NLM & FRICTION

NEWTON'S LAW OF MOTION

Section A,B,C,D - String Constrained, Wedge Constrained, Newton's Law theory Question, Equillibrium Questions (Normal and Tension), Problems with Acceleration (F=ma), Wedge problems

1. FORCE

A pull or push which changes or tends to change the state of rest or of uniform motion or direction of motion of any object is called force. Force is the interaction between the object and the source (providing the pull or push). It is a vector quantity.

Effect of resultant force :

- may change only speed
- may change only direction of motion.
- may change both the speed and direction of motion.
- may change size and shape of a body

unit of force : newton and $\frac{\text{kg.m}}{\text{s}^2}$ (MKS System)

dyne and $\frac{\text{g.cm}}{\text{s}^2}$ (CGS System)

1 newton = 10^5 dyne

Kilogram force (kgf)

The force with which earth attracts a 1 kg body towards its centre is called kilogram force, thus

$$\text{kgf} = \frac{\text{Force in newton}}{\text{g}}$$

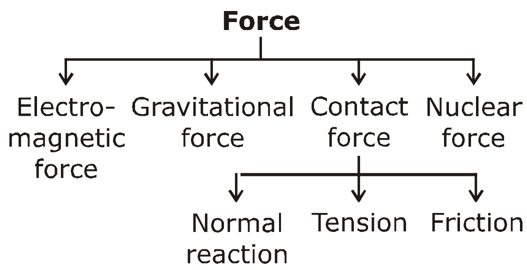
Dimensional Formula of force : [MLT^{-2}]

- For full information of force we require

  → Magnitude of force

  → direction of force

  → point of application of the force



1.1 Electromagnetic Force

Force exerted by one particle on the other because of the electric charge on the particles is called electromagnetic force.

Following are the main characteristics of electromagnetic force

- These can be attractive or repulsive
- These are long range forces
- These depend on the nature of medium between the charged particles.
- All macroscopic force (except gravitational) which we experience as push or pull or by contact are electromagnetic, i.e., tension in a rope, the force of friction, normal reaction, muscular force, and force experienced by a deformed spring are electromagnetic forces. These are manifestations of the electromagnetic attractions are repulsions between atoms/molecules.

1.2 Gravitational force :

It acts between any two masses kept anywhere in the universe. It follows inverse square rule ($F \propto \frac{1}{\text{distance}^2}$) and is attractive in nature.

$$F = \frac{GM_1M_2}{R^2}$$

The force mg, which Earth applies on the bodies, is gravitational force.

1.3 Nuclear force :

It is the strongest force. It keeps nucleons (neutrons and protons) together inside the nucleus inspite of large electric repulsion between protons. Radioactivity, fission, and fusion, etc. result because of unbalancing of nuclear forces. It acts within the nucleus that too upto a very small distance.

1.4 Contact force :

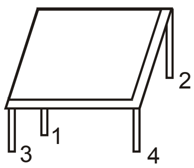
Forces which are transmitted between bodies by short range atomic molecular interactions are called contact forces. When two objects come in contact they exert contact forces on each other.

1.4.1 Normal force (N) :

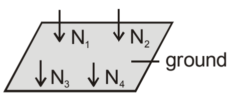
It is the component of contact force perpendicular to the surface.

It measures how strongly the surfaces in contact are pressed against each other. It is the electromagnetic force. A table is placed on

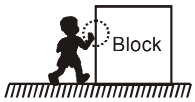
Earth as shown in figure.



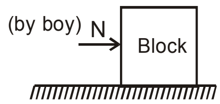
- Here table presses the earth so normal force exerted by four legs of table on earth are as shown in figure.



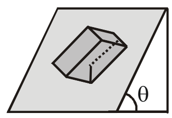
- Now a boy pushes a block kept on a frictionless surface.



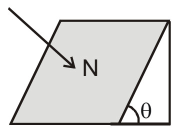
Here, force exerted by boy on block is electromagnetic interaction which arises due to similar charges appearing on finger and contact surface of block, it is normal force.



- A block is kept on inclined surface. Component of its weight presses the surface perpendicularly due to which contact force acts between surface and block.



Normal force exerted by block on the surface of inclined plane is shown in figure.



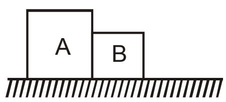
Force acts perpendicular to the surface

:

- Normal force acts in such a fashion that it tries to compress the body
- Normal is a dependent force, it comes in role when one surface presses the other.

EXAMPLE 01

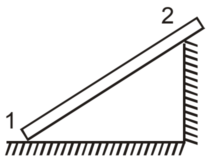
Two blocks are kept in contact on a smooth surface as shown in figure. Draw normal force exerted by A on B.



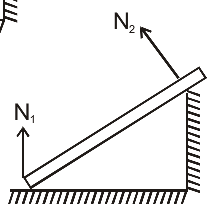
Sol. In above problem, block A does not push block B, so there is no molecular interaction between A and B. Hence normal force exerted by A on B is zero.

EXAMPLE 02

Draw normal forces on the massive rod at point 1 and 2 as shown in figure.

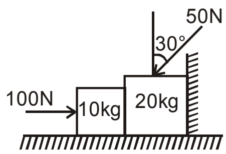


Sol. Normal force acts perpendicular to extended surface at point of contact.



EXAMPLE 03

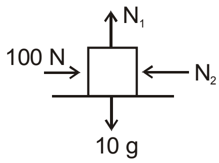
Two blocks are kept in contact as shown in figure. Find (a) forces exerted by surfaces (floor and wall) on blocks (b) contact force between two blcoks.



Sol. **F.B.D. of 10 kg block**

$N_1 = 10\text{ g} = 100\text{ N}$ ...(1)

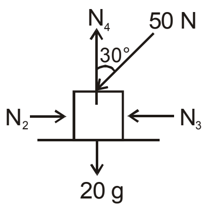
$N_2 = 100\text{ N}$ ...(2)



F.B.D. of 20 kg block

$N_2 = 50 \sin 30° + N_3$

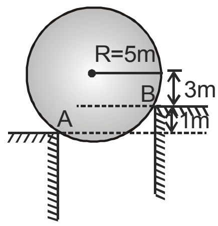
$\therefore$ $N_3 = 100 - 25 = 75\text{ N}$ ...(3)



and $N_4 = 50 \cos 30° + 20\text{ g}$

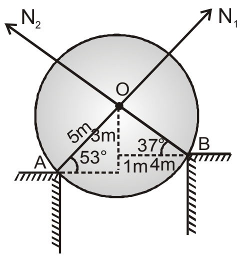
$N_4 = 243.30\text{ N}$

EXAMPLE 04

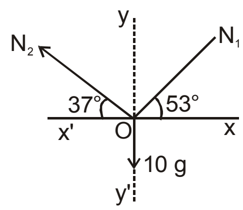


Find out the normal reaction at point A and B if the mass of sphere is 10 kg.

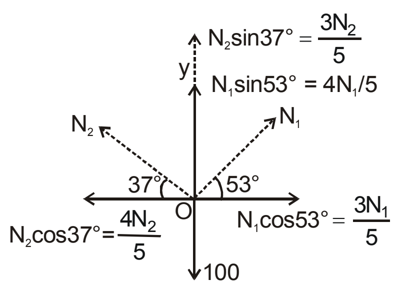
Sol.



Now F.B.D.



Now resolve the forces along x & y direction



$\because$ The body is in equilibrium so equate the force in x & y direction

In x-direction $\frac{3N_1}{5} = \frac{4N_2}{5}$ ...(1)

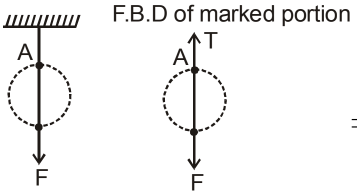
In y-direction $\frac{3N_2}{5} + \frac{4N_1}{5} = 100$ ...(2)

after solving above equation

$N_1 = 80\text{ N}$, $N_2 = 60\text{ N}$

1.4.2 Tension :

Tension in a string is an electromagnetic force. It arises when a string is pulled. If a massless string is not pulled, tension in it is zero. A string suspended by rigid support is pulled by a force 'F' as shown in figure, for calculating the tension at point 'A' we draw F.B.D. of marked portion of the string; Here string is massless.

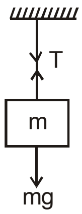


$\Rightarrow T = F$

String is considered to be made of a number of small segments which attracts each other due to electromagnetic nature. The attraction force between two segments is equal and opposite due to newton's third law.

Conclusion :

$T = mg$

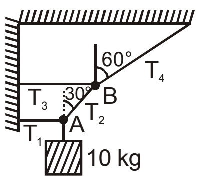


(i) Tension always acts along the string and in such a direction that it tries to reduce the length of string

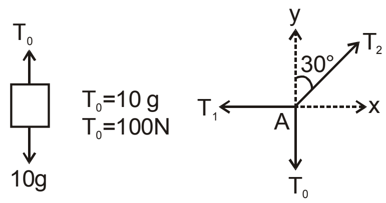
(ii) If the string is massless then the tension will be same along the string but if the string have some mass then the tension will continuously change along the string.

EXAMPLE 05

The system shown in figure is in equilibrium. Find the magnitude of tension in each string ; T_1, T_2, T_3 and T_4. ($g = 10\ m/s^{-2}$)



Sol. **F.B.D. of block 10 kg F.B.D. of point 'A'**



$\Sigma F_y = 0$

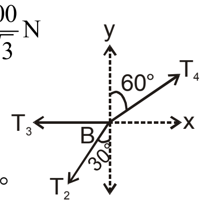
$T_2 \cos 30° = T_0 = 100$ N

$$T_2 = \frac{200}{\sqrt{3}} N$$

$\Sigma F_x = 0$

$$T_1 = T_2 \sin 30° = \frac{200}{\sqrt{3}} \cdot \frac{1}{2} = \frac{100}{\sqrt{3}} N$$

F.B.D of point of 'B'



$\Sigma F_y = 0$

$\Rightarrow$ $T_4 \cos 60° = T_2 \cos 30°$

and $\Sigma F_x = 0$

$\Rightarrow$ $T_3 + T_2 \sin 30° = T_4 \sin 60°$

$$\therefore \quad T_3 = \frac{200}{\sqrt{3}} N, \ T_4 = 200 \text{ N}$$

1.4.3 Frictional force :

It is the component of contact force tangential to the surface. It opposes the relative motion (or attempted relative motion) of the two surfaces in contact. (which is explained later)

2. NEWTON'S FIRST LAW OF MOTION :

According to this law "A system will remain in its state of rest or of uniform motion unless a net external force act on it.

1st law can also be stated as "If the net external force acting on a body is zero, only then the body remains at rest."

➢ The word external means external to the system (object under observation), interactions within the system has not to be considered.

- The word net means the resultant of all the forces acting on the system.
- Newton's first law is nothing but Galileo's law of inertia.
- Inertia means inability of a body to change its state of motion or rest by itself.
- The property of a body that determines its resistance to a change in its motion is its mass (inertia). Greater the mass, greater the inertia.
- An external force is needed to set the system into motion, but no external force is needed to keep a body moving with constant velocity in its uniform motion.
- Newton's laws of motion are valid only in a set of frame of references, these frames of reference are known as inertial frames of reference.
- Generally, we take earth as an inertial frame of reference, but strictly speaking it is not an inertial frame.
- All frames moving uniformly with respect to an inertial frame are themselves inertial.
- We take all frames at rest or moving uniformly with respect to earth, as inertial frames.

3. NEWTON'S SECOND LAW OF MOTION :

Newton's second law states, "The rate of change of a momentum of a body is directly proportional to the applied force and takes place in the direction in which the force acts"

$$\text{i.e., } \vec{F} \propto \frac{d\vec{p}}{dt} \text{ or } \vec{F} = k\frac{d\vec{p}}{dt}$$

where k is a constant of proportionality.

$$\vec{p} = m\vec{v}, \text{ So } \vec{F} = k\frac{(dm\vec{v})}{dt}$$

For a body having constant mass,

$$\Rightarrow \quad \vec{F} = km\frac{d\vec{v}}{dt} = km\vec{a}$$

From experiments, the value of k is found to be 1.

So, $\quad \vec{F}_{net} = m\vec{a}$

- Force can't change the momentum along a direction normal to it, i.e., the component of velocity normal to the force doesn't change.
- Newton's 2nd law is strictly applicable to a single point particle. In case of rigid bodies or system of particles or system of rigid bodies, $\vec{F}$ refers to total external force acting on system and $\vec{a}$ refers to acceleration of centre of mass of the system. The internal forces, if any, in the system are not to be included in $\vec{F}$.
- Acceleration of a particle at any instant and at a particular location is determined by the force (net) acting on the particle at the same instant and at same location and is not in any way depending on the history of the motion of the particle.

PROBLEM SOLVING STRATEGY :

Newton's laws refer to a particle and relate the forces acting on the particle to its mass and to its acceleration. But before writing any equation from Newton's law, you should be careful about which particle you are considering. The laws are applicable to an extended body too which is nothing but collection of a large number of particles.

Follow the steps given below in writing the equations:

Step 1 : Select the body

The first step is to decide the body on which the laws of motion are to be applied. The body may be a single particle, an extended body like a block, a combination of two blocks-one kept over another or connected by a string. The only condition is that **all the parts of the body or system must have the same acceleration.**

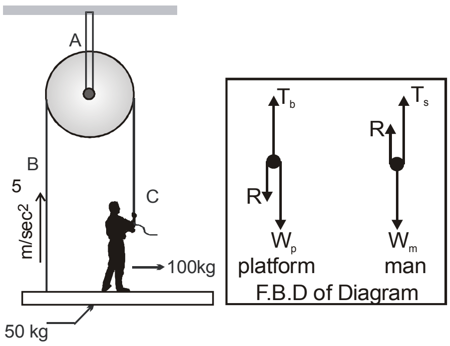
Step 2 : Identify the forces

Once the system is decided, list down all the force acting on the system due to all the objects in the environment such as inclined planes, strings, springs etc. However, any force applied by the system shouldn't be included in the list. You should also be clear about the nature and direction of these forces.

Step 3 : Make a Free-body diagram (FBD)

Make a separate diagram representing the body by a point and draw vectors representing the forces acting on the body with this point as the common origin.

This is called a free-body diagram of the body.



Look at the adjoining free-body diagrams for the platform and the man. Note that the force applied by the man on the rope hasn't been included in the FBD. Once you get enough practice, you'd be able to identify and draw forces in the main diagram itself instead of making a separate one

Step 4 : Select axes and Write equations

When the body is in equillibrium then choose the axis in such a fashion that maximum number of force lie along the axis.

If the body is moving with some acceleration then first find out the direction of real acceleration and choose the axis one is along the real acceleration direction and other perpendicular to it.

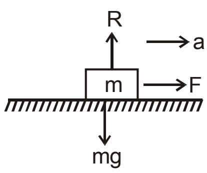
Write the equations according to the newton's second law (F_{net} = ma) in the corresponding axis.

4. APPLICATIONS :

4.1 Motion of a Block on a Horizontal Smooth Surface.

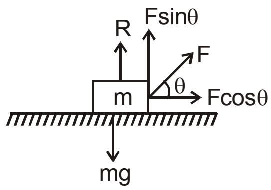
Case (i) : When subjected to a horizontal pull :

The distribution of forces on the body are shown. As there is no motion along vertical direction, hence, R = mg. For horizontal motion F = ma or a = F/m



Case (ii) : When subjected to a pull acting at an angle (θ) to the horizontal :

Now F has to be resolved into two components, F cosθ along the horizontal and F sin θ along the vertical direction.



For no motion along the vertical direction.

we have R + F sin θ = mg

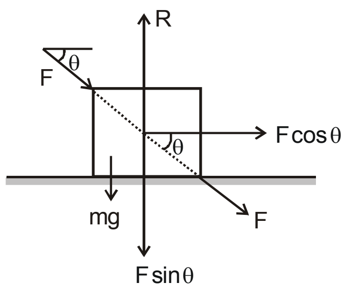
or R = mg – F sin θ

: Hence R $\neq$ mg. R < mg

For horizontal motion

$$F \cos\theta = ma,\ a = \frac{F\cos\theta}{m}$$

Case (iii) : When the block is subjected to a push acting at an angle θ to the horizontal : (down ward)



The force equation in this case

R = mg + F sin θ

: R $\neq$ mg, R > mg

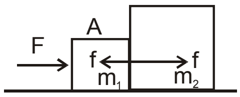
For horizontal motion

$$F \cos\theta = ma,\ a = \frac{F\cos\theta}{m}$$

4.2 Motion of bodies in contact.

Case (i) : Two body system :

Let a force F be applied on mass m_1

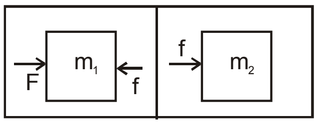


Free body diagrams :

(vertical force do not cause motion, hence they have not been shown in diagram)

$$\Rightarrow a = \frac{F}{m_1 + m_2} \text{ and } f = \frac{m_2 F}{m_1 + m_2}$$

(i) Here f is known as force of contact.



(ii) Acceleration of system can be found simply by

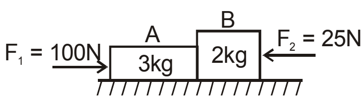
$$a = \frac{\text{force}}{\text{total mass}}$$

: If force F be applied on m_2, the acceleration will remain the same, but the force of contact will be different

$$\text{i.e., } f' = \frac{m_1 F}{m_1 + m_2}$$

EXAMPLE 06

Find the contact force between the 3 kg and 2kg block as shown in figure.

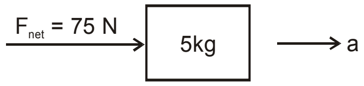


Sol. Considering both blocks as a system to find the common acceleration

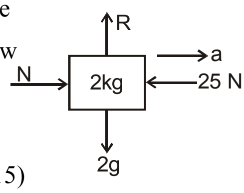
$F_{net} = F_1 - F_2 = 100 - 25 = 75$ N

common acceleration

$$a = \frac{F_{net}}{5\text{kg}} = \frac{75}{5} = 15 \text{ m/s}^2$$



To find the contact force between A & B we draw F.B.D of 2 kg block

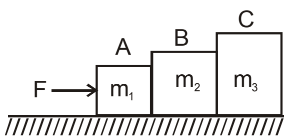


from $(\Sigma F_{net})_x = ma_x$

$\Rightarrow$ $N - 25 = (2)(15)$

$\Rightarrow$ $N = 55$ N

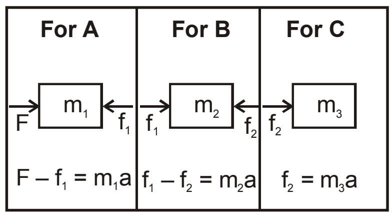
Case (ii) : Three body system :



Free body diagrams :

$$\Rightarrow \quad a = \frac{F}{m_1 + m_2 + m_3}$$

$$\text{and } f_1 = \frac{(m_2 + m_3)F}{(m_1 + m_2 + m_3)}$$



$$f_2 = \frac{m_3 F}{(m_1 + m_2 + m_3)}$$

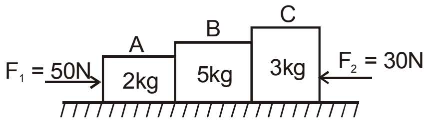
f_1 = contact force between masses m_1 and m_2

f_2 = contact force between masses m_2 and m_3

Remember **:** Contact forces will be different if force F will be applied on mass C

EXAMPLE 07

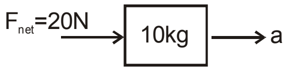
Find the contact force between the block and acceleration of the blocks as shown in figure.



Sol. Considering all the three block as a system to find the common acceleration

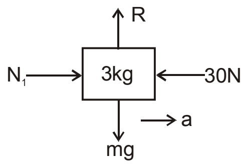
$F_{net} = 50 - 30 = 20$ N

$a = \frac{20}{10} = 2\,m/s^2$



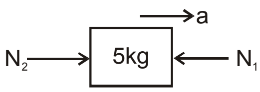
To find the contact force between B & C we draw F.B.D. of 3 kg block.

