x is the length of chain on rough surface and the remaining portion lies on smooth surface. Initially x = 0. A horizontal force P is applied to the chain (as shown in figure). In the duration x changes from x = 0 to x = L, for chain to move with constant speed.



(A) the magnitude of P should increase with time

(B) the magnitude of P should decrease with time

(C) the magnitude of P should increase first and then decrease with time

(D) the magnitude of P should decrease first and then increase with time

3. The upper portion of an inclined plane of inclination α 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) $\frac{1}{2}$

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

(A) $\frac{\cos\theta}{\mu_0}$ (B) $\frac{\sin\theta}{\mu_0}$ (C) $\frac{\tan\theta}{\mu_0}$ (D) $\frac{2\tan\theta}{\mu_0}$

5. 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 :

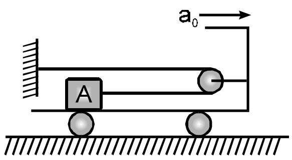
$\vec{a} = 0$ for $0 \le t \le 2.85$

$\vec{a} = (1.2t - 2.4)\hat{i}$ m/s^2 for $t > 2.85$

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

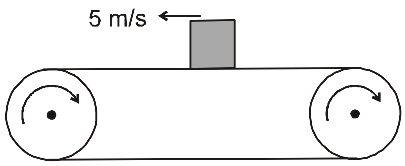
(A) 0.12 (B) 0.24 (C) 0.36 (D) 0.48

6. Starting from rest, A flat car is given a constant acceleration $a_o = 2\ m/s^2$. 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 -



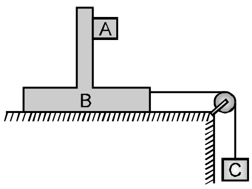
(A) 700 N (B) 350 N (C) 175 N (D) 0

7. A block lying on a long horizontal conveyor belt moving at a constant velocity receives a velocity 5 m/s relative to the ground in the direction opposite to the direction of motion of the conveyor. After t = 4 sec, the velocity of the block becomes equal to the velocity of the belt. The coefficient of friction between the block and the belt is 0.2. Then the velocity of the conveyor belt is : ($g = 10\ m/s^2$)



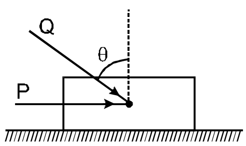
(A) 13 m/s (B) – 13 m/s (C) 3 m/s (D) 6 m/s

8. In the arrangement shown in the figure mass of the block B and A are 2 m, 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 μ and pulley is ideal)



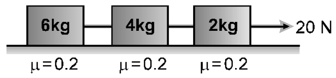
(A) $\frac{m}{\mu}$ (B) $\frac{2m}{\mu + 1}$ (C) $\frac{10\ m}{1 - \mu}$ (D) $\frac{10m}{\mu - 1}$

9. A block of mass m lying on a rough horizontal plane is acted upon by a horizontal force P and another force Q inclined an at an angle θ 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) $\frac{P\sin\theta - Q}{mg - Q\cos\theta}$

10. **(i)** In the arrangement shown tension in the string connecting 4kg and 6kg masses is



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

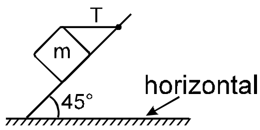
(ii) Friction force on 4 kg block is

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

(iii) Friction force on 6 kg block is

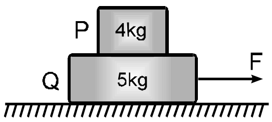
(A) 12 N (B) 8 N (C) 6 N (D) 4 N

11. 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 is ($g = 10\ m/s^2$)



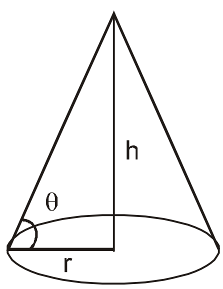
(A) 1/2 (B) 2/3 (C) 3/4 (D) 1/4

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 respectively. 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 $2 m/s^2$
(D) Slipping between 4kg and 5 kg blocks start when F is > 17N

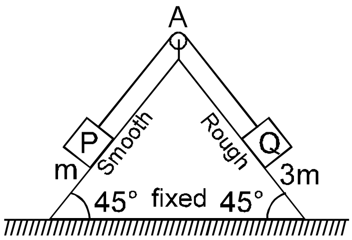
13. A worker wishes to pile a cone of sand into a circular area in his yard. The radius of the circle is r, and no sand is to spill onto the surrounding area. If μ is the static coefficient of friction between each layer of sand along the slope and the sand, the greatest volume of sand that can be stored in this manner is :



(A) $\mu\pi r^3$ (B) $\frac{1}{3}\mu\pi r^3$

(C) $2\mu\pi r^2$ (D) $2\mu\pi r$

14. A fixed wedge with both surface inclined at 45^0 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



(i) the tension in the string is :

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

(ii) In the above question the coefficient of friction between Q and the rough plane is :

(A) $\frac{4}{5}$ (B) $\frac{1}{5}$ (C) $\frac{3}{5}$ (D) $\frac{2}{5}$

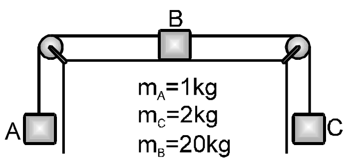
(iii) In the above question the magnitude and direction of the force exerted by the string on the pulley is:

(A) $\frac{6mg}{5}$ downward (B) $\frac{6mg}{5}$ upward

(C) $\frac{mg}{5}$downward (D) $\frac{mg}{4}$downward

More than one choice type

15.* A block on a long table is tied by massless ropes to two hanging blocks as in figure. Initially block C is moving downwards with non zero velocity. The static and kinetic friction between block B & table is 0.3 and 0.1 respectively.



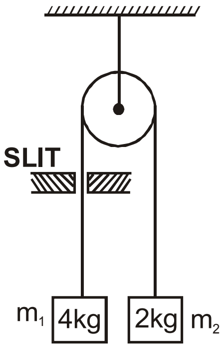
(A) Acceleration of block C is approx. 0.4 m/s^2 downwards

(B) Acceleration of block C is approx. 0.43 m/s^2 upwards

(C) Block C comes to rest after some time

(D) Acceleration of block C is zero, all the time

16.* 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)



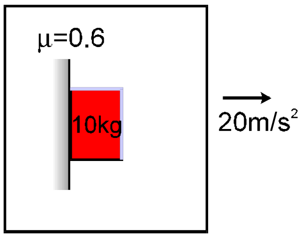
(A) Acceleration of mass m_1 is $\frac{5}{3}$ m/s², downwards.

(B) Tension in the string is same throughout.

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

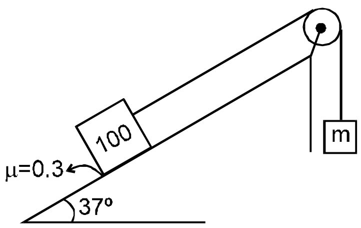
(D) If positions of both the masses are interchanged, then 2kg mass moves up with an acceleration $\frac{10}{3}$ m/s².

17.* 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 μ = 0.6.



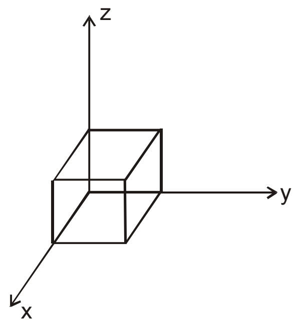
(A) The acceleration of the box will be 20 m/sec²
(B) The friction force acting on the box will be 100 N
(C) The contact force between the vertical wall and the box will be 100 $\sqrt{5}$ N
(D) The net contact force between the vertical wall and the box is only of electromagnetic in nature.

18.* In the given figure the value(s) of mass m for which the 100 kg block remains in static equilibrium is (g = 10 m/s²)



(A) 35 kg (B) 37 kg (C) 83 kg (D) 85 kg

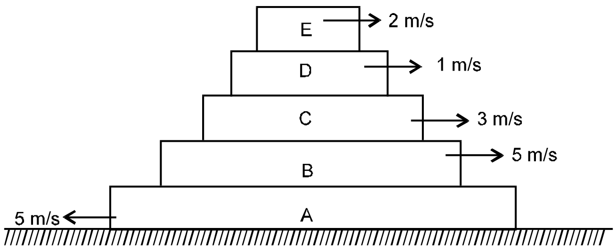
19.* A solid cube of mass 5 kg is placed on a rough horizontal surface, in xy-plane as shown. The friction coefficient between the surface and the cube is 0.4. An external force $\vec{F} = 6\hat{i} + 8\hat{j} + 20\hat{k}$ N is applied on the cube. (use g = 10 m/s^2)



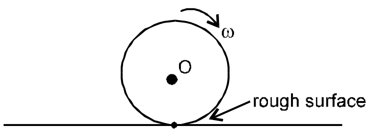
(A) The block starts slipping over the surface
(B) The friction force on the cube by the surface is 10 N.
(C) The friction force acts in xy-plane at angle 127° with the positive x-axis in clockwise direction.
(D) The contact force exerted by the surface on the cube is $10\sqrt{10}$ N.