$\left(\sum F_{net}\right)_x = ma$



$\Rightarrow \quad N_1 - 30 = 3(2) \Rightarrow N_1 = 36$ N

To find contact force between A & B we draw F.B.D. of 5 kg block



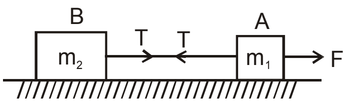
$\Rightarrow \quad N_2 - N_1 = 5a$

$N_2 = 5 \times 2 + 36 \Rightarrow N_2 = 46$ N

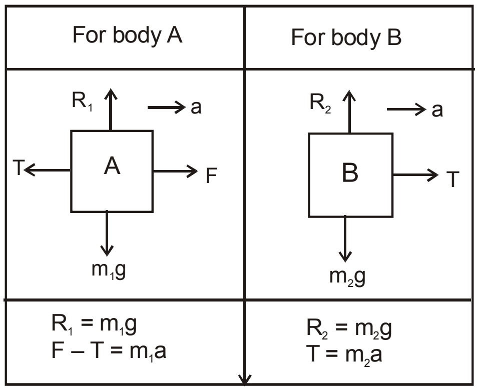
4.3 Motion of connected Bodies

Case (i) For Two Bodies :

F is the pull on body A of mass m_1. The pull of A on B is exercised as tension through the string connecting A and B. The value of tension throughout the string is T only.

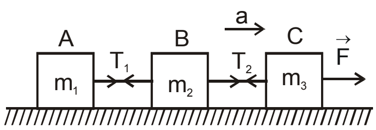


Free body diagrams :

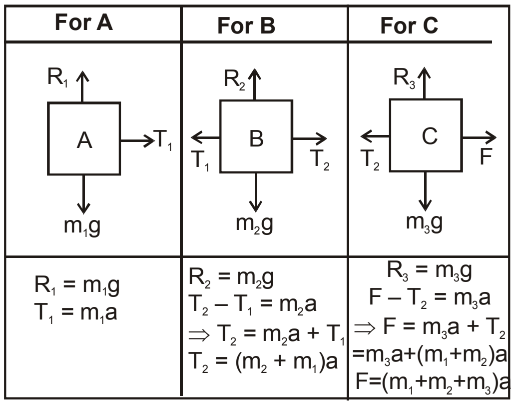


$\Rightarrow \quad a = \frac{F}{m_1 + m_2}$

Case (ii) : For Three bodies :



Free body diagrams :



$\Rightarrow a = \frac{F}{m_1 + m_2 + m_3}$

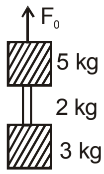
EXAMPLE 08

A 5 kg block has a rope of mass 2 kg attached to its underside and a 3 kg block is suspended from the other end of the rope. The whole system is accelerated upward is 2 m/s² by an external force F_0.

(a) What is F_0?

(b) What is the force on rope?

(c) What is the tension at middle point of the rope?

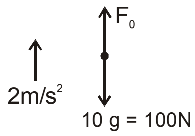


(g = 10 m/s²)

Sol. For calculating the value of F_0, consider two blocks with the rope as a system.

F.B.D. of whole system

(a)



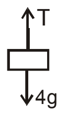
$F_0 - 100 = 10 \times 2$

$F = 120$ N ...(1)

(b) According to Newton's second law, net force on rope.

$F = ma = (2)(2) = 4$ N ...(2)

(c) For calculating tension at the middle point we draw F.B.D. of 3 kg block with half of the rope (mass 1 kg) as shown.



$T - 4g = 4.(2) = 48$ N

4.4 Motion of a body on a smooth inclined plane :

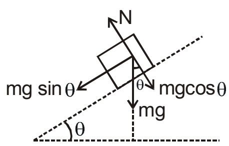
Natural acceleration down the plane = g sin θ

Driving force for acceleration a up the plane,

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

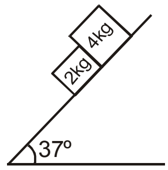
and for an acceleration a down the plane,

$F = m(a - g\sin\theta)$



EXAMPLE 09

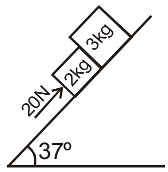
Find out the contact force between the 2kg & 4kg block as shown in figure.



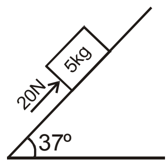
Sol. On an incline plane acceleration of the block is independent of mass. So both the blocks will move with the same acceleration (gsin 37º) so the contact force between them is zero.

EXAMPLE 10

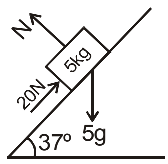
Find out the contact force between 2kg & 3kg block placed on the incline plane as shown in figure.



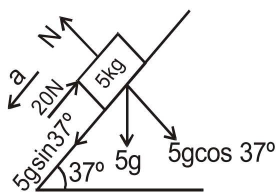
Sol. Considering both the block as a 5kg system because both will move the same acceleration.



Now show forces on the 5 kg block



∵ Acceleration of 5kg block is down the incline. So choose one axis down the incline and other perpendicular to it



From Newton's second Law

$N = 5g\cos 37^\circ$ ...(i)

$5g\sin 37^\circ - 20 = 5a$ ..(ii)

$30 - 20 = 5a$

$a = 2 m/s^2$ (down the incline)

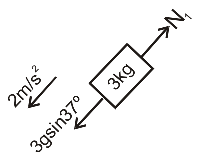
For contact force (N_1) between 2kg & 3kg block we draw F.B.D. of 3kg block

From $F_{net} = ma$

$\Rightarrow$ $3g\sin 37^\circ - N_1 = 3 \times 2$

$18 - N_1 = 6$

$N_1 = 12$ N



Note

The student can now attempt section A, B, C, D from exercise.

Section E - Pulley Block System

4.5 Pulley block system :

EXAMPLE 11

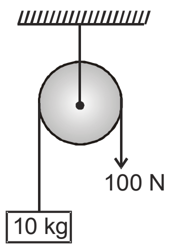
One end of string which passes through pulley and connected to 10 kg mass at other end is pulled by 100 N force. Find out the acceleration of 10 kg mass. ($g = 9.8\ m/s^2$)

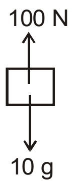
Sol. Since string is pulled by 100N force.

So tension in the string is 100 N.

F.B.D. of 10 kg block

$100 - 10\ g = 10\ a$



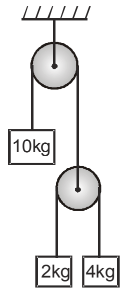


$100 - 10 \times 9.8 = 10\ a$

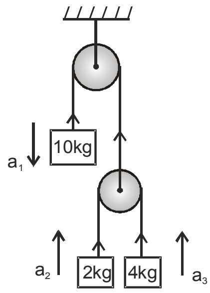
$a = 0.2\ m/s^2$

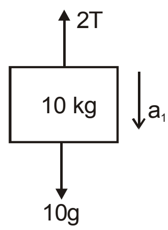
EXAMPLE 12

In the figure shown, find out acceleration of each block.

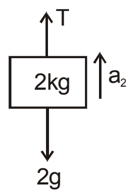


Sol. Now F.B.D. of each block and apply Newton's second law on each F.B.D

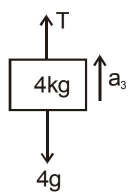


(1)


$\downarrow a_1 \Rightarrow 10g - 2T = 10a_1$ ...(i)

(2)


$\uparrow a_2 \Rightarrow T - 2g = 2a_2$ ...(2)

(3)


$\uparrow a_3 \Rightarrow T - 4g = 4a_3$ ...(3)

from constrain relation $2a_1 = a_2 + a_3$ ...(4)

Solving equations (1), (2), (3) and (4) we get

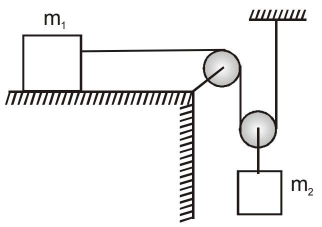
$$T = \frac{800}{23} N$$

a_1 = 70/23 m/s^2 (downward), a_2 = 170/23 m/s^2 (upward),

a_3 = 30/23 m/s^2 (downward)

EXAMPLE 13

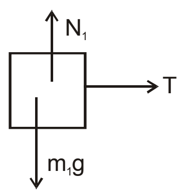
Find the acceleration of each block in the figure shown below; in terms of their masses m_1, m_2 and g. Neglect any friction.



Sol. Let T be the tension in the string that is assumed to be massless.

For mass m_1, the FBD shows that

$N_1 = m_1 g$



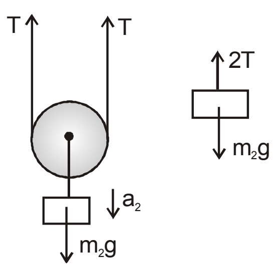
Where N_1 is the force applied upward by plane on the mass m_1. If acceleration of m_1 along horizontal is a_1. then

$T = m_1 a_1$ ...(i)

For mass m_2, the FBD shows that

$m_2 g - 2T = m_2 a_2$ ...(ii)

Where a_2 is vertical acceleration of mass m_2. Note that upward tension on m_2 is 2T applied



by both sides of the string from constrain relation

$$a_2 = \frac{a_1}{2}$$

Thus, the acceleration of m_1 its twice that of m_2. with this input, solving (i) and (ii) we find

$$a_1 = \frac{2m_2 g}{4m_1 + m_2}$$

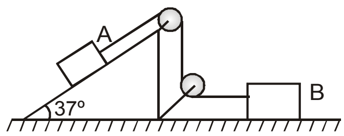
$$a_2 = \frac{m_2 g}{4m_1 + m_2}$$

EXAMPLE 14

Two blocks A and B each having a mass of 20 kg, rest on frictionless surfaces as shown in the figure below. Assuming the pulleys to be light and frictionless, compute :

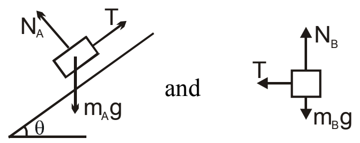
(a) the time required for block A, to move down by 2m on the plane, starting from rest,

(b) tension in the string, connecting the blocks.

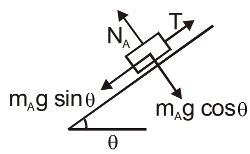


Sol.

Step 1. Draw the FBDs for both the blocks. If tension in the string is T, then we have



Note that $m_A g$, should better be resolved along and perpendicular to the plane, as the block A is moving along the plane.



Step 2. From FBDs, we write the force equations 'for block A where

$N_A = m_A\, g \cos\theta = 20 \times 10 \times 0.8 = 160$ N

and $m_A g \sin\theta - T = m_A\, a$ ... (i)

Where 'a' is acceleration of masses of blocks A and B.

Similarly, force equations for block B are

$N_B = m_B g = 20 \times 10 = 200$ N

and $T = m_B a$ ...(ii)

From (i) and (ii), we obtain

$$a = \frac{m_A g \sin\theta}{m_A + m_B} = \frac{20 \times 10 \times 0.6}{40} = 3\ ms^{-2}$$

$T = m_B a = 20 \times 3 = 60$ N

Step 3. With constant acceleration $a = 3\ ms^{-2}$, the block A moves down the inclined plane a distance S = 2 m in time t given by

$$S = \frac{1}{2}at^2 \text{ or } t = \sqrt{\frac{2S}{a}} = \frac{2}{\sqrt{3}} \text{seconds.}$$

EXAMPLE 15

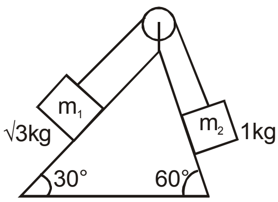
Two blocks m_1 and m_2 are placed on a smooth inclined plane as shown in figure. If they are released from rest.

Find :

(i) acceleration of mass m_1 and m_2

(ii) tension in the string

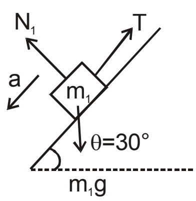
(iii) net force on pulley exerted by string



Sol. **F.B.D of m_1 :**

$m_1 g \sin\theta - T = m_1 a$

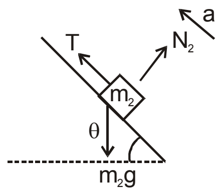
$$\frac{\sqrt{3}}{2}g - T = \sqrt{3}\,a \quad ...(i)$$



F.B.D. of m_2 :

$T - m_2 g \sin\theta = m_2 a$

$$T - 1.\frac{\sqrt{3}}{2}g = 1.a...(ii) .$$



Adding eq. (i) and (ii)

we get a = 0

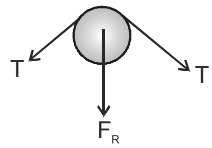
Putting this value in eq. (i) we get

$$T = \frac{\sqrt{3}g}{2},$$

F.B.D. of pulley

$F_R = \sqrt{2}\,T$

$$F_R = \sqrt{\frac{3}{2}}g$$



5. NEWTONS' 3^RD^ LAW OF MOTION :

Statement : "To every action there is equal and opposite reaction".

But what is the meaning of action and reaction and which force is action and which force is reaction?

Every force that acts on body is due to the other bodies in environment. Suppose that a body A experiences a force $\vec{F}_{AB}$ due to other body B. Also body B will experience a force $\vec{F}_{BA}$ due to A. According to Newton third law two forces are equal in magnitude and opposite in direction Mathematically we write it as

$$\vec{F}_{AB} = -\vec{F}_{BA}$$

Here we can take either $\vec{F}_{AB}$ or $\vec{F}_{BA}$ as action force and other will be the reaction force.

 **:** (i) Action-Reaction pair acts on two different bodies.

(ii) Magnitude of force is same.

(iii) Direction of forces are in opposite direction.

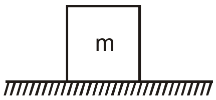
(iv) For action-reaction pair there is no need of contact

EXAMPLE 16

A block of mass 'm' is kept on the ground as shown in figure.

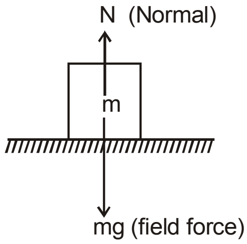
(i) Draw F.B.D. of block

(ii) Are forces acting on block action-reaction pair



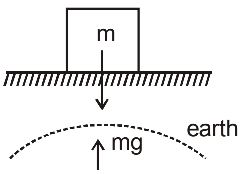
(iii) If answer is no, draw action reaction pair.

Sol. (i) F.B.D. of block

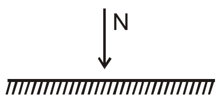


(ii) 'N' and Mg are not action - reaction pair. Since pair act on different bodies, and they are of same nature.

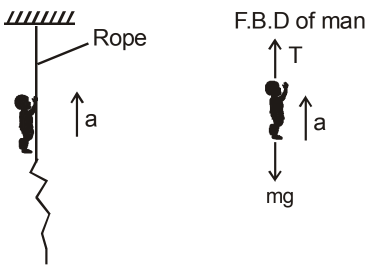
(iii) Pair of 'mg' of block acts on earth in opposite direction.



and pair of 'N' acts on surface as shown in figure.



5.1 Climbing on the Rope :



Now three condition arises.

if T > mg $\Rightarrow$ man accelerates in upward direction

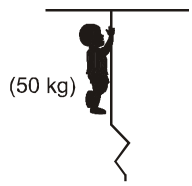
T < mg $\Rightarrow$ man accelerates in downward direction

T = mg $\Rightarrow$ man's acceleration is zero

* Either climbing or decending on the rope man exerts force downward

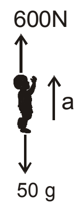
EXAMPLE 17

If the breaking strength of string is 600N then find out the maximum acceleration of the man with which he can climb up the road



Sol. Maximum force that can be exerted on the man by the rope is 600 N.

F.B.D of man

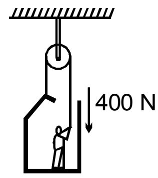


$\Rightarrow$ $600 - 50\,g = 50\,a$

$a_{max} = 2\ m/s^2$

EXAMPLE 18

A 60 kg painter on a 15 kg platform. A rope attached to the platform and passing over an overhead pulley allows the painter to raise himself along with the platform.

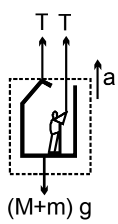


(i) To get started, he pulls the rope down with a force of 400 N. Find the acceleration of the platform as well as that of the painter.

(ii) What force must he exert on the rope so as to attain an upward speed of 1 m/s in 1 s ?

(iii) What force should apply now to maintain the constant speed of 1 m/s?

Sol. The free body diagram of the painter and the platform as a system can be drawn as shown in the figure. Note that the tension in the string is equal to the force by which he pulles the rope.



(i) Applying Newton's Second Law

$2T - (M + m)g = (M + m)a$

or $a = \dfrac{2T - (M+m)g}{M+m}$

Here M = 60 kg; m = 15 kg ; T = 400 N

$g = 10\ m/s^2$

$$a = \frac{2(400) - (60+15)(10)}{60+15} = 0.67\ m/s^2$$

(ii) To attain a speed of 1 m/s in one second the acceleration a must be 1 m/s^2

Thus, the applied force is

$$F = \frac{1}{2}(M+m)(g+a) = (60+15)(10+1) = 412.5\text{ N}$$

(iii) When the painter and the platform move (upward) together with a constant speed, it is in a state of dynamic equilibrium

Thus, $2F - (M + m)g = 0$

or $$F = \frac{(M+m)g}{2} = \frac{(60+15)(10)}{2} = 375\text{ N}$$

Note

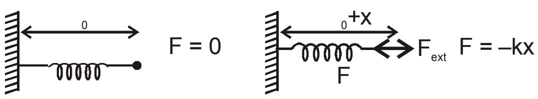
The student can now attempt section E from exercise.

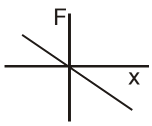
Section F - Spring force and spring cutting problems

6. SPRING FORCE :

Every spring resists any attempt to change its length; when it is compressed or extended, it exerts force at its ends. The force exerted by a spring is given by $F = -kx$, where x is the change in length and k is the stiffness constant or spring constant (unit Nm^{-1})

When spring is in its natural length, spring force is zero.

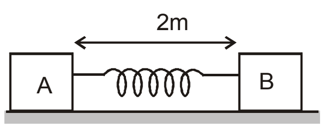




Graph between spring force v/s x

EXAMPLE 19

Two blocks are connected by a spring of natural length 2 m. The force constant of spring is 200 N/m. Find spring force in following situations.



(a) If block 'A' and 'B' both are displaced by 0.5 m in same direction.

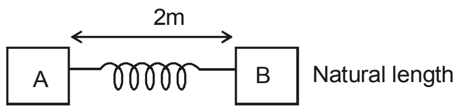
(b) If block 'A' and 'B' both are displaced by 0.5 m in opposite direction.

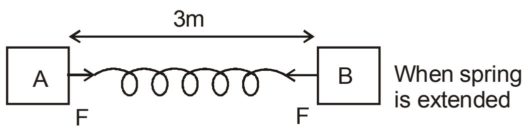
Sol. (a) Since both blocks are displaced by 0.5 m in same direcetion, so change in length of spring is zero. Hence, spring force is zero.

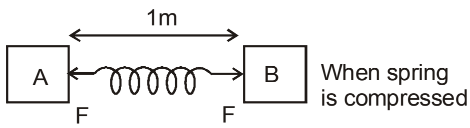
(b) In this case, change in length of spring is 1 m. So spring force is $F = -Kx$

$= -(200).(1)$

$F = -200$ N



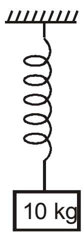




EXAMPLE 20

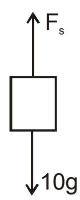
Force constant of a spring is 100 N/m. If a 10 kg block attached with the spring is at rest, then find extension in the spring

($g = 10$ m/s^2)



Sol. In this situation, spring is in extended state so spring force acts in upward direction. Let x be the extension in the spring.