PART - II : SUBJECTIVE QUESTIONS

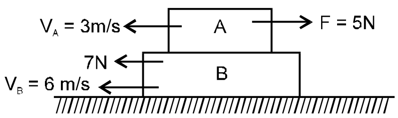
1. In the given diagram find the direction of friction forces on each block and the ground (Assume all surfaces are rough and all velocities are with respect to ground).



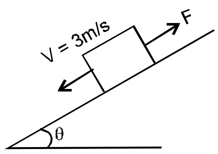
2. The wheel shown in the diagram is fixed at 'O' and is in contact with a rough surface as shown . The wheel rotates with an angular velocity ω. What is the direction and nature of friction force on the wheel and on the ground.



3. In the following figure, find the direction of friction on the blocks and ground .

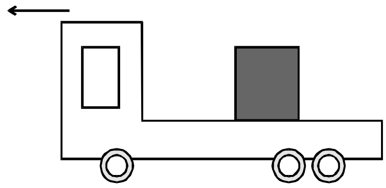


4. In the following figure, find the direction and nature of friction on the block.

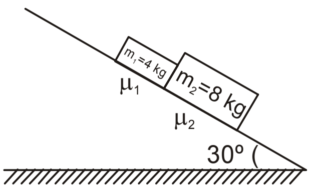


5. A block is shot with an initial velocity $5ms^{-1}$ on a rough horizontal plane. Find the distance covered by the block till it comes to rest. The coefficient of kinetic friction between the block and plane is 0.1.

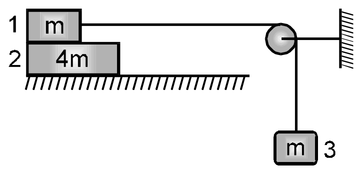
6. The rear side of a truck is open and a box of 40 kg mass is placed 5 m away from the open end as shown in figure. The coefficient of friction between the box and the surface below it is 0.15. On a straight road, the truck starts from rest and accelerates with $2\ ms^{-2}$. Find the distance travelled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



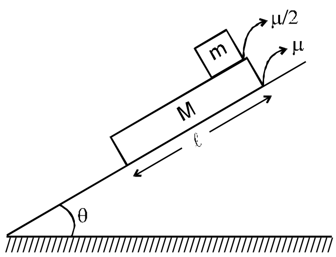
7. In the figure shown below the friction between the 4 kg block and the incline as μ_1 and between 8 kg and incline is μ_2. Calculate the accelerations of the blocks 8kg & 4kg respectively when (a) $\mu_1 = 0.2$ and $\mu_2 = 0.3$ (b) $\mu_1 = 0.3$ and $\mu_2 = 0.2$. (take g = 10 m/s²)



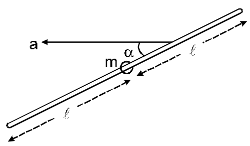
8. In figure block 1 is one fourth the length ℓ of block 2 of mass also one fourth. No friction exists between block 2 and surface on which it rests. Coefficient of friction is μ_k between 1 & 2. Find the distance block 2 moves when only half of block 1 is still on block 2. Block 1 and block 3 have same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



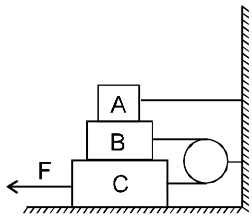
9. In the given situation it is known that when released the blocks slide. Find the accelerations of the two blocks. Also find the time when the small block will fall off from the larger block. (The size of m is very –very small then M, see figure)