F.B.D. of 10 kg block :



$F_s = 10g$

$\Rightarrow$ $Kx = 100$

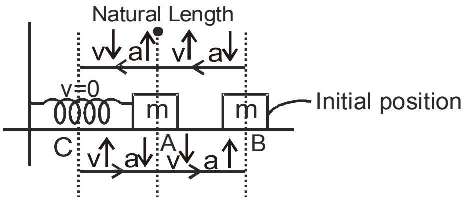
$\Rightarrow$ $(100)x = (100)$

$\Rightarrow$ $x = 1$ m

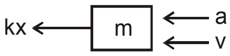
6.1 SPRING FORCE SYSTEM :

Initially the spring is in natural length at A with block m. But when the block displaced towards right then the spring is elongated and now block is released at B then the block move towards left due to spring force (kx).

Analysis of motion of block :



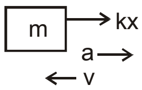
(i) From B to A speed of block increase and acceleration decreases.



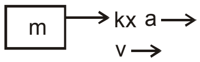
(due to decrease in springforce kx)

(ii) Due to inertia block crosses natural length at A.

From A to C speed of the block decreases and acceleration increases.(due to increase in springforce kx)

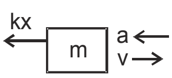


(iii) At C the block stops momentarily at this instant and since the spring is compressed spring force is towards right and the block starts to move towards right. From C to A speed of block increases and acceleration decreases.



(due to decrease in springforce kx)\

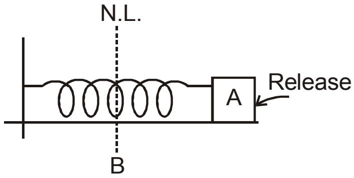
(iv) Again block crosses point A due to inertia then from A to B speed decreases and acceleration increases.



In this way block does SHM (to be expalined later) if no resistive force is acting on the block.

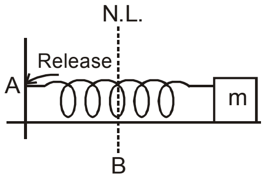
Note :

(i)



when the block A is released then it take some finite time to reach at B. i.e., spring force doesn't change instantaneously.

(2)

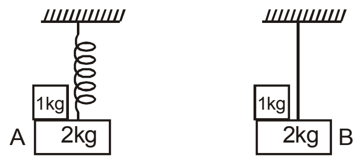


When point A of the spring is released in the above situation then the spring forces changes instantaneously and becomes zero because one end of the spring is free.

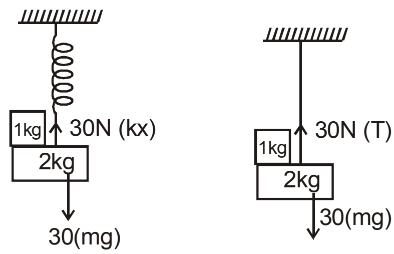
(3) In string tension may change instantaneously.

EXAMPLE 21

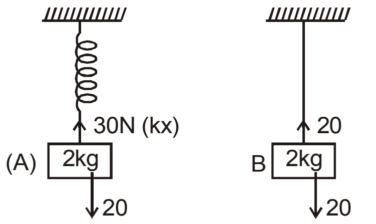
Find out the acceleration of 2 kg block in the figures shown at the instant 1 kg block falls from 2 kg block. (at t = 0)



Sol. F.B.D.s before fall of 1kg block



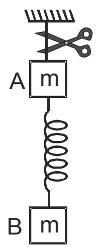
after the fall of the 1 kg block tension will change instantaneously but spring force (kx) doesn't change instantaneously. F.B.D.s just after the fall of 1 kg block



$a_A = \dfrac{30-20}{2} = 5\ m/s^2$ (upward) $a_B = 0\ m/s^2$

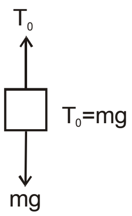
EXAMPLE 22

Two blocks 'A' and 'B' of same mass 'm' attached with a light spring are suspended by a string as shown in figure. Find the acceleration of block 'A' and 'B' just after the string is cut.

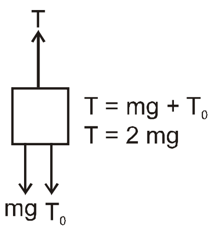


Sol. When block A and B are in equilibrium position

F.B.D of 'B' ...(i)

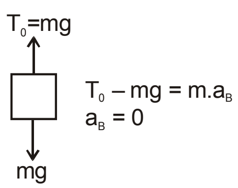


F.B.D of 'A' ...(ii)

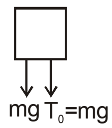


when string is cut, tension T becomes zero. But spring does not change its shape just after cutting. So spring force acts on mass B, again draw F.B.D. of block A and B as shown in figure

F.B.D of 'B'



F.B.D. of 'A'



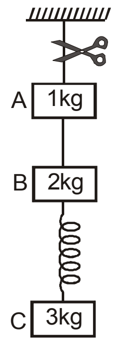
$mg + T_0 = m.\ a_A$

$2\ mg = m.\ a_A$

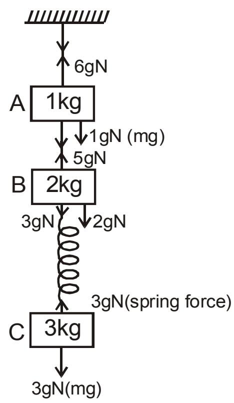
$a_A = 2g$ (downwards)

EXAMPLE 23

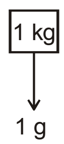
Find out the acceleration of 1kg, 2kg and 3kg block and tension in the string between 1 kg & 2 kg block just after cutting the string as shown in figure.



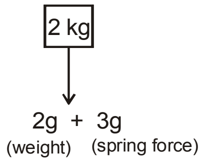
Sol. F.B.D before cutting of string



Let us assume the Tension in the string connecting blocks A & B becomes zero just after cutting the string then.



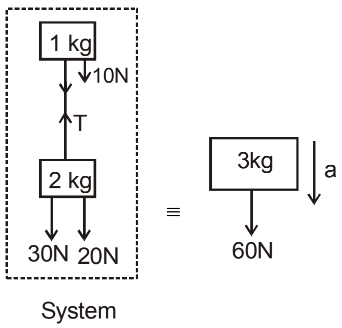
$a_1 = \dfrac{1g}{1} = g\ ms^{-2}$



$a_2 = \frac{5g}{2} = 2.5 \text{ g ms}^{-2}$

$\because \quad a_2 > a_1$ i.e., $\quad \therefore \quad T \neq 0$

If $T \neq 0$ that means string is tight and Both block A & B will have same acceleration. So it will take as a system of 3 kg mass.

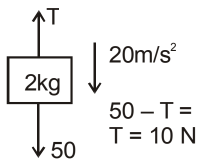


Total force down ward

= 10 + 30 + 20 = 60 N

Total mass = 3 kg

$\Rightarrow a = \frac{60}{3} = 20 \text{ m/s}^2$

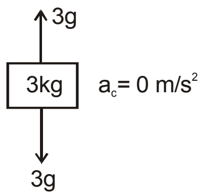


50 – T = 2 × 20

T = 10 N

Now apply $F_{net} = ma$ at block B.

$\because$ the spring force does not change instantaneously the F.B.D of 'C'



Reference Frame :

A frame of reference is basically a coordinate system in which motion of object is analyzed. There are two types of reference frames.

(a) **Inertial reference frame :** Frame of reference moving with constant velocity or stationary

(b) **Non-inertial reference frame :** A frame of reference moving with non-zero acceleration

: (i) Although earth is a non inertial frame (due to rotation) but we always consider it as an inertial frame.

(ii) A body moving in circular path with constant speed is a non intertial frame (direction change cause acceleration)

Note

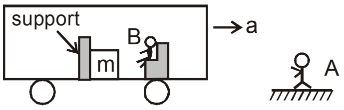
The student can now attempt section F from exercise.

Section G - Pseudo force, Weighing Machine

7. PSEUDO FORCE :

Consider the following

example to understand the pseudo force concept



The block m in the bus is moving with constant acceleration a with respect to man A at ground. Force required for this acceleration is the normal reaction exerted by the support

So, $N = ma$ ..(i)

This block m is at rest with respect to man B who is in the bus (a non intertial frame). So the acceleration of the block with respect to man B is zero.

$N = m(0) = 0$ ..(ii)

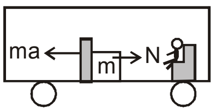
But the normal force is exerted in a non-inertial frame also. So the equation (ii) is wrong therefore we conclude that Newton's law is not valid in non-inertial frame.

If we want to apply Newton's law in non-inertial frame, then we can do so by using of the cencept pseudo force.

Pseudo force is an imaginary force, which in actual is not acting on the body. But after applying it on the body we can use Newton's laws in non-inertial frames.

This imaginary force is acting on the body only when we are solving the problem in a non-inertial frame of reference.

In the above example. The net force on the block m is zero with respect to man B after applying the pesudo force.



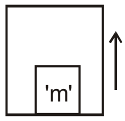
$N = ma$

:

1. Direction of pseudo force is opposite to the acceleration of frame
2. Magnitude of pseudo force is equal to mass of the body which we are analyzing multiplied by acceleration of frame
3. Point of application of pseudo force is the centre of mass of the body which we are analysing

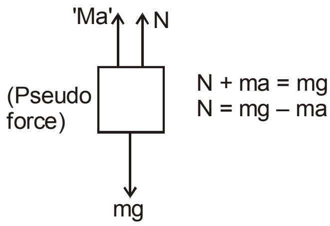
EXAMPLE 24

A box is moving upward with retardation 'a' < g, find the direction and magnitude of "pseudo force" acting on block of mass 'm' placed inside the box. Also calculate normal force exerted by surface on block



Sol. **Pseudo force** acts opposite to the direction of acceleration of reference frame.

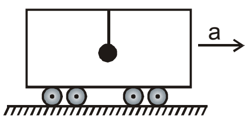
pseudo force = ma in upward direction



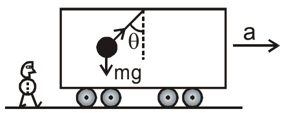
F.B.D of 'm' w.r.t box (non-inertial)

EXAMPLE 25

Figure shows a pendulum suspended from the roof of a car that has a constant acceleration a relative to the ground. Find the deflection of the pendulum from the vertical as observed from the ground frame and from the frame attached with the car.



Sol.



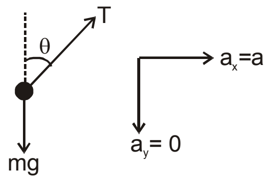


Figure represents free Body diagram of the bob w.r.t ground.

In an inertial frame the suspended bob has an acceleration a caused by the horizontal component of tension T.

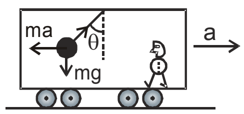
$T \sin\theta = ma$ ...(i)

$T \cos\theta = mg$ ...(ii)

From equation (i) and (ii)

$$\tan\theta = \frac{a}{g} \quad \Rightarrow \quad q = \tan^{-1}\left(\frac{a}{g}\right)$$

In a non-inertial frame



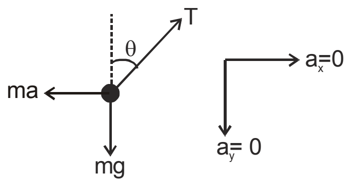


Figure represents free Body diagram of bob w.r.t car.

In the non-intertial frame of the car, the bob is in static equilibrium under the action of three froces, T, mg and ma (pseudo force)

$T \sin\theta = ma$ ...(iii)

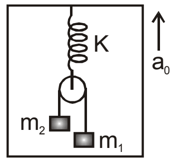
$T \cos\theta = mg$ ....(iv)

From equation (iii) and (iv)

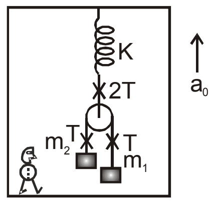
$$\tan\theta = \frac{a}{g} \quad \Rightarrow \quad \theta = \tan^{-1}\left(\frac{a}{g}\right)$$

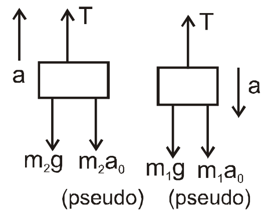
EXAMPLE 26

A pulley with two blocks system is attached to the ceiling of a lift moving upward with an acceleration a_0. Find the deformation in the spring.



Sol. Non-Inertial Frame





Let relative to the centre of pulley, m_1 accelerates downward with a and m_2 accelerates upwards with a. Applying Newton's 2nd law.

$m_1g + m_1a_0 - T = m_1a$ ...(i)

$T - m_2g - m_2a_0 = m_2a$ ...(ii)

On adding (iv) and (v) we get

$$a = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)(g + a_0) \qquad ...(iii)$$

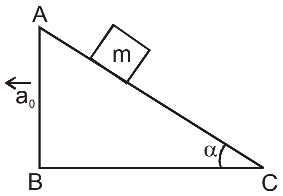
Substituting a in equation (i)

$$\text{We get } T = \frac{2m_1m_2(g + a_0)}{m_1 + m_2}$$

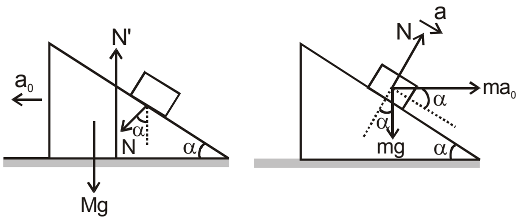
$$\therefore \; x = \frac{F}{k} = \frac{2T}{k} = \frac{4m_1m_2(g + a_0)}{(m_1 + m_2)k}$$

EXAMPLE 27

All the surfaces shown in figure are assumed to be frictionless. The block of mass m slides on the prism which in turn slides backward on the horizontal surface. Find the acceleration of the smaller block with respect to the prism.



Sol. Let the acceleration of the prism be a_0 in the backward direction. Consider the motion of the smaller block from the frame of the prism The forces on the block are (figure)



(i) N normal force

(ii) mg downward (gravity),

(iii) ma_0 forward (Psuedo Force)

The block slides down the plane. Components of the forces parallel to the incline give

$$ma_0 \cos\alpha + mg \sin\alpha = ma$$

or, $\quad a = a_0 \cos\alpha + g \sin\alpha \quad$ ...(i)

Components of the forces perpendicular to the incline give

$$N + ma_0 \sin\alpha = mg \cos\alpha \quad ...(ii)$$

Now consider the motion of the prism from the ground frame. No pseudo force is needed as the frame used is inertial. The forces are (figure)

(i) Mg downward

(ii) N normal to the incline (by the block)

(iii) N' upward (by the horizontal surface)

Horizontal components give,

$N \sin\alpha = Ma_0$ or $N = Ma_0 / \sin\alpha$, ...(iii)

Putting in (ii)

$$\frac{Ma_0}{\sin\alpha} + ma_0 \sin\alpha = mg \cos\alpha$$

or, $$a_0 = \frac{mg\sin\alpha\cos\alpha}{M + m\sin^2\alpha}$$

From (i) $$a = \frac{mg\sin\alpha\cos^2\alpha}{M + m\sin^2\alpha} + g\sin\alpha$$

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

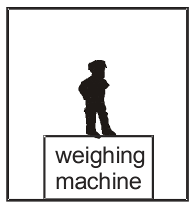
8. WEIGHING MACHING :

A weighing machine does not measure the weight but measures the force. exerted by object on its upper surface or we can say weighing machine measure normal force on the man.

8.1 Motion in a lift :

(A) If the lift is unaccelerated (v = 0 or constant)

In this case no pseudo force act on the man



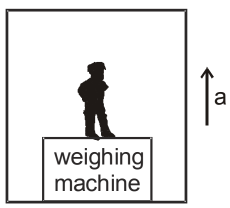
In this case the F.B.D. of the man

$$N = mg$$

In this case machine read the actual weight

(B) If the lift is accelerated upward.

(where a = constant)



F.B.D of man with respect to lift

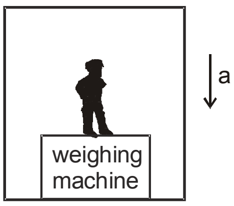
So weighing machine read

$N = m(g + a)$

Apparent weight

N > Actual weight (mg)

(c) If the lift is accelerated down ward.



F.B.D of man with respect to lift

So weighing machine read

$N = m(g - a)$

Apparent weight

N < Actual weight (mg)

Note :

(i) If $a = g \Rightarrow N = 0$

Thus in a freely falling lift, the man will experience a state of weightlessness

(ii) If the lift is accelerated downwards such that a > g : So the man will be accelerated upward and will stay at the ceiling of the lift.

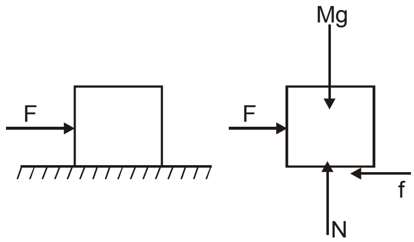
(iii) Apparent weight is greater than or less than actual weight only depends on the direction and magnitude of acceleration. Magnitude and direction of velocity doesn't play any roll in apparent weight.

FRICTION

Section H - Static friction, Kinetic friction

1. FRICTION :

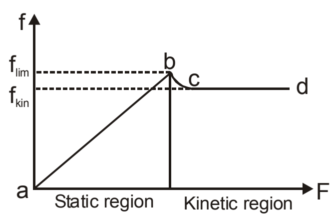
Friction is a contact force that opposes the relative motion or tendency of relative motion of two bodies.



Consider a block on a horizontal table as shown in the figure. If we apply a force, acting to the right, the block remains stationary if F is not too large. The force that counteracts F and keeps the block in rest from moving is called frictional force. If we keep on increasing the force, the block will remain at rest and for a particular value of applied force, the body comes to state of about to move. Now if we slightly increase the force from this value, block starts its motion with a jerk and we observe that to keep the block moving we need less effort than to start its motion.

So from this observation, we see that we have three states of block, first, block does not move, second, block is about to move and third, block starts moving. The friction force acting in three states are called static frictional force, limiting frictional force and kinetic frictional force respectively. If we draw the graph between applied force and frictional force for this observation its nature is as shown in figure.

1.1 Static frictional force



When there is no relative motion between the contact surfaces, frictional force is called static frictional force. It is a self-adjusting force, it adjusts its value according to requirement (of no relative motion). In the taken example static frictional force is equal to applied force. Hence one can say that the portion of graph ab will have a slope of 45º.

The Direction of Static Friction

The direction of static friction on a body is such that the total force acting on it keeps it at rest with respect to the body in contact.

The direction of static friction is as follows. For a moment consider the surfaces to be frictionless. In absence of friction the bodies will start slipping against each other. One should then find the direction of friction as opposite to the velocity with respect to the body applying the friction.

1.2 Limiting Frictional Force

This frictional force acts when body is about to move. This is the maximum frictional force that can exist at the contact surface.

(i) The magnitude of limiting frictional force is proportional to the normal force at the contact surface.

$$f_{lim} \propto N \Rightarrow f_{lim} = \mu_s N$$

Here μ_s is a constant the value of which depends on nature of surfaces in contact and is called as ‘coefficient of static firction’.

1.3 Kinetic Frictional Force

Once relative motion starts between the surface in contact, the frictional force is called as kinetic frictional force. The magnitude of kinetic frictional force is also proportional to normal force.

$$f_k = \mu_k N$$

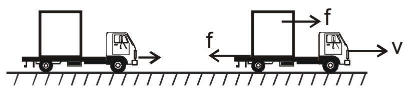
From the previous observation we can say that $\mu_k < \mu_s$

Although the coefficient of kinetic friction varies with speed, we shall neglect any variation i.e., when relative motion starts a constant frictional force starts opposing its motion.

Direction of Kinetic Friction

The kinetic friction on a body A slipping against another body B is opposite to the velocity of A with respect to B.

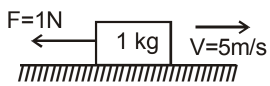
It should be carefully noted that the velocity coming into picture is with respect to the body applying the force of friction.