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



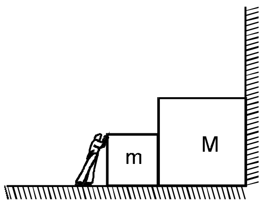
11. $M_A = 3$ kg, $M_B = 4$ kg and $M_C = 8$ kg. μ between any two surfaces is 0.25. Pulley is frictionless and string is massless block. A is connected to the wall through a massless rigid rod as shown in figure.($g=10 m/s^2$)



(a) find the value of F to keep C moving with constant speed
(b) if F is 200 N then find acceleration of B

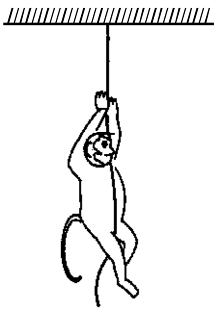
Section (B) : Static Friction

12. The person applies F force on the smaller block as shown in figure. The coefficient of static friction is μ 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?

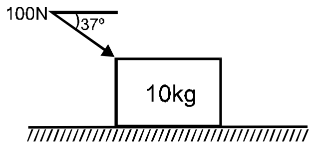


13. The angle between the resultant contact force and the normal force exerted by a body on the other is called the angle of friction. Show that, if λ be the angle of friction and μ the coefficient of static friction, $\lambda \leq \tan^{-1}\mu$

14. In the given figure a monkey of mass m is climbing a rope hanging from the roof with acceleration a. The coefficient of static friction between the body of the monkey and the rope is μ. Find the direction and value of friction force on the monkey.

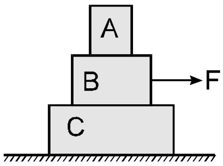


15. In the figure shown calculate the angle of friction. The block does not slide. Take g = 10 m/s^2.

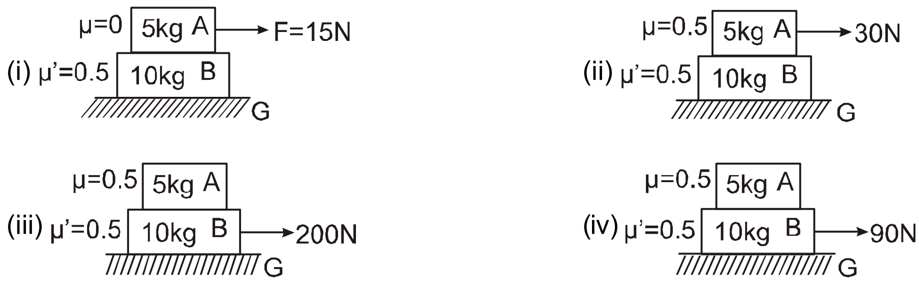


16. What is the minimum value of force required to pull a block of mass M on a horizontal surface having coefficient of friction μ? Also find the angle this force makes with the horizontal.

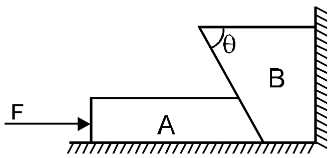
17. In the figure shown, the coefficient of static friction between C and ground is 0.5, coefficient of static friction between A and B is 0.25, coefficient of static friction between B and C is zero. Find the minimum value of force 'F', to cause sliding between A and B. Masses of A, B and C are respectively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



19. In the given figures find the accelerations and the friction forces involved :



20. In the figure shown, the coefficient of static friction between block B and the wall is 2/3 and the coefficient of kinetic friction between B and the wall is 1/3. Other contacts are smooth. Find the minimum force 'F' required to lift B, up. Now if the force applied on A is slightly increased than the calculated value of minimum force, then find the acceleration of B. Mass of A is 2m and the mass of B is m. Take tan θ = 3/4.



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

22. A block of mass 2 kg is pushed against a rough vertical wall with a force of 40 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. Will the block move? If yes, in which direction & what is the acceleration ? If no, find the frictional force exerted by the wall on the block.