Suppose we have a long truck moving on a horizontal road. A small block is placed on the truck which slips on the truck to fall from the rear end. As seen from the road, both the truck and the block are moving towards right, of course the velocity of the block is smaller than that of the truck. What is the direction of the kinetic friction acting on the block due to the truck ? The velocity of the block as seen from the truck is towards left. Thus, the friction on the block is towards right. The friction acting on the truck due to the block is towards left.

EXAMPLE 01

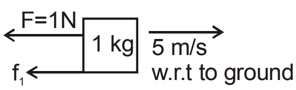
Find the direction of kinetic friction force



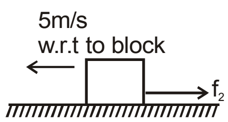
(a) on the block, exerted by the ground.

(b) on the ground, exerted by the block.

Sol. (a)



(b)



where f_1 and f_2 are the friction forces on the block and ground respectively.

EXAMPLE 02

The correct relation between magnitude of f_1 and f_2 in above problem is :

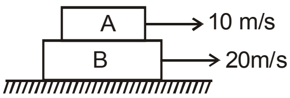
(A) $f_1 > f_2$ (B) $f_2 > f_1$ (C) $f_1 = f_2$

(D) not possible to decide due to insufficient data.

Sol. By Newton's third law the above friction forces are action-reaction pair and equal but opposite to each other in direction. Hence (C)

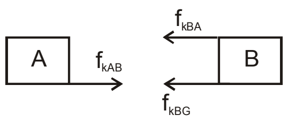
Also note that the direction of kinetic friction has nothing to do with applied force F.

EXAMPLE 03



All surfaces are rough. Draw the friction force on A & B

Sol.



Kinetic friction acts to reduce relative motion.

Summary

We can summarise the laws of friction between two bodies in contact as follows:

(i) If the bodies slip over each other, the force of friction is given by

$$f_k = \mu_k N$$

where N is the normal contact force and μ_k is the coefficient of kinetic friction between the surfaces.

(ii) The direction of kinetic friction on a body is opposite to the velocity of this body with respect to the body applying the force of friction.

(iii) If the bodies do not slip over each other, the force of friction is given by

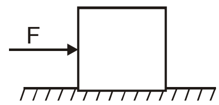
$$f_s \le \mu_s N$$

where μ_s is the coefficient of static friction between the bodies and N is the normal force between them. The direction and magnitude of static friction are such that the condition of no slipping between the bodies is ensured.

(iv) The frictional force f_k or f_s does not depend on the area of contact as long as the normal force N is same.

EXAMPLE 04

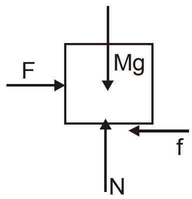
A block of mass 5 kg is resting on a rough surface as shown in the figure. It is acted upon by a force of F towards right. Find frictional force acting on block when (a) F = 5N (b) 25 N (c) 50 N ($\mu_s = 0.6$, $\mu_k = 0.5$) [$g = 10\ ms^{-2}$]



Sol. Maximum value of frictional force that the surface can offer is

$f_{max} = f_{lim} = \mu_s N$

$= 0.6 \times 5 \times 10 = 30$ newton



Therefore, it $F \le f_{max}$ body will be at rest and $f = F$

or $F > f_{max}$ body will more and $f = f_k$

(a) $F = 5N < F_{max}$

So body will not move hence static frictional force will act and ,

$f_s = f = 5N$

(b) $F = 25\ N < F_{max}$ $\therefore f_s = 25$ N

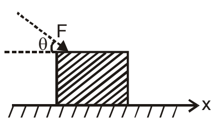
(c) $F = 50\ N > F_{max}$

So body will move and kinetic frictional force will act, its value will be

$f_k = \mu_k N = 0.5 \times 5 \times 10 = 25$ newton

EXAMPLE 05

A block having a mass 3 kg is initially at rest on a horizontal surface. The coefficient of static friction $\mu_s = 0.3$ between the block and the surface and μ_k is 0.25. A constant force F of 50 N, acts on the body at the angle $\theta = 37^\circ$. What is the acceleration of the block?

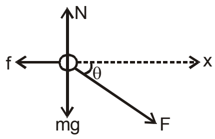


Sol. We have two possibilities here, the block may remain at rest, or it may accelerate towards the right. The decision hinges on whether or not the x-component of the force F has magnitude, less than or greaer than the maximum static friction force.

The x-component of F is

F_x = Fcos θ = (50 N) (0.8) = 40 N

To find $f_{s,\,max}$, we first calculate the normal force N, whether or not the block accelerates horizontally, the sum of the y-component of all the forces on the block is zero.



N - F sin θ – mg = 0

or N = F sin θ + mg

= (50 N) (0.6) + (3 kg)(9.8ms^{-2})

= 59.4 N

The maximum static frictional force

f_s,max = μ_sN = (0.3) (59.4 N) = 17.8 N

This value is smaller than the x-component of F, hence the block moves. We now interpret the force f in the figure as a kinetic frictional force. This value is obtained as

$f_K = \mu_k$ N = (0.25) (59.4 N) = 14.8 N

Therefore resultant force in the x-direction is

$$\sum F_x = F\cos\theta - f = 40\text{ N} - 14.8\text{ N} = 25.2\text{ N}$$

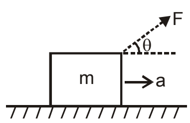
Then the acceleration 'a' of the block is

$$a = \frac{25.2\,\text{N}}{3\,\text{kg}} = 8.4\,\text{ms}^{-2}$$

Think : What would happen if the magnitude of F_x happened to be less than f_s.max but larger than f_k ?

EXAMPLE 06

In the previous example, suppose we move the block by pulling it with the help of a massless string tied to the block as shown here. What is the force F required to produce the same acceleration in the block as obtained in the last example ?

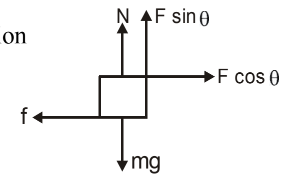


Sol. We are given that,

m = 3kg, μ_s = 0.3, μ_k = 0.25, θ = 37º,

and a = 8.4 ms^{-2}

In order to determine the force F, we first draw the FBD as shown below



The equations of motion therefore, are

N + Fsin θ = mg

N = mg – Fsin θ

F cos θ – f = ma

and where f = μ_s N before the start of the motion, once motion is set, f = μ_kN.

Hence, force F which produces a = 8.4 m/s^2 is given by

Fcosθ – μ_k (mg – F sin θ) = ma

or $$F = \frac{ma + \mu k mg}{\cos\theta + \mu k \sin\theta}$$

$$= \frac{3(0.4 + 0.25 \times 9.8)}{0.8 + 0.25 \times 0.6} = 34.26\text{ N}$$

: Fsinθ works out to be less than mg. Otherwise we would lift the block up in the above analysis

COMMENT

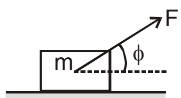
It is easier to pull then to push. Only about 34 N force is required to pull than 50 N required during pushing why ?

Because, when we pull at an angle, the effective normal force N by which block is pressing down on surface is reduced and consequently friction is reduced. Just the contrary happens when you are pushing.

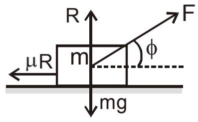
2. MINIMUM FORCE REQUIRED TO MOVE THE PARTICLE :

A body of mass m rests on a horizontal floor with which it has a coefficient of static friction μ. It is desired to make the body slide by applying the minimum possible force F.

Fig. A



Let the applied force F be at angle ϕ with the horizontal

Fig. B 

R = Normal force

For vertical equilibrium,

$R + F \sin \phi = mg$

or, $R = (mg - F \sin\phi)$ ...(i)

For horizontal equilibrium i.e. when the block is just about to slide,

$F \cos \phi = \mu R$ ...(ii)

Substituting for R,

$F \cos\phi = \mu\,(mg - F \sin\phi)$

or $F = \mu mg / (\cos \phi + \mu \sin\phi)$

for minimum F $(\cos\phi + \mu\sin\phi)$ is maximum,

$\Rightarrow$ Let $x = \cos \phi + \mu \sin\phi$

$$\frac{dx}{d\phi} = -\sin\phi + \mu\cos\phi$$

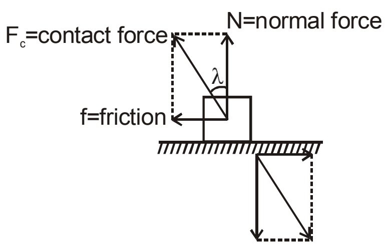
for maximum of x, $\frac{dx}{d\phi} = 0$

$\tan \phi = \mu$ and at this value of ϕ

$$F_{min} = \frac{\mu mg}{\sqrt{1+\mu^2}}$$

3. FRICTION AS THE COMPONENT OF CONTACT FORCE :

When two bodies are kept in contact, electromagnetic forces act between the charged particles at the surfaces of the bodies. As a result, each body exerts a contact force on other The magnitudes of the contact forces acting on the two bodies are equal but their directions are opposite and hence the contact forces obey Newton's third law.



The direction of the contact force acting on a particular body is not necessarily perpendicular to the contact surface. We can resolve this contact force into two components, one perpendicular to the contact surface and the other parallel to it. The perpendicular component is called the normal contact force or normal force and parallel component is called friction.

Contact force = $\sqrt{f^2 + N^2}$

$F_{c\,min} = N$ {when $f_{min} = 0$}

$F_{c\,max} = \sqrt{\mu^2 N^2 + N^2}$ {when $f_{max} = \mu N$}

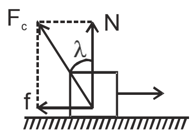
$N \le F_c \le \sqrt{(\mu^2+1)}\,N$

$0 \le \lambda \le \tan^{-1}\mu$

EXAMPLE 07

A body of mass 400 g slides on a rough horizontal surface. If the frictional force is 3.0 N, find (a) the angle made by the contact force on the body with the vertical and (b) the magnitude of the contact force. Take $g = 10\ m/s^2$.

Sol. Let the contact force on the block by the surface be F_c which makes an angle λ with the vertical (shown figure)



The component of F_c perpendicular to the contact surface is the normal force N and the component of F parallel to the surface is the firction f. As the surface is horizontal, N is vertically upward. For vertical equilirbrium,

$N = Mg = (0.400\ kg)\ (10\ m/s^2) = 4.0\ N$

The frictional force is f = 3.0 N

(a) $\tan\lambda = \frac{f}{N} = \frac{3}{4}$ or, $\lambda = \tan^{-1}(3/4) = 37^o$

(b) The magnituded of the contact force is

$F = \sqrt{N^2 + f^2} = \sqrt{(4.0N)^2 + (3.0N)^2} = 5.0\,N$

4. MOTION ON A ROUGH INCLINED PLANE

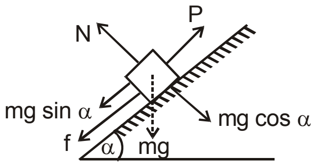
Suppose a motion up the plane takes place under the action of pull P acting parallel to the plane

$N = mg \cos \alpha$

Frictional force acting down the plane

$F = \mu N = \mu\, mg \cos \alpha$

Appling Newton's second law for motion up the plane



$P - (mg \sin \alpha + f) = ma$

$P - mg \sin \alpha - \mu\, mg \cos \alpha = ma$

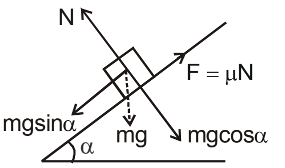
If P = 0 the block may slide downwards with an acceleration a. The frictional force would then act up the plane

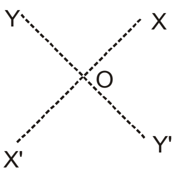
$mg \sin \alpha - F = ma$

or, $mg \sin \alpha - \mu\, mg \cos \alpha = ma$

EXAMPLE 08

A 20 kg box is gently placed on a rough inclined plane of inclination 30° with horizontal. The coefficient of sliding friction between the box and the plane is 0.4. Find the acceleration of the box down the incline.





Sol. In solving inclined plane problems, the X and Y directions along which the forces are to be considered, may be taken as shown. The components of weight of the box are

(i) mg sin α acting down the plane and

(ii) mg cos α acting perpendicular to the plane.

$N = mg \cos \alpha$

$mg \sin \alpha - \mu N = ma$

$\Rightarrow \quad mg \sin \alpha - \mu\, mg \cos \alpha = ma$

$a = g \sin \alpha - \mu g \cos \alpha \quad = g (\sin \alpha - \mu \cos \alpha)$

$$= 9.8\left(\frac{1}{2} - 0.4 \times \frac{\sqrt{3}}{2}\right) = 4.9 \times 0.3072 = 1.505 \text{ m/s}^2$$

The box accelerates down the plane at 1.505 m/s^2.

EXAMPLE 09

A force of 400 N acting horizontal pushes up a 20 kg block placed on a rough inclined plane which makes an anlge of 45° with the horizontal. The acceleration experienced by the block is 0.6 m/s^2. Find the coefficient of sliding friction between the box and incline.

Sol. The horizontally directed force 400 N and weight 20 kg of the block are resolved into two mutually perpendicular components, parallel and perpendicular to the plane as shown.

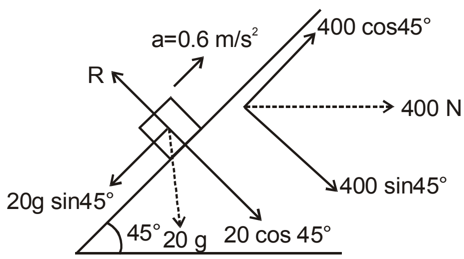
$N = 20\, g \cos 45° + 400 \sin 45° = 421.4$ N

The frictional force experienced by the block

$F = \mu N = \mu \times 421.4 = 421.4\, \mu N.$

As the accelerated motion is taking placed up the plane.

$400 \cos 45° - 20\, g \sin 45° - f = 20a$



$$\frac{400}{\sqrt{2}} - \frac{20 \times 9.8}{\sqrt{2}} - 421.4\, \mu = 20a = 20 \times 0.6 = 12$$

$$\mu = \left(\frac{400}{\sqrt{2}} = -\frac{196}{\sqrt{2}} - 12\right) \times \frac{1}{421.4}$$

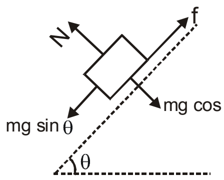
$$= \frac{282.8 - 138.6 - 12}{421.4} = 0.3137$$

The coefficient of sliding friction between the block and the incline = 0.3137

5. ANGLE OF REPOSE :

Consider a rough inclined plane whose angle of inclination θ with ground can be changed. A block of mass m is resting on the plane. Coefficient of (static) friction between the block and plane is μ.

For a given angle θ, the FBD (Free body diagram) of the block is



Where f is force of static friction on the block. For normal direction to the plane, we have $N = mg\cos\theta$

As θ increases, the force of gravity down the plane, mg sin θ, increases. Friction force resists the slide till it attains its maximum value.

$f_{max} = \mu N = \mu\, mg\cos\theta$

Which decreases with θ (because cos θ decreases as θ increases)

Hence, beyond a critical value $\theta = \theta_c$, the blocks starts to slide down the plane. The critical angle is the one when mg sin θ is just equal of f_{max}, i.e., when

$mg\sin\theta_c = \mu\, mg\cos\theta_c$

or $\tan\theta_c = \mu$

where θ_C is called angle of repose

If $\theta > \theta_c$, block will slide down.For $\theta < \theta_c$ the block stays at rest on the incline.

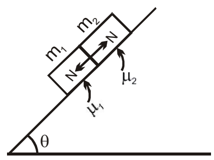
Note

The student can now attempt section H from exercise.

Section I, J, K - Direction of friction, Pulley Block system on horizontal plane, Pulley Block system on inclined plane, Two Block system, Two Block on Inclined plane

6. TWO BLOCKS ON AN INCLINED PLANE :

Consider two blocks having masses m_1 & m_2 placed on a rough inclined plane. μ_1 & μ_2 are the friction coefficient for m_1 & m_2 respectively. If N is the normal force between the contact surface of m_1 & m_2



Now three condition arises.

(i) If $\mu_1 = \mu_2 = \mu$ then

N = 0 because, Both the blocks are in contact but does not press each other.

$$a_1 = a_2 = g\sin\theta - \mu\, mg\cos\theta$$

(a_1, a_2 are acceleration of block μ_1 & μ_2 respectively)

(ii) If $\mu_1 < \mu_2$ then

N = 0 because, there is no contact between the blocks.

$$a_1 = g\sin\theta - \mu_1 g\cos\theta$$

$$a_2 = g\sin\theta - \mu_2 g\cos\theta$$

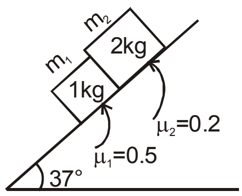
$\Rightarrow \quad a_1 > a_2$

(iii) If $\mu_1 > \mu_2$ then $\quad N \neq 0$

$$a_1 = a_2$$

EXAMPLE 10

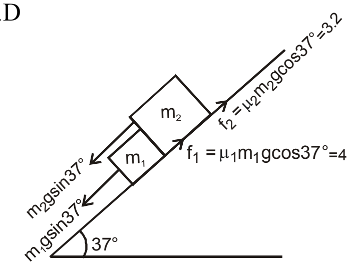
Mass m_1 & m_2 are placed on a rough inclined plane as shown in figure. Find out the acceleration of the blocks and contact force in between these surface.



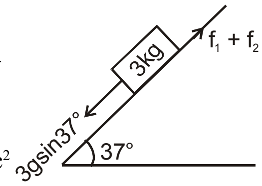
Sol. As we know if $\mu_1 > \mu_2$ both will travel together so

$a_1 = a_2 = a$

F.B.D



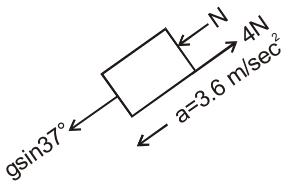
which is equivalent to



$$a = \frac{3g\sin37° - (f_1 + f_2)}{3}$$

$$a = \frac{18 - 7.2}{2} = 3.6 \text{ m/sec}^2$$

Now F.B.D of 1 kg block is



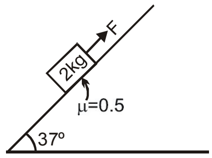
$g\sin37° + N - 4 = (1)\,a$

$N = 3.6 + 4 - 6 = 1.6$ Newton

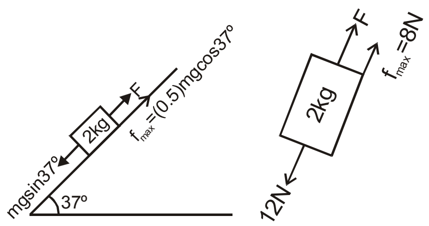
7. RANGE OF FORCE F FOR WHICH ACCELERATION OF BODY IS ZERO.

EXAMPLE 11

Find out the range of force in the above situation for which 2kg block does not move on the incline.



Sol. **F.B.D of 2 kg block**

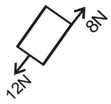


Now take different value of F

Force (F) F.B.D.
Acceleration Direction & magnitude
Friction Type

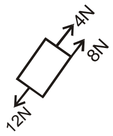
$$a = \frac{F_{net}}{m}$$

(i) F = 0N



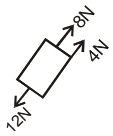
$2 m/s^2$ ↗ 8N Kinetic

(ii) F = 4N



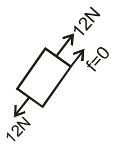
$0 m/s^2$ ↗ 8N Static

(iii) F = 8N



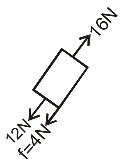
$0 m/s^2$ ↗ 4 N Static

(iv) F = 12N



$0 m/s^2$ 0 Static

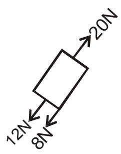
(v) F = 16N



$0 m/s^2$ ↙ 4N Static

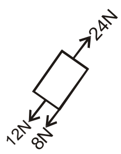
(in this condition friction change its direction to stop relative slipping)

(vi) F = 20N



$0 m/s^2$ ↙ 8N Static

(vii) F = 24N



$2 m/s^2$ ↙ 8N Kinetic

From the above table block doesn't move from F = 4N (mgsinθ – μmgcosθ) to F = 20N (mgsinθ + μmgcosθ). So friction develope a range of force for which block doesn't move

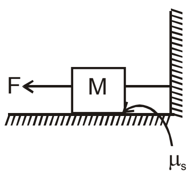
: If Friction is not present then only for F = 12N the block will not move but friction develop a range of force 4N to 20N to prevent slipping. So we can write the range of force F for which acceleration of the body is zero.

$mg \sin\theta - \mu mg \cos\theta \le F \le mg \sin\theta + \mu\, mg \cos\theta$.

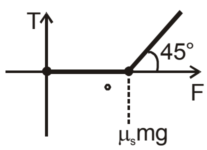
SOLVED EXAMPLE

EXAMPLE 12

In the following figure force F is gradually increased from zero. Draw the graph between applied force F and tension T in the string. The coefficient of static friction between the block and the ground is μ_s.



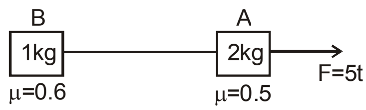
Sol. As the external force F is gradually increased from zero it is compensated by the friction and the string beares no tension. When limiting friction is achieved by increasing force F to a value till μ_s mg, the further increase in F is transferred to the string.



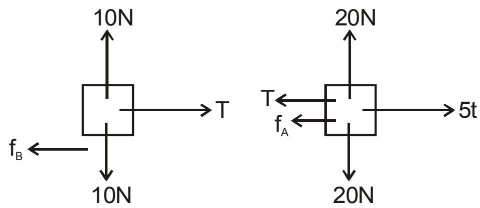
EXAMPLE 13

Fig. shows two blocks tied by a string. A variable force F = 5t is applied on the block. The coefficient of friction for the blocks are 0.6 and 0.5 respectively. Find the frictional force between blocks and ground as well as tension in the string at

(A) t = 1 s (B) t = 2s (C) t = 3s



Sol.



(a) At t = 1s, F = 5 × 1 = 5 N

Maximum value of friction force

$f_A = \mu N = 0.5 \times 20 = 10$ N

To keep the block stationary the magnitude of frictional force should be 5N. So

$f_A = 5$ N

Now from the figure it becomes clear that if

$f_A = 5$N & F = 5 N, Tension T = 0

Since tension is not in application so frictional force on block B is 0 i.e.,

$f_B = 0$

(b) At t = 2s, F = 5 × 2 = 10 N

Maximum value of friction force

$f = \mu N = 0.5 \times 20 = 10$ N

To keep the block stationary the magnitude of friction force should be 10 N. So

$f_A = 10$ N

From the figure it is clear that if

$f_A = 10$ N and F = 10 N

Tension T = 0

Hence friction force on block B is $f_B = 0$

(c) At t = 3s, F = 5 × 3 = 15 N

Maximum value of friction force

$f = \mu N = 0.5 \times 20 = 10$ Newton

Again applying the same analogy $f_A = 10$ N

From the figure it is clear that if

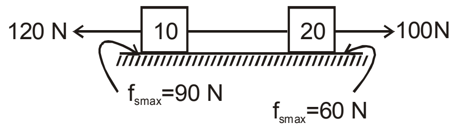
$f_A = 10$ N and F = 15 N

Tension T = 5 N

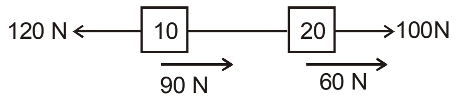
So frictional force on block B is $f_B = 5$ Newton

EXAMPLE 14

Find the tension in the string in situation as shown in the figure below. Forces 120 N and 100 N start acting when the system is at rest.

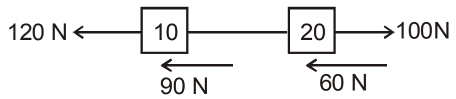


Sol. (i) Let us assume that system moves towards left then as it is clear from FBD, net force in horizontal direction is towards right. Therefore the assumption is not valid.



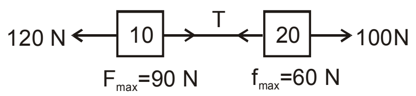
Above assumption is not possible as net force on system comes towards right. Hence system is not moving towards left.

(ii) Similarly let us assume that system moves towards right.

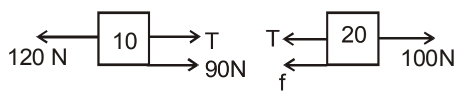


Above assumption is also not possible as net force on the system is towards left in this situation. Hence assumption is again not valid.

Therefore it can be concluded that the system is stationary



Assuming that the 10 kg block reaches limiting friction first then using FBD's



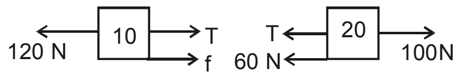
$120 = T + 90 \quad \Rightarrow \quad T = 30$ N

Also $\quad T + f = 100$

$\therefore \quad 30 + f = 100 \quad \Rightarrow \quad f = 70$ N

which is not possible as the limiting value is 60 N for this surface of block.

$\therefore$ Our assumption is wrong and now taking the 20 kg surface to be limiting we have



$T + 60 = 100 \text{ N} \Rightarrow \quad T = 40$ N

Also $\quad f + T = 120 \text{ N} \quad \Rightarrow \quad f = 80$ N

This is acceptable as static friction at this surface should be less than 90 N.

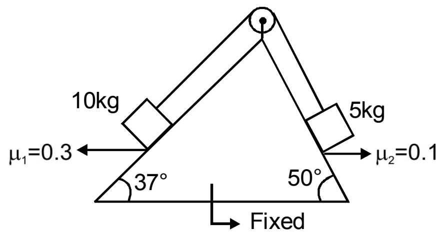
Hence the tension in the string is T = 40 N

8. PULLEY BLOCK SYSTEM INVOLVING FRICTION :

- If friction force is acting and value of acceleration of a particle is negative, then it means direction of friction force is opposite to that what we assumed and acceleration would be having a different numerical value.

EXAMPLE 15

Two blocks of masses 5 kg and 10 kg are attached with the help of light string and placed on a rough incline as shown in the figure. Coefficients of friction are as marked in the figure. The system is released from rest. Determine the acceleration of the two blocks.



Sol. Let 10 kg block is sliding down, then acceleration of both the blocks are given by,

$$a = \frac{10g\sin 37° - \mu_1 \times 10g\cos 37° - 5g\sin 53° - \mu_2 \times 5g\cos 53°}{15} = -ve$$

It means our assumed direction of motion is wrong and 5 kg block is going to slide down, if this would be the case, the direction of friction force will reverse and acceleration of blocks would be given by :

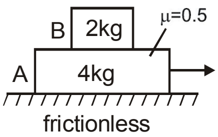
$$a_1 = \frac{5g\sin 53° - \mu_2 \times 5g\cos 53° - \mu_1 \times 10g\cos 37° - 10g\sin 37°}{15}$$

$= -ve$

It means in this direction also there is no motion. So we can conclude that the system remains at rest and friction force is static in nature.

9. TWO BLOCK SYSTEM :

EXAMPLE 16

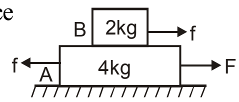


Find out the maximum value of F for which both the blocks will move together

Sol. In the given situation 2kg block will move only due to friction force exerted by the 4 kg block

F.B.D.

The maximum friction force exerted on the block B is



$f_{max} = \mu N$

$f_{max} = (0.5)\,(20) = 10\text{ N}$

So the maximum acceleration of 2 kg block is

$$a_{2\,max} = \frac{10}{2} = 5\,m/s^2$$

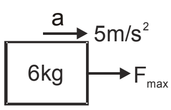
a_{max} is the maximum acceleration for which both the block will move together. i.e., for $a \le 5\ ms^{-2}$ acceleration of both blocks will be same and we can take both the blocks as a system.

F.B.D

$F_{max} = 6 \times 5 = 30\text{ N}$

for $0 < F < 30$

Both the block move together.



EXAMPLE 17

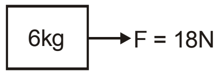
In the above question find the acceleration of both the block when

(i) F = 18 N (ii) F = 36 N

Sol. (i) Since F < 30 both the blocks will move together

F.B.D

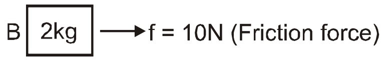
$$a = \frac{18}{6} = 3\,m/s^2$$



(ii) When F = 36 N

When F > 30 both the blocks will move separately so we treat each block independently

F.B.D of 2 kg block

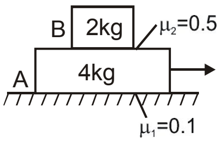


$a_B = 5\ m/s^2$

F.B.D of 4 kg block

$$a_A = \frac{36-10}{4} = \frac{26}{4}\,m/s^2$$

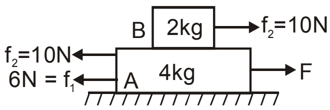
EXAMPLE 18



Find out the range of force in which both the blocks move together

Sol. If f_1 is friction force between block A & lower surface and f_2 is friction force between both the block's surface.

F.B.D

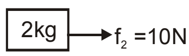


$f_{1\,max} = \mu_1 N_1 = (0.1)\,(60) = 6\text{ N}$

$f_{2\,max} = \mu_2 N_2 = (0.5)\,(20) = 10\text{ N}$

Upper 2kg block is move only due to friction force so maximum acceleration of that block is

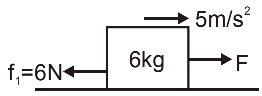
$$a_{max} = \frac{10}{2} = 5\,m/s^2$$



This is the maximum acceleration for which both the blocks will move together.

Therefore for $a \le 5ms^{-2}$ we can take both the blocks as one system.

F.B.D.



For F < 6 N. Blocks will not move at all.

Now the value of F_{max} for which both the blocks will move together.

$$F_{max} - 6 = 6 \times 5$$

$$F_{max} = 36 \text{ N}$$

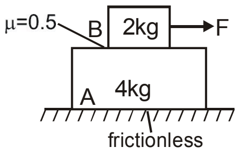
Conclusion if

0N < F < 6N No blocks will move

6N < F < 36 N Both blocks will move together

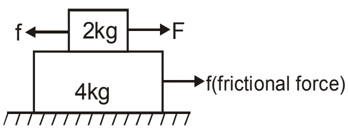
F > 36 N Both move separately.

EXAMPLE 19



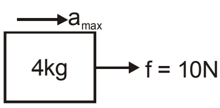
The lower block A will move only due to friction force

F.B.D.



$$f_{max} = \mu N = (0.5)(20) = 10 \text{ N}$$

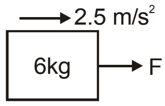
F.B.D. of 4 kg blocks



The maximum acceleration of 4 kg block is

$$\Rightarrow \quad a_{max} = \frac{10}{4} = 2.5 m/s^2$$

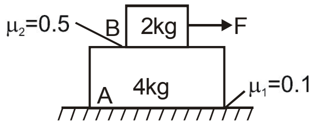
This is the maximum acceleration for which both the blocks move together



F_{max} for which both the blocks will move together

$F_{max} = 2.5 \times 6 = 15$ N

EXAMPLE 20



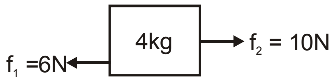
If f_2 is the friction force between A & B and f_1 is the friction force between A & floor

$$f_{1\,max} = 6 \text{ N}$$

$$f_{2\,max} = 10 \text{ N}$$

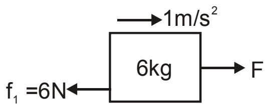
Lower block A will move only due to friction force

So a_{max} for 4 kg block



$$a_{max} = \frac{10-6}{4} = 1 \text{ m/s}^2$$

This is the maximum acceleration for which both the blocks will move together



$$F - 6 = 6 \times 1$$

$$F = 12 \text{ N}$$

If F is less than 6N both the blocks will be stationary

Conclusion :

0 < F < 6 N = Both blocks are stationary

6 N < F < 12 N = Both move together

F > 12 N = Both move separately

EXAMPLE 21

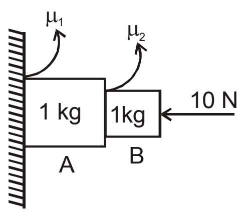
Find the accelerations of blocks A and B for the following cases.

(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

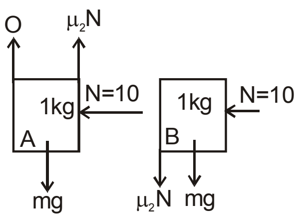
(D) $\mu_1 = 1.0$ and $\mu_2 = 0.1$ (S) $a_A = 1$, $a_B = 9$ m/s^2



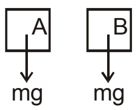
Sol. (a) R, (b) Q, (c) P, (d) S

(i) FBD in (case (i))

$\{\mu_1 = 0, \mu_2 = 0.1\}$

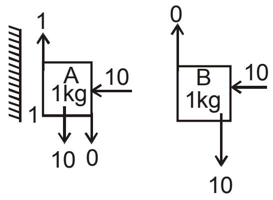


While friction's work is to oppose the relative motion and here if relative motion will start then friction comes and without relative motion there is no friction so both the block move together with same acceleration and friction will not come.



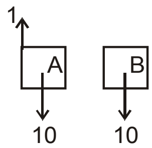
$\Rightarrow a_A = a_B = 10$ m/s^2

(ii)



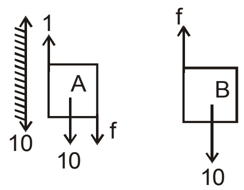
Friction between wall and block A oppose relative motion since wall is stationary so friction wants to slop block A also and maximum friction will act between wall and block while there is no friction between block.

: Friction between wall and block will oppose relative motion between wall and block only it will not do anything for two block motion.

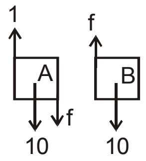


$a_A = 9$ m/s^2 ; $a_B = 10$ m/s^2

(iii)



Friction between wall and block will be applied maximum equal to 1N but maximum friction available between block A and B is 10 N but if this will be there then relative motion will increase while friction is to oppose relative motion. So friction will come less than 10 so friction will be f that will be static.

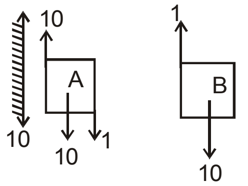


by system (20–1) = 2 × a

$\Rightarrow \quad a = \dfrac{19}{2} = 9.5 \text{ m/s}^2$

(iv) $a_A = \dfrac{11-10}{1} = 1\,\text{m/s}^2$

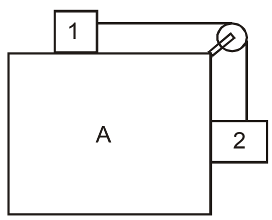
$a_B = \dfrac{10-1}{1} = 9\,\text{m/s}^2$



10. FRICTION INVOLVING PSEUDO CONCEPT :

EXAMPLE 22

What is the minimum acceleration with which bar A should be shifted horizontally to keep the bodies 1 and 2 stationary relative to the bar ? The masses of the bodies are equal and the coefficient of friction between the bar and the bodies equal to μ. The masses of the pulley and the threads are negligible while the friction in the pulley is absent. see in fig.

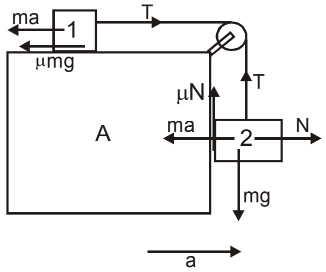


Sol. Let us place the observer on A.

Since we have non-inertial frame we have pseudo forces.

For body '1' we have,

$T = ma + \mu mg$ ....(1)



For body '2' we have,

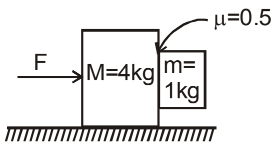
$N = ma$

$mg - T - \mu ma = 0$

$\therefore\ mg = T + \mu mg$ ....(2)

From (1) and (2) $a_{min} = g\left(\dfrac{1-\mu}{1+\mu}\right)$

EXAMPLE 23



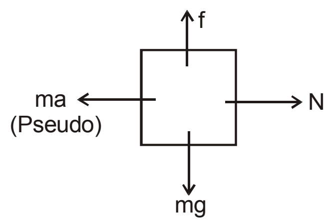
Find out the range of force for which smaller block is at rest with respect to bigger block.

Sol. Smaller block is at rest w.r.t. the bigger block. Let both the block travel together with acceleration a F.B.D of smaller block w.r. to the bigger block.

$f_{max} = \mu \times N$

$N = ma$

$f = \mu ma$ ...(1)



$\Rightarrow \quad f = mg \quad ...(2)$

from (1) & (2)

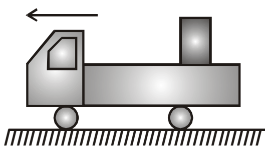
$a = g/\mu = 20\ m/s^2$

So F = 20 (M + m) = 20 (5) = 100 N

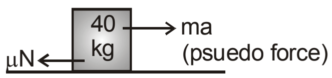
If $F \geq 100$ N Both will travel together

EXAMPLE 24

The rear side of a truck is open and a box of 40 kg mass is placed 5m away from the open end as shown. The coefficient of friction between the box & the surface below it is 0.15. On a straight road, the truck starts from rest and accelerates with 2 ms^{-2}. At what distance from the starting point does the box fall off the truck (i.e. distance travelled by the truck) ? [Ignore the size of the box]



Sol. In the reference frame of the truck FBD of 40 kg block



Net force $\Rightarrow ma - \mu N \Rightarrow 40 \times 2 - \frac{15}{100} \times 40 \times 10$

$ma_{block} \Rightarrow 80 - 60 \Rightarrow a_{block} = \frac{20}{40} = \frac{1}{2}\ m/s^2$

This acceleration of the block in reference frame of truck so time taken by box to fall down from truck

$S_{rel} = u_{rel}t + \frac{1}{2}a_{rel}t^2 \Rightarrow 5 = 0 + \frac{1}{2} \times \frac{1}{2} \times t^2 \Rightarrow t^2 = 20$

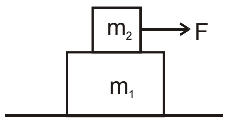
So distance moved by the truck

$\Rightarrow \quad \frac{1}{2} \times a_{truck} \times t^2$

$\Rightarrow \quad \frac{1}{2} \times 2 \times (20) = 20$ meter.

EXAMPLE 25

Mass m_2 placed on a plank of mass m_1 lying on a smooth horizontal plane. A horizontal force $F = \alpha_0 t$ (α_0 is a constant) is applied to a bar. If acceleration of the plank and bar are a_1 and a_2 respectively and the coefficient of friction between m_1 and m_2 is μ. Then find acceleration a with time t.



Sol. If $F < \mu m_2 g$ then both blocks move with common acceleration, i.e., $a_1 = a_2$

When $F > \mu m_2 g$, then

Equation for block of mass m

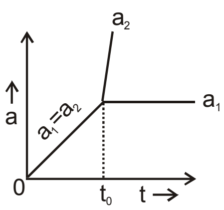
$F - \mu m_2 g = m_2 a_2 \quad ...(1)$

and $\mu m_2 g = m_1 a_1 \quad ...(2)$

From equation (1)

$\alpha_0 t - \mu m_2 g = m_2 a_2$

i.e., acceleration a_2 varies with time linearly,



its slope positive and intercept negative.

From equation (2) a_1 is independent of time.

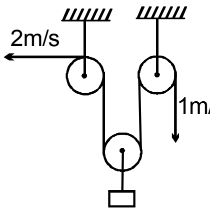
So, the graph between a & t is as follow.

Note

The student can now attempt section I,J,K from exercise.