EXERCISE # 3

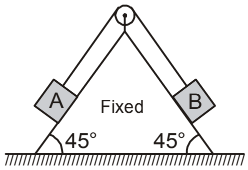
PART-I IIT-JEE (PREVIOUS YEARS PROBLEMS)

***Marked Questions are having more than one correct option.**

1. A block of mass 0.1kg is held against a wall by 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 friction force acting on the block is : **[JEE 1994, 1 Mark]**

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

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

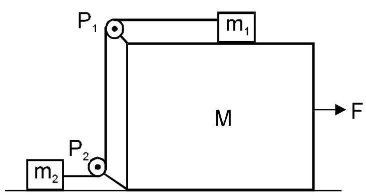


(i) the acceleration of A

(ii) tension in the string

(iii) the magnitude and the direction of friction acting on A. **[JEE 1997, 5/100]**

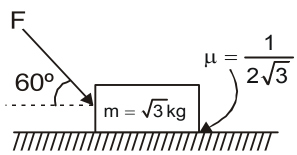
3. In the figure masses m_1, m_2 and M are 20 kg, 5 kg and 50 kg respectively . The coefficient of friction between M & ground is zero. The coefficient of friction between m_1 & M and that between m_2 & ground is 0.3 . The pulleys & the string are massless . The string is perfectly horizontal between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



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

(ii) Let the magnitude of the force of friction between m_1 and M be f_1 and that between m_2 and ground be f_2. For a particular F it is found that $f_1 = 2 f_2$. Find f_1 and f_2. Write down equations of motion of all the masses. Find F, tension in the string and accelerations of the masses. **[JEE 2000, 2+8/100]**

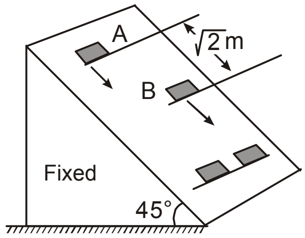
4. What is the maximum value of the force F such that the block shown in the arrangement, does not move :



[JEE 2003 (Screening); 3/90]

(A) 20 N (B) 10 N (C) 12 N (D) 15 N

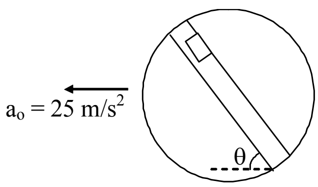
5. Two blocks A and B of equal masses are sliding down along straight parallel lines on an inclined plane of 45°. Their coefficients of kinetic friction are $\mu_A = 0.2$ and $\mu_B = 0.3$ respectively. At t = 0, both the blocks are at rest and block A is $\sqrt{2}$ meter behind block B. The time and distance 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]

(A) 2s, $8\sqrt{2}$ m (B) $\sqrt{2}$ s, 7m (C) $\sqrt{2}$ s, $7\sqrt{2}$ m (D) 2s, $7/\sqrt{2}$ m

6. 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 a mass m inside the groove and the 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]**



7. **STATEMENT -1**

It is easier to pull a heavy object than to push it on a level ground. **[JEE 2008, 3/163, –1]**

STATEMENT -2

The magnitude of frictional force depends on the nature of the two surfaces in contact.

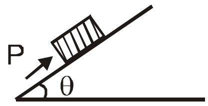
(A) STATEMENT -1 is True, STATEMENT -2 is True; STATEMENT -2 **is** a correct explanation for STATEMENT -1

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

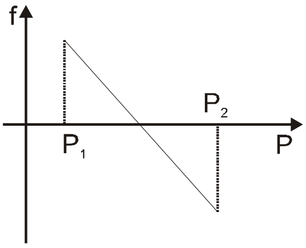
(C) STATEMENT -1 is True, STATEMENT -2 is False

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

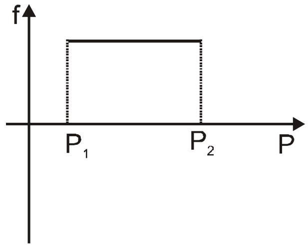
8. A block of mass m is on inclined plane of angle θ. The coefficient of friction between the block and the plane is μ and $\tan\theta > \mu$. The block is held stationary by applying a force P parallel to the plane. The direction of force pointing up the plane is taken to be positive. As P is varied 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]**



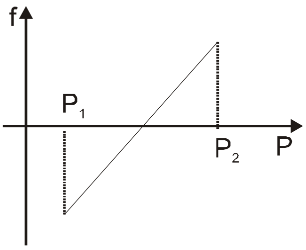
(A)



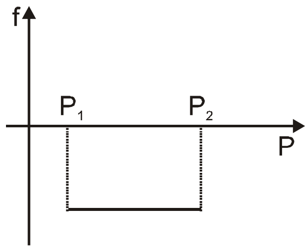
(B)



(C)

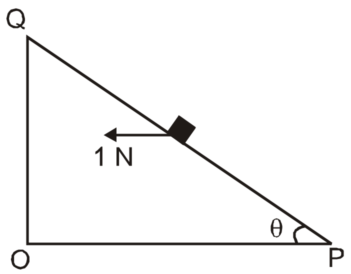


(D)



9. A block is moving on an inclined plane making an angle 45° with the horizontal and the coefficient of friction is μ. Thje 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 **[JEE 2011]**

10. 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 of1N act on the block through its center of mass as shown in the figure. The block remains stationary if (take $g = 10\ m/s^2$)



(A) $\theta = 45^o$

(B) $\theta > 45^o$ and a frictional force acts on the block towards P.

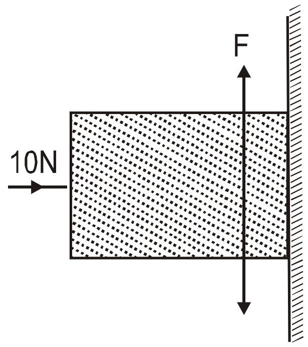
(C) $\theta > 45^o$ and a frictional force acts on the block towards Q.

(D) $\theta < 45^o$ and a frictional force acts on the block towards Q. **[JEE 2012, 4/136]**

PART-II AIEEE (PREVIOUS YEARS PROBLEMS)

*** Marked Questions are having more than one correct option.**

1. 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 : **[AIEEE-2003; 4/300]**



(1) 20 N (2) 50 N (3) 100 N (4) 2 N

2. A marble block of mass 2 kg lying on ice when given a velocity of 6 m/s is stopped by friction in 10s. Then the coefficient of friction is : **[AIEEE-2003; 4/300]**

(1) 0.02 (2) 0.03 (3) 0.06 (4) 0.01

3. A block rests on a rough inclined plane making an angle of 30º 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 $g = 10\ m/s^2$) : **[AIEEE-2004; 4/300]**

(1) 2.0 (2) 4.0 (3) 1.6 (4) 2.5

4. A smooth block is released at 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) $\mu_k = \sqrt{1 - \frac{1}{n^2}}$

5. The upper half of an incline 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 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) $2 \cos \phi$

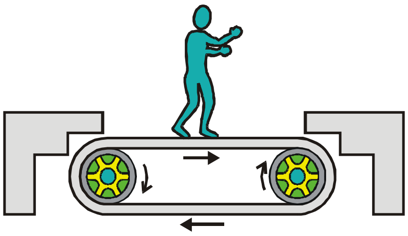
6. Consider a car moving on a straight road with a speed of 100 m/s. The distance at which car can be stopped is [$\mu_k = 0.5$] **[AIEEE-2005; 4/300]**

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

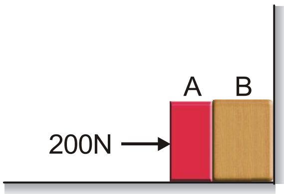
EXERCISE # 4

NCERT QUESTIONS

1. figure shows a man standing stationary with respect to a horizontal conveyor belt that is accelerating with 1 m s^{-2}. What is the net force on the man ? If the coefficient of static friction between the mans shoes and the belt is 0.2, up to what acceleration of the belt can the man continue to be stationary relative to the belt ? (Mass of the man = 65 kg.)

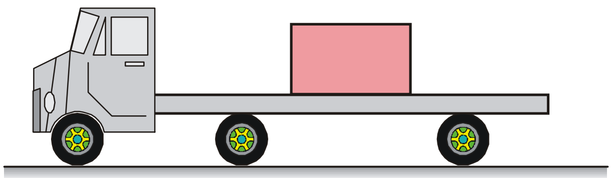


2. Two bodies A and B of masses 5 kg and 10 kg in contact with each other rest on a table against a rigid partition (figure). The co-efficient of friction between the bodies and the table is 0.15. A force of 200 N is applied horizontally at A. What are (a) the reaction of the partition (b) the action-reaction forces between A and B? What happens when, the partition is removed ? Does the answer to (b) change, when the bodies are in motion ? Ignore the difference between μ_s and μ_k.



3. A block of mass 15 kg is placed on a long trolley. The co-efficient of static friction between the block and the trolley is 0.18. The trolley accelerates from rest with 0.5 m s^{-2} for 20 s and then moves with uniform velocity. Discuss the motion of the block as viewed by (a) a stationary observer on the ground, (b) an observer moving with the trolley.