Section A - String Constrained, Wedge Constrained

1. Find the velocity of the hanging block if the velocities of the free ends of the rope are as indicated in the figure.



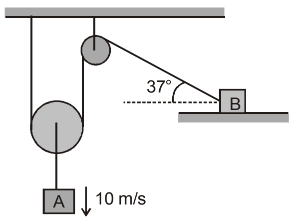
(A) 3/2 m/s ↑

(B) 3/2 m/s ↓

(C) 1/2 m/s ↑

(D) 1/2 m/s ↓

2. Find velocity of block 'B' at the instant shown in figure.



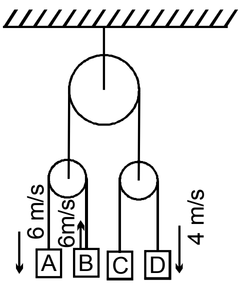
(A) 25 m/s

(B) 20 m/s

(C) 22 m/s

(D) 30 m/s

3. In the figure shown the velocity of different blocks is shown. The velocity of C is



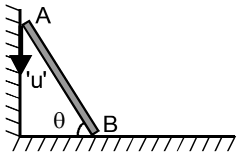
(A) 6 m/s

(B) 4 m/s

(C) 0 m/s

(D) none of these

4. The velocity of end 'A' of rigid rod placed between two smooth vertical walls moves with velocity 'u' along vertical direction. Find out the velocity of end 'B' of that rod, rod always remains in constant with the vertical walls.



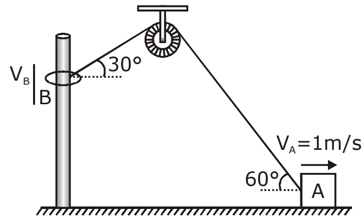
(A) u tan 2θ

(B) u cot θ

(C) u tan θ

(D) 2u tan θ

5. Find velocity of ring B (V_B) at the instant shown. The string is taut and inextensible:



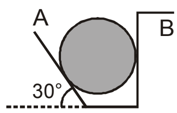
(A) $\frac{1}{2}$ m/s

(B) $\frac{\sqrt{3}}{4}$ m/s

(C) $\frac{1}{4}$ m/s

(D) 1 m/s

6. The 50 kg homogeneous smooth sphere rests on the 30° incline A and bears against the smooth vertical wall B. Calculate the contact forces at A and B.



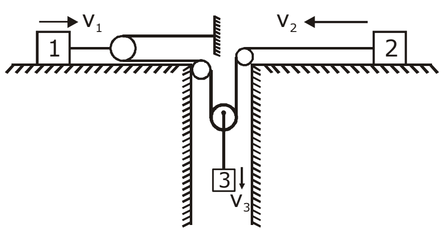
(A) $N_B = \frac{1000}{\sqrt{3}}$ N , $N_A = \frac{500}{\sqrt{3}}$ N

(B) $N_A = \frac{1000}{\sqrt{3}}$ N , $N_B = \frac{500}{\sqrt{3}}$ N

(C) $N_A = \frac{100}{\sqrt{3}}$ N , $N_B = \frac{500}{\sqrt{3}}$ N

(D) $N_A = \frac{1000}{\sqrt{3}}$ N , $N_B = \frac{50}{\sqrt{3}}$ N

7. Three blocks 1, 2 and 3 are arranged as shown in the figure. The velocities of the blocks v_1, v_2 and v_3 are shown in the figure. What is the relationship between v_1, v_2 and v_3?



(A) $2v_1 + v_2 = v_3$

(B) $v_1 + v_2 = v_3$

(C) $v_1 + 2v_2 = v_3$

(D) None of these

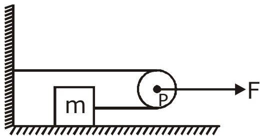
8. The ratio of acceleration of pulley to the acceleration of the block is (string is inextensible)

(A) 0.5

(B) 2

(C) 1

(D) None of these



Section B - Newton's Law theory Question

9. When force $\vec{F}_1, \vec{F}_2, \vec{F}_3 .....\vec{F}_n$ act on a particle, the particle remains in equilibrium. If $\vec{F}_1$ is now removed then acceleration of the particle is

(A) $\frac{\vec{F}_1}{m}$ (B) $-\frac{\vec{F}_1}{m}$

(C) $-\frac{\vec{F}_2 + \vec{F}_3 + ...\vec{F}_n - \vec{F}_1}{m}$ (D) $\frac{\vec{F}_2}{m}$

10. You are on a friction less horizontal plane. How can you get off if no horizontal force is exerted by pushing against the surface ?

(A) by jumping (B) by spitting or sneezing

(C) by rolling your body on the surface

(D) by running on the plane

11. A particle moves in the xy plane under the action of a force **F** such that the value of its linear momentum (**P**) at any time t is, P_x = 2 cost, P_y = 2 sint. The angle θ between **P** and **F** at that time t will be -

(A) 0º (B) 30º

(C) 90º (D) 180º

12. You fall in the forward direction when a moving bus apply brakes to stop and fall backward when it accelerates from rest because of..

(A) Newton's First law (B) Newton's Second law

(C) Newton's Third law (D) E = mc^2

13. According to Newton's third law action is always equal to the reaction, a horse can pull a cart because it applies a...

(A) Force on cart (B) Force on ground

(C) Both of than(D) None of these

14. Which of the Newton's law explain difficultly for a fireman to hold a hose pipe, which ejects large amounts of water at high velocity.

(A) Newton's First law (B) Newton's Second law

(C) Newton's Third law (D) E = mc^2

15. When a carpet is beaten with a stick, dust comes out of it. Explains by

(A) Newton's First law (B) Newton's Second law

(C) Newton's Third law (D) E = mc^2

16. As an inclined plane is made slowly horizontal by reducing the value of angle θ with horizontal. The component of weight parallel to the plane of a block resting on the inclined plane-

(A) decreases (B) remains same

(C) increases

(D) increases if the plane is smooth

Section C - Equillibrium Questions (Normal and Tension), Problems with Acceleration (F=ma)

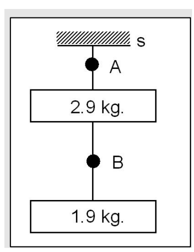
17. Two blocks of masses 2.9 kg and 1.9 kg are suspended from a rigid support S by two inextensible wires each of length 1 m. The upper wire has negligible mass and the lower wire has a uniform mass of 0.2 kg/m. Thewhole system of block, wire and support have an upward acceleration of 0.2 m/s^2. g=9.8 m/s^2. The tension at the mid-point of lower wire is-

(A) 10 N

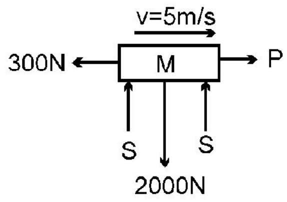
(B) 20 N

(C) 30 N

(D) 50 N



18. The forces acting on an object are shown in the fig. If the body moves horizontally at a constant speed of 5 m/s, then the values of the forces P and S are, respectively-



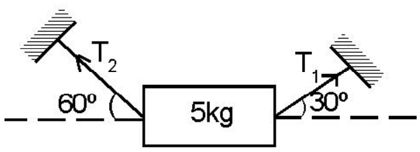
(A) 0 N, 0 N

(B) 300 N, 200 N

(C) 300 N, 1000 N

(D) 2000 N, 300 N

19. A body of mass 5 kg is suspended by the strings making angles 60º and 30º with the horizontal -



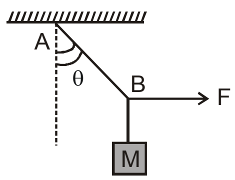
(a) $T_1 = 25$ N (b) $T_2 = 25$ N

(c) $T_1 = 25\sqrt{3}$ N (d) $T_2 = 25\sqrt{3}$ N

(A) a, b (B) a, d

(C) c, d (D) b, c

20. A mass M is suspended by a rope from a rigid support at A as shown in figure. Another rope is tied at the end B, and it is pulled horizontally with a force F. If the rope AB makes an angle θ with the vertical in equilibrium, then the tension in the string AB is :



(A) F sin θ

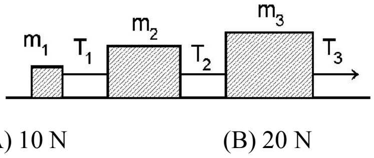
(B) F/sin θ

(C) F cos θ

(D) F/cos θ

21. Three block are connected as shown, on a horizontal frictionless table and pulled to the right with a force $T_3 = 60$ N. If $m_1 = 10$ kg, $m_2 = 20$ kg and $m_3 = 30$ kg, the tension T_2 is-

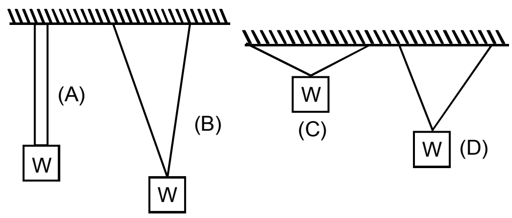
-



(A) 10 N (B) 20 N

(C) 30 N (D) 60 N

22. A weight can be hung in any of the following four ways by string of same type. In which case is the string most likely to break ?



(A) A (B) B

(C) C (D) D

23. An aeroplane, which together with its load has a mass M =9600kg, is falling with an acceleration of a = 5 m/s^2 . If a part of the load equal to m kg be thrown out, the aeroplane will begin to rise with an acceleration of a = 5 m/s^2. Find the value of m?

(A) 6400 (B) 6450

(C) 6600 (D) 6700

24. A stretching force of 1000 Newton is applied at one end of a spring balance and an equal stretching force is applied at the other end at the same time. The reading of the balance will be :

(A) 2000 N (B) Zero

(C) 1000 N (D) 500 N

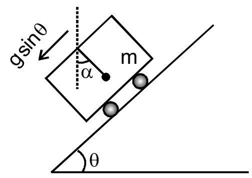
Section D - Wedge problems

25. Body A is placed on frictionless wedge making an angle θ with the horizon. The horizontal acceleration towards left to be imparted to the wedge for the body A to freely fall vertically, is –

(A) g sinθ (B) g cosθ

(C) g tanθ (D) g cotθ

26. A trolley is accelerating down an incline of angle θ with acceleration gsinθ. Which of the following is correct. (α is the constant angle made by the string with vertical)

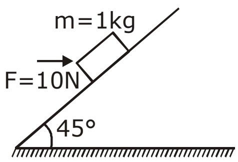


(A) $\alpha = \theta$ (B) $\alpha = 0^\circ$

(C) Tension in the string, T = mg

(D) Tension in the string, T = mg sec θ

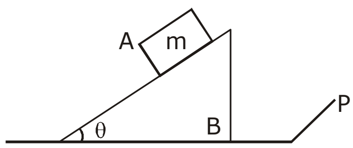
27. A body of mass 1 kg lies on smooth inclined plane. The block of mass m is given force F = 10 N horizontally as shown. The magnitude of net normal reaction on the block is :



(A) $10\sqrt{2}$N (B) $\frac{10}{\sqrt{2}}$N

(C) 10 N (D) none of these

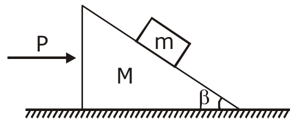
28. In the figure shown 'P' is a plate on which a wedge B is placed and on B a block A of mass m is placed. The plate is suddenly removed and system of B and A is allowed to fall under gravity. Neglecting any force due to air on A and B, the normal force on A due to B is



(A) $\frac{mg}{\cos\theta}$ (B) mg cosθ

(C) zero (D) $\frac{2mg}{\cos\theta}$

29. Two wooden blocks are moving on a smooth horizontal surface such that the mass m remains stationary with respect to block of mass M as shown in the figure. The magnitude of force P is :



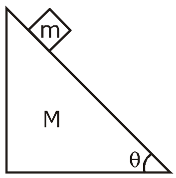
(A) (M+m)g tan β

(B) g tan β

(C) mg cos β

(D) (M+m)g coses β

30. A block of mass m is kept on a wedge of mass M. Initially the system is held. At certain time the sytstem is released and the wedge is observed to move with accelertion A on inclined surface as shown. There is no friction anywhere. The acceleration of block (m) with respect to wedge (M) will be

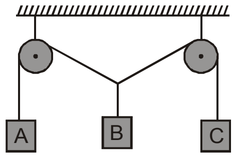


(A) A rightward (B) A cos θ rightward

(C) A cos θ leftward (D) none of these

Section E - Pulley Block system

31. Three blocks A, B and C are suspended as shown in the figure. Mass of each blocks A and C is m. If system is in equilibrium and mass of B is M, then :



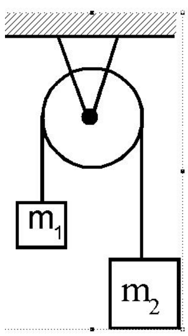
(A) M = 2m

(B) M < 2 m

(C) M > 2m

(D) M = m

32. Two masses are hanging vertically over frictionless pulley. The acceleration of the two masses is–



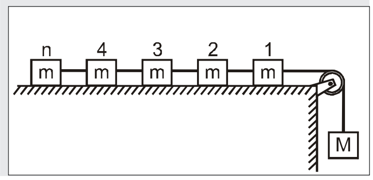
(A) $\frac{m_1}{m_2}g$

(B) $\frac{m_2}{m_1}g$

(C) $\left(\frac{m_2 - m_1}{m_1 + m_2}\right)g$

(D) $\left(\frac{m_1 + m_2}{m_2 - m_1}\right)g$

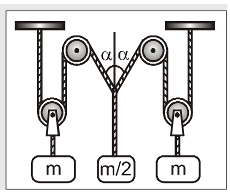
33. In the given arrangement, n number of equal masses are connected by strings of negligible masses. The tension in the string connected to n^{th} mass is –



(A) $\frac{mMg}{nm+M}$ (B) $\frac{mMg}{nmM}$

(C) mg (D) $\frac{mMg}{mN+M}$

34. In the given figure, pulleys and strings are massless. For equilibrium of the system, the value of α is –



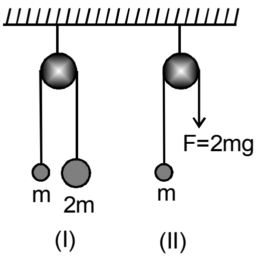
(A) 60°

(B) 30°

(C) 90°

(D) 120°

35. The pulley arrangements shown in figure are identical the mass of the rope being negligible. In case I, the mass m is lifted by attaching a mass 2m to the other end of the rope. In case II, the mass m is lifted by pulling the other end of the rope with cosntant downward force F = 2mg, where g is acceleration due to gravity. The acceleration of mass in case I is



(A) zero

(B) more than that in case II

(C) less than that in case II

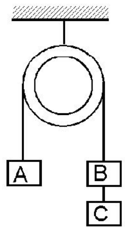
(D) equal to that in case II

36. A particle of small mass m is joined to a very heavy body by a light string passing over a light pulley. Both bodies are free to move. The total downward force in the pulley is

(A) mg (B) 2 mg

(C) 4 mg (D) can not be determined

37. Three equal weights A, B, C of mass 2 kg each are hanging on a string passing over a fixed frictionless pulley as shown in the fig. The tension in the string connecting weights B and C is-



(A) zero

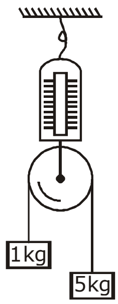
(B) 13 Newton

(C) 3.3 Newton

(D) 19.6 Newton

Section F - Spring force and spring cutting problems

38. Two masses of 1 kg and 5 kg are attached to the ends of a massless string passing over a pulley of negligible weight. The pulley itself is attached to a light spring balance as shown in figure. The masses start moving during this interval; the reading of spring balance will be:



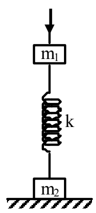
(A) more than 6 kg

(B) less than 6 kg

(C) equal to 6 kg

(D) none of the above

39. A system consists of two cubes of masses m_1 and m_2 respectively connected by a spring of force constant k. The force (F) that should be applied to the upper cube for which the lower one just lifts after the force is removed is-



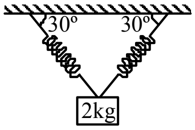
(A) m_1g

(B) $\frac{m_1m_2}{m_1+m_2}g$

(C) $(m_1 + m_2)$ g

(D) m_2g

40. A block of mass 2 kg is hanging with two identical massless springs as shown in figure. The acceleration of the block at the moment, the right spring breaks is (g = 10 m/s^2)



(A) 10 m/s^2

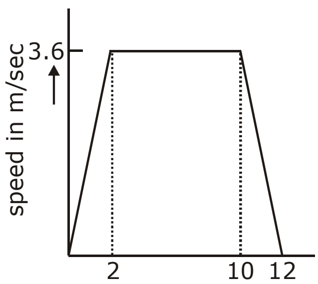
(B) 5 m/s^2

(C) 25 m/s^2

(D) 4 m/s^2

Section G - Pseudo force, Weighing Machine

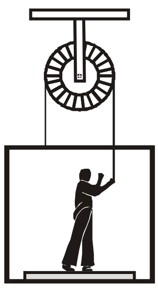
41. A lift is going up. The total mass of the lift and the passenger is 1500 kg. The variation in the speed of the lift is as given in the graph. The tension in the rope pulling the lift at t = 11th sec will be



(A) 17400 N (B) 14700 N

(C) 12000 N (D) Zero

42. Figure shows a man of mass 50 kg standing on a light weighting machine kept in a box of mass 30 kg. The box is hanging from a pulley fixed to theceiling throught a light rope, the other end of which is held by the man himself. If the man manages to keep the box at rest, the weight shown by the machine is.



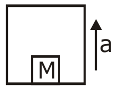
(A) 10 N

(B) 100 N

(C) 800 N

(D) 200 N

43. With what acceleration 'a' should the box of figure moving up so that the block of mass M exerts a force 7 Mg/4 on the floor of the box?



(A) g/4

(B) g/2

(C) 3g/4

(D) 4g

44. A triangular block of mass M with angle 30º, 60º, 90º rests with its 30º– 90º side on a horizontal smooth fixed table. A cubical block of mass m rests on the 60º – 30º side of the triangular block. What horizontal acceleration a must M have relative to the stationary table so that m remains stationary with respect to the triangular block [M = 9 kg, m = 1 kg]

(A) 2.8 m/s^2 (B) 5.6 m/s^2

(C) 8.4 m/s^2 (D) Zero

45. Which of the following statement is absolutely correct about mass -

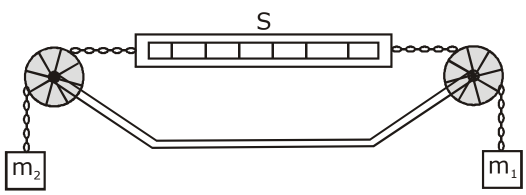
(A) More the mass of a body connected with spring balance more will be elongation in spring balance

(B) More the mass of body kept in one pan of beam balance more the mass has to be kept on the other pan to keep beam-horizontal

(C) More the mass of a body, lesser will be its acceleration for a given force

(D) All

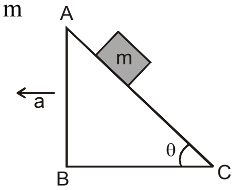
46. In the arrangement shown, the pulleys are fixed and ideal, the strings are light, $m_1 > m_2$ and S is a spring balance which is itself massless. The reading of S (in unit of mass) is



(A) $m_1 - m_2$ (B) $\frac{1}{2}(m_1 + m_2)$

(C) $\frac{m_1m_2}{m_1 + m_2}$ (D) $\frac{2m_1m_2g}{m_1 + m_2}$

47. A block of mass m resting on a wedge of angle θ as shown in the figure. The wedge is given an acceleration a. What is the minimum value of a so that the mass m falls freely ?



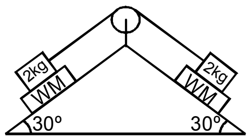
(A) g

(B) g cos θ

(C) g cot θ

(D) g tan θ

48. Find out the reading of the weighing machine in the following cases.



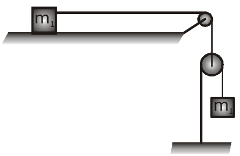
(A) $10\sqrt{3}$

(B) $10\sqrt{2}$

(C) $20\sqrt{3}$ (D) $30\sqrt{3}$

Section H - Static friction, Kinetic friction

49. The maximum value of the block m_2 for which the system will remain in equilibrium (coefficient of friction between block m_1 and plane surface is μ, Pulley are mass less) is :



(A) $\mu\frac{m_1}{2}$

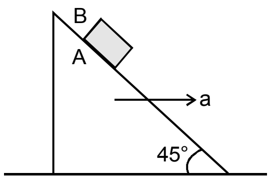
(B) $\frac{m_1}{2}$

(C) μm_1 (D) $2\mu m_1$

50. If the coefficient of friction between A and B is μ, the maximum horizontal acceleration of the wedge A for which B will remain at rest w.r.t the wedge is :

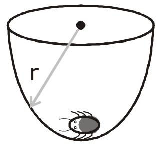
(A) μ g (B) $g\left(\frac{1+\mu}{1-\mu}\right)$

(C) $\frac{g}{\mu}$



(D) $g\left(\frac{1-\mu}{1+\mu}\right)$

51. If the coefficient of friction between an insect and bowl is μ and the radius of the bowl, is r, the maximum height to which the insect can crawl in the bowl is :



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

(C) $r\sqrt{1+\mu^2}$ (D) $r\sqrt{1+\mu^2}-1$

52. A block is placed on a rough floor and a horizontal force F is applied on it. The force of friction f by the floor on the block is measured for different values of F and a graph is plotted between them -

(a) The graph is a straight line of slope 45°

(b) The graph is straight line parallel to the F axis

(c) The graph is a straight line of slope 45° for small F and a straight line parallel to the F-axis for largeF.

(d) There is small kink on the graph

(A) c, d (B) a, d

(C) a, b (D) a, c

53. Mark the correct statements about the friction between two bodies -

(a) static friction is always greater than the kinetic friction

(b) coefficient of static friction is always greater than the coefficient of kinetic friction

(c) limiting friction is always greater than the kinetic friction

(d) limiting friction is never less than static friction

(A) b, c, d (B) a, b, c

(C) a, c, d (D) a, b, d

54. A body is placed on a rough inclined plane of inclination θ. As the angle θ is increased from 0° to 90° the contact force between the block and the plane

(A) remains constant

(B) first remains constant then decreases

(C) first decreases then increases

(D) first increases then decreases

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

(A) 0.7×9.8 Newton

(B) 9.8 Newton

(C) $0.7 \times 9.8\sqrt{3}$ Newton

(D) $9.8 \times \sqrt{3}$ Newton

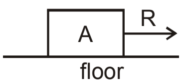
56. A body of mass m moves with a velocity v on a surface whose friction coefficient is μ. If the body covers a distance s then v will be :

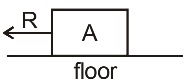
(A) $\sqrt{2\mu gs}$ (B) $\sqrt{\mu gs}$

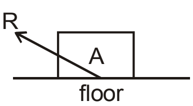
(C) $\sqrt{\mu gs/2}$ (D) $\sqrt{3\mu gs}$

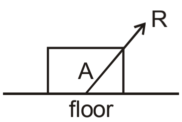
Section I - Direction of friction, Pulley Block system on horizontal plane

57. 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 reaction R by the floor on the box is given best by

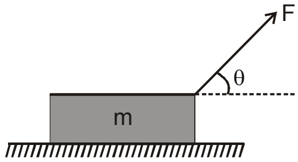
(A) 

(B) 

(C) 

(D) 

58. 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 :



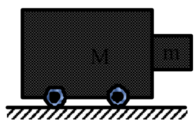
(A) $\frac{F\cos\theta}{m}$

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

(C) $\frac{F}{m}(\cos\theta + \mu\sin\theta) - \mu g$

(D) none

59. A cart of mass M has a block of mass m attached to it as shown in figure. The coefficient of friction between the block and cart is μ. The minimum acceleration of the cart so that the block m does not fall is ?



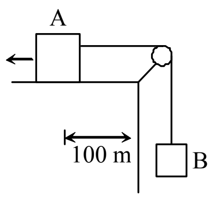
(A) g/μ

(B) μ/g

(C) μg

(D) Mμg/m

60. In the arrangement as shown, block A of mass 3 kg moves towards left with velocity 10 m/s. Initially block A is 100 m from pulley on a smooth surface. Block B is of mass 2 kg ($g = 10 m/s^2$) :



(A) At t = 1 sec, velocity of A will be 6 m/s towards left

(B) A will stop at t = 4.5 sec

(C) Block A will be at a distance 108 m from pulley at t = 5s

(D) Block A will again be a distance of 100 m from pulley at t = 10s

61. A body is projected up a 45° rough incline. If the coefficient of friction is 0.5, then the retardation of the block is

(A) $\frac{g}{2\sqrt{2}}$ (B) $\frac{g}{\sqrt{2}}$

(C) $\frac{3g}{2\sqrt{2}}$ (D) $\frac{g}{2}$

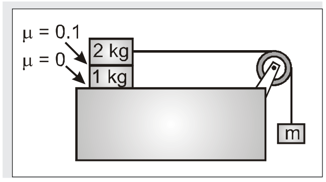
62. Mass of upper block and lower block kept over the table is 2 kg and 1 kg respectively and coefficient of friction between the blocks is 0.1. Table surface is smooth. The maximum mass M for which all the three blocks move with same acceleration is (g = 10 m/s^2) -

(A) 1 kg

(B) 2/3 kg

(C) 1/3 kg

(D) 3/4 kg



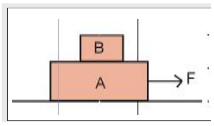
63. A body A of mass 1 kg rests on a smooth surface. Another body B of mass 0.2 kg is placed over A as shown. The coefficient of static friction between A and B is 0.15. B will begin to slide on A, if A is pulled with a force greater than

(A) 1.764 N

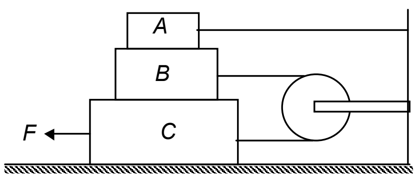
(B) 0.1764 N

(C) 0.3 N

(D) it will not slide for any F



64. In the figure shown, blocks A, B and C weigh 3 kg, 4 kg and 8 kg respectively. The coefficient of sliding friction between any two surfaces is 0.25. A is held at rest by a massless rigid rod fixed to the wall while B and C are connected by a string passing round a frictionless pulley. Find the force needed to drag C along the horizontal surface to left at constant speed.



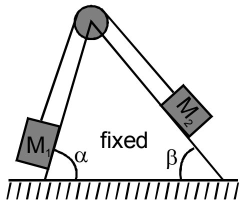
Assume the arrangement shown in figure is maintained all through. (g = 10 m/s^2)

(A) 75 (B) 80

(C) 85 (D) None of these

Section J - Pulley Block system on inclined plane

65. Two masses M_1 and M_2 are attached to the ends of a light string which passes over a massless pulley attached to the top of a double inclined smooth plane of angles of inclination α and β. The tension in the string is :



(A) $\frac{M_2(\sin\beta)g}{M_1+M_2}$ (B) $\frac{M_1(\sin\alpha)g}{M_1+M_2}$

(C) $\frac{M_1 M_2(\sin\beta+\sin\alpha)g}{M_1+M_2}$

(D) zero

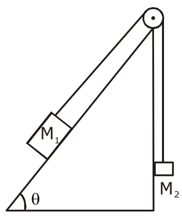
66. Two masses M_1 and M_2 are attached to the ends of a string which passes over a pulley attached to the top of an inclined plane. The angle of inclination of the plane is 30° and M_1 = 10 kg. M_2=5 kg. What is the acceleration of mass M_2 ?

(A) 10 m/s^2

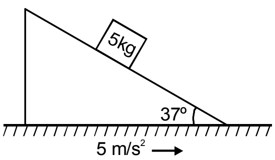
(B) 5 m/s^2

(C) Zero

(D) Data insufficient



67. Inclined plane is moved towards right with an acceleration of 5ms^{-2} as shown in figure. Find force in newton which block of mass 5 kg exerts on the incline plane. (All surfaces are smooth)



(A) 50 N (B) 60 N

(C) 55 N (D) 70 N

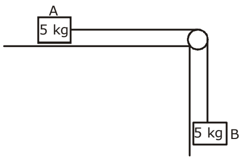
68. A block of mass 5 kg resting on a horizontal surface is connected by a cord, passing over a light frictionless pulley to a hanging block of mass 5 kg. The coefficient of kinetic friction between the block and the surface is 0.5. Tension in the cord is ($g = 9.8\ m/s^2$)

(A) 49 N

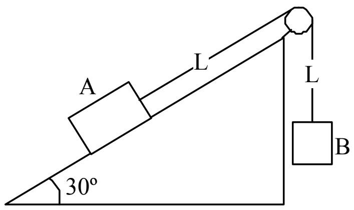
(B) Zero

(C) 36.75 N

(D) 12.75



69. In the arrangement as shown, when mass of block A is m_1 and mass of block B is m_2, time taken by m_1 to reach maximum height is 3 times the time taken by m_2 to reach maximum height, when block A is of mass m_2 and block B is of mass m_1. All ropes and pulleys are smooth and massless -



(A) The ratio of acceleration in first to second case is 2/9.

(B) The ratio of acceleration in first to second case is 9.

(C) The ratio of (m_1/m_2) is (19/11)

(D) The ratio of (m_1/m_2) is (4/3)

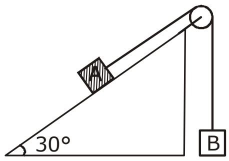
70. Two blocks are connected over a massless pulley as shown in figure. The mass of block A is 10 kg and the coefficient of kinetic friction is 0.2. Block A sliders down the incline at constant speed. The mass of block B in kg is

(A) 5.4

(B) 3.3

(C) 4.2

(D) 6.8



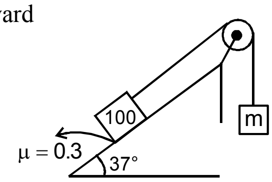
71. The value(s) of mass m for which the 100 kg block does not move upward

(A) 39 kg

(B) 40 kg

(C) 83 kg

(D) 85 kg



72. For the arrangement shown in the figure the tension in the string is

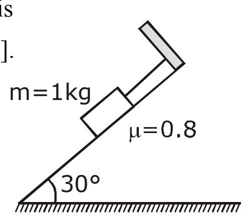
[Given: $\tan^{-1}(0.8) = 39°$].

(A) 6 N

(B) 6.4 N

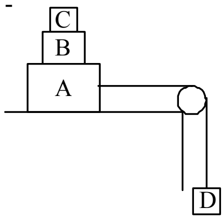
(C) 0.4 N

(D) zero



Section K - Two Block system, Two Block on Inclined plane

73. Three blocks A, B and C of equal mass m are placed on a smooth surface as shown. Coefficient of friction between any block A, B and C is μ. The maximum value of mass D so the block A, B & C move without slipping over each other is -



(A) $\frac{3m\mu}{\mu+1}$

(B) $\frac{3m(1-\mu)}{\mu}$

(C) $\frac{3m(1+\mu)}{\mu}$

(D) $\frac{3m\mu}{(1-\mu)}$

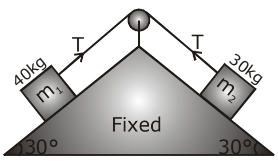
74. Two masses 40 kg and 30 kg connected by a massless string passing over a frintionless light pulley as shown in the figure. The tension (almost) in the string will be : (All surfaces are frictionless)

(A) 188 N

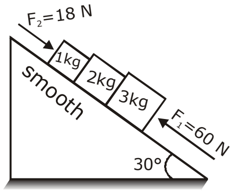
(B) 368 N

(C) 288 N

(D) 168 N



75. In the figure ($g = 10$ m/s^2). Acceleration of 2 kg block is :



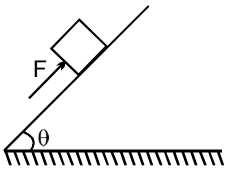
(A) 2 m/sec^2

(B) 4 m/sec^2

(C) 6 m/sec^2

(D) 8 m/sec^2

76. A block placed on a rough inclined plane of inclination ($\theta = 30°$) can just be pushed upwards by applying a force "F" as shown. If the angle of inclination of the inclined plane is increased to ($\theta = 60°$), the same block can just be prevented from sliding down by application of a force of same magnitude. The coefficient of friction between the block and the inclined plane is



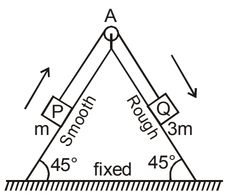
(A) $\frac{\sqrt{3}+1}{\sqrt{3}-1}$

(B) $\frac{2\sqrt{3}-1}{\sqrt{3}+1}$

(C) $\frac{\sqrt{3}-1}{\sqrt{3}+1}$

(D) none of these

77. 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 :



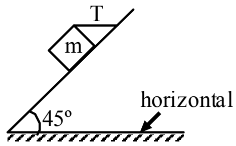
(A) mg

(B) $\frac{6mg}{5\sqrt{2}}$

(C) $\frac{mg}{2}$

(D) $\frac{mg}{4}$

78. 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)



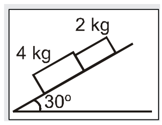
(A) 1/2

(B) 2/3

(C) 3/4

(D) ¼

79. Figure shows two blocks in contact sliding down an inclined surface of inclination 30°. The friction coefficient between the block of mass 2.0 kg and the incline is μ_1, and that between the block of mass 4.0 kg and the incline is μ_2. Calculate the acceleration of the 2.0 kg block if $\mu_1 = 0.30$ and $\mu_2 = 0.20$, Take $g = 10$ m/s^2



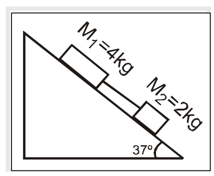
(A) 2 m/s^2

(B) 2.7 m/s^2

(C) 4 m/s^2

(D) 2.4 m/s^2

80. Two blocks connected by a massless string slide down an inclined plane having angle of inclination 37°. The masses of the two blocks are $M_1 = 4$ kg and $M_2 = 2$ kg respectively and the coefficients of friction 0.75 and 0.25 respectively –



(A) The common acceleration of the two masses is 1.3 ms^{-2}

(b) The tension in the string is 14.7 N

(c) The common acceleration of the two masses is 2.94 ms^{-2}

(d) The tension in the string is 5.29 N

(A) a, d

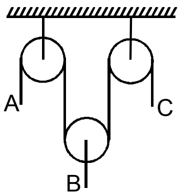
(B) c, d

(C) b, d

(D) b, c

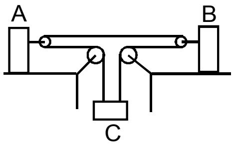
Section A - String Constrained, Wedge Constrained

1. The pulleys in the diagram are all smooth and light. The acceleration of A is a upwards and the acceleration of C is f downwards. The acceleration of B is



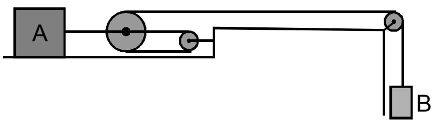
(A) 1/2 (f – a) up
(B) 1/2 (a + f) down
(C) 1/2 (a + f) up
(D) 1/2 (a – f) up

2. If acceleration of A is 2 m/s^2 to left and acceleration of B is 1 m/s^2 to left, then acceleration of C is -



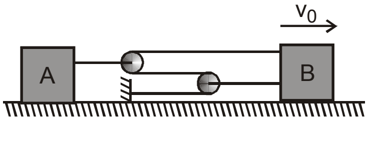
(A) 1 m/s^2 upwards
(B) 1 m/s^2 downwards
(C) 2 m/s^2 downwards
(D) 2 m/s^2 upwards

3. If block A has a velocity of 0.6 m/s to the right, determine the velocity of block B.



(A) 1.8 m/s in downward direction
(B) 1.8 m/s in upward direction
(C) 0.6 m/s in downward direction
(D) 0.6 m/s in upward direction

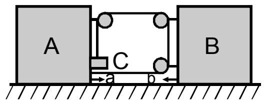
4. Block B moves to the right with a constant velocity v_0. The velocity of body A relative to B is :



(A) $\frac{v_0}{2}$, towards left (B) $\frac{v_0}{2}$, towards right

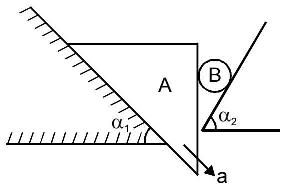
(C) $\frac{3v_0}{2}$, towards left (D) $\frac{3v_0}{2}$, towards right

5. Find the acceleration of C w.r.t. ground.



(A) $a\hat{i}-(2a+2b)\hat{j}$
(B) $a\hat{i}-(2a+b)\hat{j}$
(C) $a\hat{i}-(a+2b)\hat{j}$
(D) $b\hat{i}-(2a+2b)\hat{j}$

6. Find the acceleration of B..

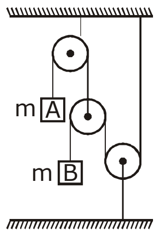


(A) $\frac{a\cos\alpha_1}{\cos\alpha_2}$

(B) $\frac{a\sin\alpha_1}{\cos\alpha_2}$

(C) $\frac{a\cos\alpha_2}{\cos\alpha_1}$ (D) $\frac{\cos\alpha_1}{\cos\alpha_2}$

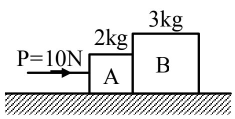
7. In the arrangement shown, the pulleys and the strings are ideal. The acceleration of block B is



(A) g/5
(B) g/2
(C) 2g/5
(D) 2g/3

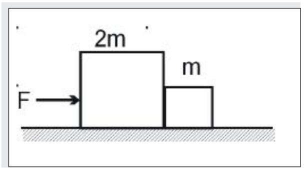
Section B - Newton's Law theory Question

8. Blocks A and B have masses 2 kg and 3 kg respectively. The ground is smooth. P is an external force of 10 N. The force exerted by B on A is-



(A) Attractive electromagnetic force
(B) Repulsive electromagnetic force
(C) Gravitation force (D) None of these

9. Two blocks are in contact on a frictionless table one has a mass m and the other 2m. A force F is applied on 2m as shown is Figure. Now the same force F is applied on m. In the two cases respectively the ratio of force of contact between the two blocks will be-



(A) 1 : 1 (B) 1 : 2

(C) 1 : 3 (D) 1 : 4

10. A man getting down a running bus, falls forward because-

(A) due to inertia of rest, road is left behind and man reaches forward

(B) due to inertia of motion upper part of body continues to be in motion in forward direction while feet come to rest as soon as they touch the road

(C) he leans forward as a matter of habbit

(D) of the combined effect of all the three factors stated in (A), (B) and (C)

11. If the tension in the cable supporting an elevator is equal to the weight of the elevator, the elevator may be -

(a) going up with increasing speed

(b) going down with increasing speed

(c) going up with uniform speed

(d) going down with uniform speed

(A) a, d (B) a, b, c

(C) c, d (D) a, b

12. When a body is stationary :

(A) there is no force acting on it

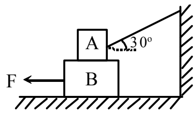
(B) the forces acting on its are not in contact with it

(C) the combination of forces acting on it balance each other

(D) the body is in vaccuum

Section C - Equillibrium Questions (Normal and Tension), Problems with Acceleration (F=ma)

13. In the figure given below, if all surface are assumed to be smooth and the force F = 100 N. If acceleration of block B of mass 20 kg is 'a' and tension in string connecting block A of mass 20 kg is T,then just after when the force F is applied.



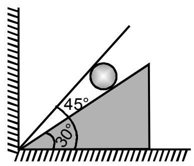
(A) T = 0 and a = 5m/s^2

(B) T = 100 N and a = 0

(C) T = 200 N and a = 5 m/s^2

(D) None

14. A sperical ball of mass m = 5 kg rests between two planes which make angles of 30° and 45° respectively with the horizontal. The system is in equilibrium. Find the normal forces exerted on the ball by each of the planes. The planes are smooth.