4. 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 Fig. The co-efficient of friction between the box and the truck below it is 0.15. On a straight road, the truck starts from rest and accelerates with a constant acceleation of 2 m s^{-2}. At what distance from the starting point does the box fall off the truck ? (Ignore the size of the box).



5. A disc revolves with a speed of $33\frac{1}{3}$ rev/min, and has a radius of 15 cm. Two coins are placed at 4 cm and 14 cm away from the centre of the record. If the co-efficient of friction between the coins and the record is 0.15, which of the coins will revolve with the record ?

6. A 70 kg man stands in contact against the inner wall of a hollow cylindrical drum of radius 3 m rotating about its vertical axis. The co-efficient of friction between the wall and his clothing is 0.15. What is the minimum rotational speed of the cylinder to enable the man to remain stuck to the wall (without falling) when the floor is suddenly removed ?

ANSWERS

Exercise # 1

PART-I

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

B-4. (A) **B-5.** (A) **B-6.*** (B) **B-7.** (A) **B-8.** (A) **B-9.*** (AD) **C-1.** (A)

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

PART-II

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

8. (A) **9.** (A) r, (B) q, (C) p , (D) s **10.** (A) s (B) r (C) p, s (D) q, r

11. (C) **12.** (D) **13.** (C) **14.** (A) **15.** (i) False, (ii) False, (iii) True

16. (i) Since the initial velocity of block is along positive x-axis. So the direction of frictional force will be in $-\hat{i}$ at that moment $-\hat{i}$ ...

(ii) 5 N (iii) 10 sec (iv) zero

Exercise # 2

PART-I

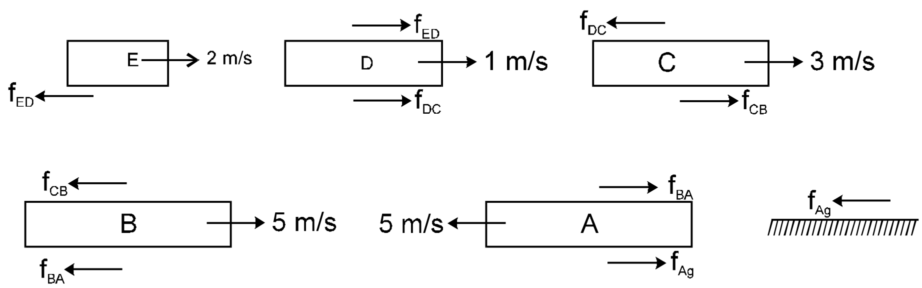
1. (C) **2.** (A) **3.** (A) **4.** (C) **5.** (B) **6.** (B) **7.** (C)

8. (D) **9.** (A) **10.** **(i)** (A), **(ii)** (D), **(iii)** (B) **11.** (A) **12.** (C)

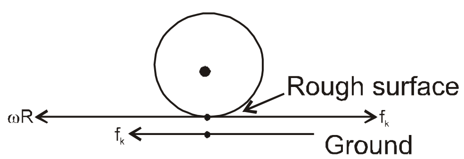
13. (B) **14.** (i) (B), (ii) (D), (iii) (A) **15.*** (BC) **16.*** (AC) **17.*** (ABCD)
18.* (BC) **19.*** (BCD)

PART-II

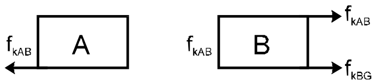
1.



2.



Kinetic friction is involved.

3. 

4. Up the incline, kinetic friction.

5. 12.5 m

6. 20 m

7. (a) $5-\frac{4}{\sqrt{3}}$ (= 2.7 m/s²) for both ; (b) $5-\sqrt{3}$ (=3.2 m/s²), $5-1.5\sqrt{3}$ (= 2.4 m/s²)

8. $x_2 = \dfrac{7\mu_k \ell}{8(2-3\mu_k)}$

9. $a_m = g\sin\theta - \frac{\mu}{2} g\cos\theta$; $a_M\ \dfrac{Mg\sin\theta + \frac{\mu}{2}mg\cos\theta - \mu(M+m)g\cos\theta}{M}$; $t=\sqrt{\dfrac{4\ell M}{\mu g\cos\theta(M+m)}}$.

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

11. (a) 80 N, (b)10 m/s² ,

12. action-reaction force between M and vertical wall
N = 0 for $F \le \mu(M+m)g$
$N = F - \mu(M+m)g$ 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 $F < \mu mg$

13. $\lambda \le \tan^{-1}\mu$

14. Upwards, f = m(g+a)

15. $\theta = \tan^{-1}\frac{1}{2}$

16. $\dfrac{\mu Mg}{\sqrt{1+\mu^2}}$, $\tan^{-1}\mu$.

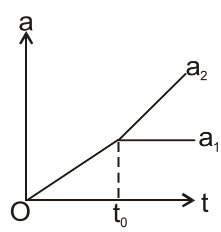
17. F_{min} = 15 N

18. $\mu_s = 0.60$, $\mu_k = 0.52$

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

20. (i) $F_{min} = \frac{3}{2}$ mg (ii) $b = \frac{3g}{22}$

21. When $t \le t_0$, the accelerations $a_1 = a_2 = kt/(m_1+m_2)$; when $t \ge t_0$
$a_1 = \mu g m_2 / m_1$, $a_2 = (kt - \mu m_2 g)/m_2$. Here $t_0 = \dfrac{\mu g(m_1+m_2)}{k} \times \dfrac{m_2}{m_1}$



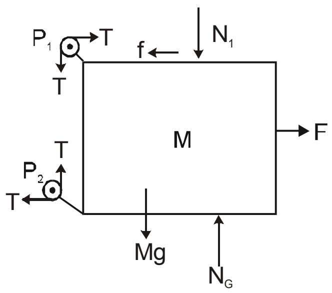
22. It will move at an angle of 53° with the 15N force and with acceleration 5/2 m/s².

Exercise # 3

PART-I

1. (B) **2.** (i) zero (ii) $\frac{2\sqrt{2}}{3}mg$ (iii) $\frac{mg}{3\sqrt{2}}$, downwards

3. F = 60 N, T = 18 N, $a_{m1} = a_{m2} = a_M = 0.6\ m/s^2$



4. (A) **5.** (A) **6.** 10 m/s² **7.** (B) **8.** (A) **9.** 5 **10.*** (AC)

PART-II

1. (4) **2.** (3) **3.** (1) **4.** (3) **5.** (1) **6.** (4)

Exercise # 4

1. Net force = 65 kg × 1 m s^{-2} = 65 N
$a_{max} = \mu_s g$ = 2 m s^{-2}

2. We assume perfect contact between bodies A and B and the rigid partition. In that case, the self-adjusting normal force on B by the partition (reaction) equals 200 N. There is no impending motion and no friction. The action-reaction forces between A and B are also 200 N. When the partition is removed, kinetic friction comes into play.
Acceleration of A + B = [200 – (150 × 0.15)]/ 15 = 11.8 m s^{-2}
Friction on A = 0.15 × 50 = 7.5 N
200 – 7.5 – F_{AB} = 5 × 11.8
F_{AB} = 133.5 N; opposite to motion.
F_{BA} = 133.5 N; in the direction of motion.

3. (a) Maximum frictional force possible for opposing impending relative motion between the block and the trolley = 150 × 0.18 = 27 N, which is more thanthe frictional force of 15 × 0.5 = 7.5 N needed to accelerate the box with the trolley. When the trolley moves with uniform velocity, there is no force of friction acting on the block.
(b) For the accelerated (non-inertial)observer, frictional force is opposed by the pseudo force of the samemagnitude, keeping the box at rest relative to the observer. When the trolley moves with uniform velocity there is no pseude-force for the moving (inertial) observer and no friction).

4. 20 m

5. For the coin to revolve with the disc, the force of friction should be enough to provide the necessary centripetal force, i.e. $\frac{mv^2}{R} \le \mu mg$. Now r = rω, where $\omega = \frac{2\pi}{T}$ is the angular frequency of the disc. For a given μ and ω, the condition is $r \le \mu g/\omega^2$. The condition is satisfied by the nearer coin (4 cm from the centre).

6. The horizontal force N by the wall on the man provides the needed centripetal force : $N = m R\omega^2$. The frictional force f (vertically upwards) opposes the weight mg. The man remains stuck to the wall after the floor is removed if mg = f < μN i.e. $mg < \mu m R \omega^2$. The minimum angular speed of rotation of the cylinder is $\omega_{min} = \sqrt{g/\mu R}$ = 4.7 s^{-1}.