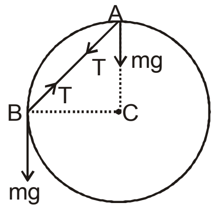
(A) N_{45} = 96.59 N, N_{30} = 136.6 N

(B) N_{30} = 96.59 N, N_{45} = 136.6 N

(C) N_{45} = 136.6 N, N_{30} = 96.56 N

(D) none of these

15. Objects A and B each of mass m are connected by light inextensible cord. They are constrained to move on a frictionless ring in a vertical plane as shown in figure. The objects are released from rest at the positions shown. The tension in the cord just after release will be

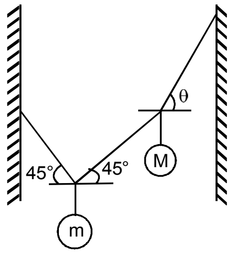


(A) $mg\sqrt{2}$

(B) $\frac{mg}{\sqrt{2}}$

(C) $\frac{mg}{2}$ (D) $\frac{mg}{4}$

16. Two masses m and M are attached to the strings as shown in the figure. If the system is in equilibrium, then

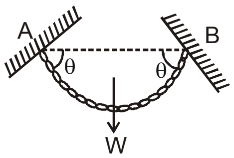


(A) $\tan\theta = 1 + \frac{2M}{m}$

(B) $\tan\theta = 1 + \frac{2m}{M}$

(C) $\cot\theta = 1 + \frac{2M}{m}$ (D) $\cot\theta = 1 + \frac{2m}{M}$

17. A flexible chain of weight W hangs between two fixed points A & B which are at the same horizontal level. The inclination of the chain with the horizontal at both the points of support is θ. What is the tension of the chain at the mid point ?

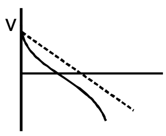


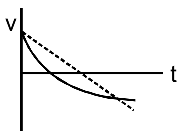
(A) $\frac{W}{2}.\text{cosec}\,\theta$

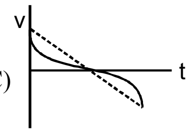
(B) $\frac{W}{2}.\tan\theta$

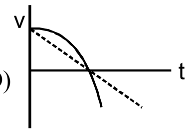
(C) $\frac{W}{2}.\cot\theta$ (D) none

18. Which graph shows best the velocity-time graph for an object launched vertically into the air when air resistance is given by $|D| = bv$? The dashed line shows the velocity graph if there were no air resistance.

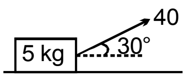
(A) 

(B) 

(C) 

(D) 

19. Adjoining figure shows a force of 40 N acting at 30° to the horizontal on a body of mass 5 kg resting on a smooth horizontal surface. Assuming that the acceleration of free-fall is 10 ms^{-2}, which of the following statements A, B, C, D, E is (are) correct?

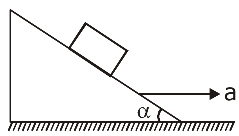


(1) The horizontal force acting on the body is 20 N
(2) The weight of the 5 kg mass acts vertically downwards
(3) The net vertical force acting on the body is 30 N

(A) 1, 2, 3 (B) 1, 2
(C) 2 only (D) 1 only

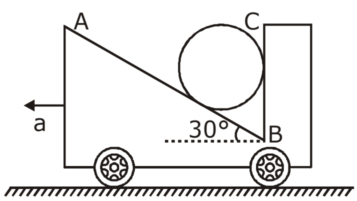
Section D - Wedge problems

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



(A) g
(B) g tan α
(C) g/tan α
(D) g cosec α

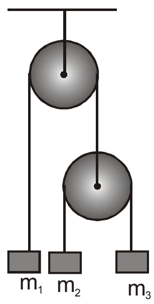
21. A cylinder rests in a supporting carriage as shown. The side AB of carriage makes an angle 30° with the horizontal and side BC is vertical. The carriage lies on a fixed horizontal surface and is being pulled towards left with an horizontal acceleration 'a'. The magnitude of normal reactions exerted by sides AB and BC of carriage on the cylinder be N_{AB} and N_{BC} respectively. Neglect friction everywhere. Then as the magnitude of acceleration 'a' of the carriage is increased, pick up the correct statement:



(A) N_{AB} increases and N_{BC} decreases.
(B) Both N_{AB} and N_{BC} increases.
(C) N_{AB} remains constant and N_{BC} increases.
(D) N_{AB} increases and N_{BC} remains constant.

Section E - Pulley Block system

22. In the arrangement shown in figure, pulleys are massless and frictionless and threads are inextensible. The Block of mass m_1 will remain at rest, if



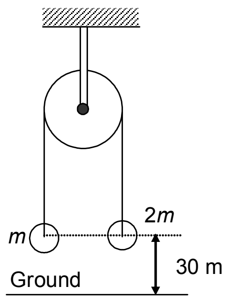
(A) $\frac{1}{m_1} = \frac{1}{m_2} + \frac{1}{m_3}$

(B) $m_1 = m_2 + m_3$

(C) $\frac{4}{m_1} = \frac{1}{m_2} + \frac{1}{m_3}$

(D) $\frac{1}{m_3} = \frac{2}{m_2} + \frac{3}{m_1}$

23. Two masses m and 2m are connected by a massless string, which passes over a pulley as shown in figure. The masses are held initially with equal lengths of the strings on either side of the pulley. Find the velocity of masses at the instant the lighter mass moves up a distance of 15m. ($g = 10\ m/s^2$)



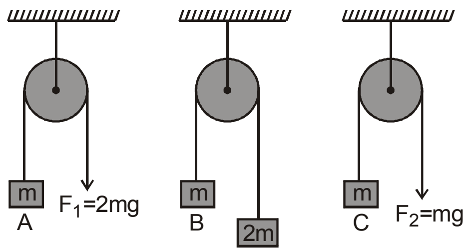
(A) 8

(B) 10

(C) 12

(D) 15

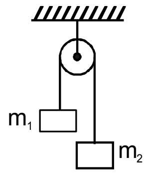
24. In the figure, the blocks A, B and c of mass m each have acceleration a_1. a_2 and a_3 respectively. F_1 and F_2 are external forces of magnitudes 2 mg and mg respectively.



(A) $a_1 = a_2 = a_3$ (B) $a_1 > a_2 > a_3$

(C) $a_1 = a_2, a_2 > a_3$ (D) $a_1 > a_2 , a_2 = a_3$

25. A student calculates the acceleration of m_1 in figure shown as $a_1 = \frac{(m_1 - m_2)g}{m_1 + m_2}$. Which assumption is not required to do this calculation.



(A) pulley is frictionless

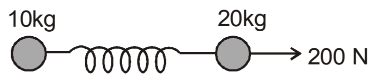
(B) string is massless

(C) pulley is massless

(D) string is inextensible

Section F - Spring force and spring cutting problems

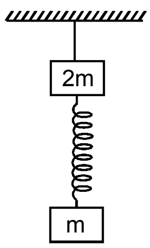
26. Two masses of 10 kg and 20 kg respectively are connected by a massless spring as shown in figure. A force of 200 N acts on the 20 kg mass at the instant when the 10 kg mass has an acceleration of 12 ms^{-2} towards right, the aceleration of the 20 kg mass is :



(A) 2 ms^{-2} (B) 4 ms^{-2}

(C) 10 ms^{-2} (D) 20 ms^{-2}

27. Two blocks are connected by a spring. The combination is suspended, at rest, from a string attatched to the ceiling, as shown in the figure. The string breaks suddenly. Immediately after the string breaks, what is the initial downward acceleration of the upper block of mass 2m ?

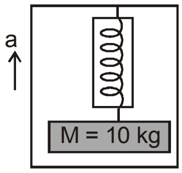


(A) 0 (B) 3g/2

(C) g (D) 2g

28. What will be the reading of spring balance in the figure shown in following situations.

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



(i) $a = 0, v = 0$

(A) 100 N (B) 80 N
(C) 120 N (D) 150 N

(ii) $a = 0, v = 2$ m/s

(A) 100 N (B) 80 N
(C) 120 N (D) 150 N

(iii) $a = 0, v = -2$m/s

(A) 100 N (B) 80 N
(C) 120 N (D) 150 N

(iv) $a = 2\ m/s^2, v = 0$

(A) 100 N (B) 80 N
(C) 120 N (D) 150 N

(v) $a = -2m/s^2, v = 0$

(A) 100 N (B) 80 N
(C) 120 N (D) 150 N

(vi) $a = 2\ m/s^2, v = 2$ m/s

(A) 100 N (B) 80 N
(C) 120 N (D) 150 N

(vii) $a = 2\ m/s^2, v = -2$m/s

(A) 100 N (B) 80 N
(C) 120 N (D) 150 N

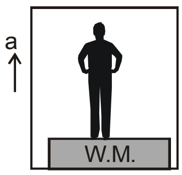
(viii) $a = -2\ m/s^2, v = -2$ m/s

(A) 100 N (B) 80 N
(C) 120 N (D) 150 N

Section G - Pseudo force, Weighing Machine

29. A man of mass 60 kg is standing on a weighing machine placed in a lift moving with velocity 'v' and acceleration 'a' as shown in figure. Calculate the reading of weighing machine in following situation:

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



(i) $a = 0, v = 0$

(A) 600 N (B) 500 N
(C) 450 N (D) 700 N

(ii) $a = 0, v = 2$m/s

(A) 600 N (B) 500 N
(C) 450 N (D) 700 N

(iii) $a = 0, v = -2$m/s

(A) 450 N (B) 500 N
(C) 600 N (D) 700 N

(iv) $a = 2m/s^2, v = 0$

(A) 600 N (B) 500 N
(C) 450 N (D) 720 N

(v) $a = -2m/s^2, v = 0$

(A) 600 N (B) 480 N
(C) 450 N (D) 700 N

(vi) $a = 2m/s^2, v = 2$m/s

(A) 600 N (B) 480 N
(C) 450 N (D) 720 N

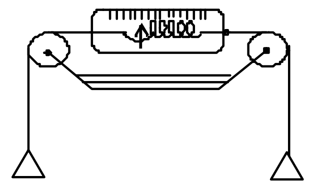
(vii) $a = 2\ m/s^2, v = -2$m/s

(A) 600 N (B) 720 N
(C) 450 N (D) 700 N

(viii) $a = -2m/s^2, v = -2$ m/s

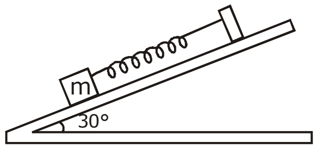
(A) 600 N (B) 480 N
(C) 450 N (D) 700 N

30. Two weights of 15 kg each are attached by means of two strings to the two ends of a spring balance, as shown in the diagram. The pulleys are frictionless. The reading of the balance would be-



(A) zero (B) 15 kg
(C) 30 kg (D) 75 kg

31. A body of mass 5 kg is suspended by a spring balance on an inclined plane as shown in figure. The spring balance measure

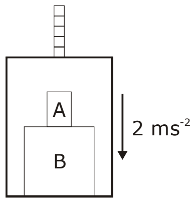


(A) 50 N (B) 25 N

(C) 500 N (D) 10 N

32. The elevator shown in figure is descending with an acceleration of 2 ms^{-2}. The mass of the block A = 0.5 kg. The force exerted by the block A on the block B is :

Take g = 10 m/s^2.



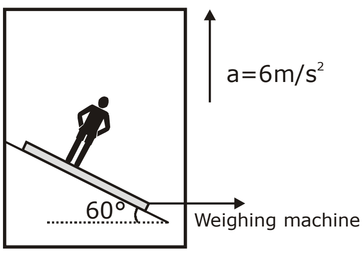
(A) 2 N

(B) 4 N

(C) 6 N

(D) 8 N

33. An elevator is accelerating upwards with a acceleration of 6 m/s^2. Inside it a person of mass 50 kg is standing on a weighing machine which is kept on an inclined plane having angle of inclination 60°. The reading of the weighing machine is :

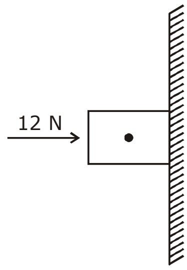


(A) 40 kg (B) 160 kg

(C) 80 kg (D) 50 kg

Section H - Static friction, Kinetic friction

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



(A) 12 N

(B) 5 N

(C) 7.2 N

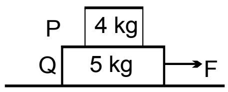
(D) 13 N

35. A body of mass 2 kg is at rest on a horizontal table. The coefficient of friction between the body and the table is 0.3. A force of 5 N is appliedon the body. The acceleration of the body is

(A) 0 ms^{-2} (B) 2.5 ms^{-2}

(C) 5 ms^{-2} (D) 7.5 ms^{-2}

36. The coefficient of friction between 4 kg 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 17N

(B) When force is 4N static friction at all surfaces is 4 N to keep system at rest.

(C) Maximum acceleration of 4 kg block is 2 m/s^2

(D) Slipping between 4 kg and 5 kg blocks start when F is 17 N

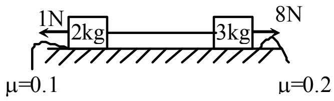
37. A body is moving down a long inclined plane of slope 37º. The coefficient of friction between the body and plane varies as $\mu = 0.3\,x$, where x is distance travelled down the plane. The body will have maximum speed.

($\sin 37° = \frac{3}{5}$ and g = 10 m/s^2)

(A) at x = 1.16 m (B) at x = 2m

(C) at bottom of plane (D) at x = 2.5 m

38. In the shown arrangement if f_1, f_2 and T be the frictional forces on 2 kg block, 3kg block and tension in the string respectively, then their values are:

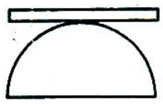


(A) 2N, 6N, 3.2 N (B) 2N, 6N, 0N

(C) 1N, 6N, 2N

(D) Data insufficient to calculate the required values

39. A board is balanced on a rough horizontal semicircular log. Equilibrium is obtained with the help of addition of a weight to one of the ends of the board when the board makes an angle θ with the horizontal. Coefficient of friction between the log and the board is



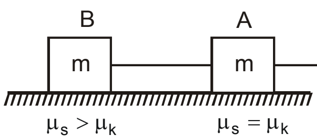
(A) tan θ

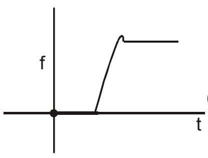
(B) cos θ

(C) cot θ

(D) sin θ

40. 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 a time 't'.



(A)


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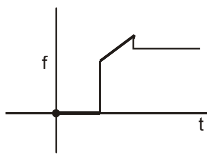
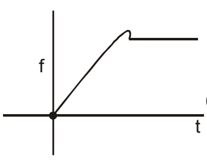


(C)


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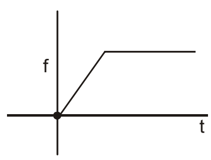
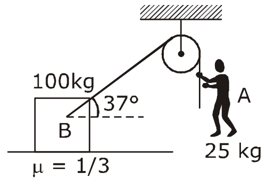


Section I - Direction of friction, Pulley Block system on horizontal plane

41. Block B of mass 100 kg rests on a rough surface of friction coefficient $\mu = 1/3$. A rope is tied to block B as shown in figure. The maximum acceleration with which boy A of 25 kg can climbs on rope without making block move is

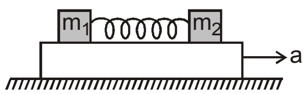


(A) $\frac{4g}{3}$

(B) $\frac{g}{3}$

(C) $\frac{g}{2}$ (D) $\frac{3g}{4}$

42. Two blocks of masses m_1 and m_2 are connected with a massless unstretched 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.



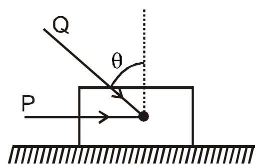
(A) spring will be stretched if $a > \mu g$

(B) spring will be compressed if $a \leq \mu g$

(C) spring will neither be compressed nor be stretched for $a \leq \mu g$

(D) spring will be in its natural length under all conditions.

43. 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 :

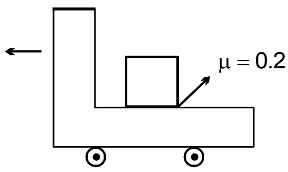


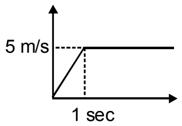
(A) $\frac{P+Q\sin\theta}{mg+Q\cos\theta}$

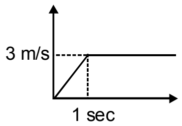
(B) $\frac{P\cos\theta+Q}{mg-Q\sin\theta}$

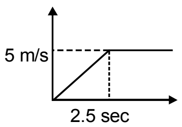
(C) $\frac{P+Q\cos\theta}{mg+Q\sin\theta}$ (D) $\frac{P\sin\theta-Q}{mg-Q\cos\theta}$

44. A truck starting from rest moves with an acceleration of 5 m/s^2 for 1 sec and then moves with constant velocity. The velocity w.r.t. ground v/s time graph for block in truck is (Assume that block does not fall off the truck)



(A) 

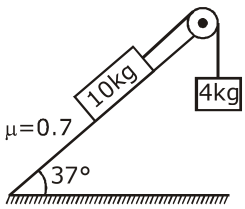
(B) 

(C) 

(D) None of these

Section J - Pulley Block system on inclined plane

45. In the arrangement shown in the figure [sin 37° = 3/5]



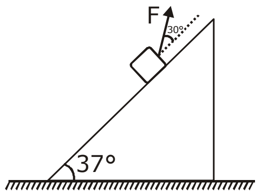
(A) direction of force of friction is up the plane

(B) the magnitude of force of friction is zero.

(C) the tension in the string is 20 N.

(D) magnitude of force of friction is 56 N

46. A block of mass m = 4 kg is placed over a rough inclined plane as shown in figure. The coefficient of friction between the block and the plane is $\mu = 0.5$. A force F = 10 N is applied on the block at an angle of 30°. The friction force between the block and wedge is



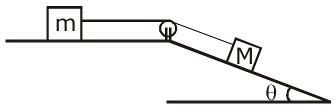
(A) static in nature in the direction up the plane and have the value 30.2 N.

(B) static in nature in the direction down the plane and have the value of 30.2 n

(C) kinetic in nature in the direction up the plane and have the v alue 13.5 N.

(D) None of these

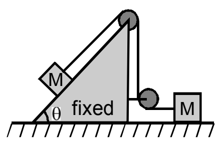
47. Find the maximum value of (M/m) in the situation shown in figure so that the system remains at rest. Friction coefficient of both the contacts is μ, string is massless and pulley is friction less.



(A) $\dfrac{\cos\theta}{\sin\theta - \mu\cos\theta}$ (B) $\dfrac{\sin\theta}{\sin\theta - \mu\cos\theta}$

(C) $\dfrac{\mu\cos\theta}{\sin\theta - \mu\cos\theta}$ (D) $\dfrac{\mu}{\sin\theta - \mu\cos\theta}$

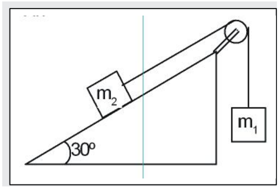
48. Two blocks, each having mass M rest on frictionless surfaces as shown in the figure. If the pulleys are light and frictionless, and M on the incline is allowed to move down, then the tension in the string will be



(A) $\frac{2}{3}\text{Mg}\sin\theta$ (B) $\frac{3}{2}\text{Mg}\sin\theta$

(C) $\dfrac{\text{Mg}\sin\theta}{2}$ (D) 2 Mg sin θ

49. Two masses m_1 and m_2 are connected by light string, which passes over the top of a smooth plane inclined at 30º to the horizontal, so that one mass rests on the plane and the other hangs vertically as shown in fig. It is found that m_1, hanging vertically can draw m_2 up the full length of the plane in half the time in which m_2 hanging vertically draws m_1 up. Find m_1/m_2 . Assume pulley to be smooth –

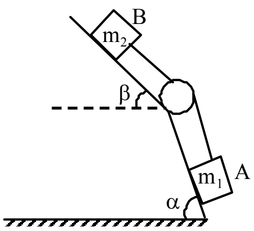


(A) $\frac{2}{3}$

(B) $\frac{3}{2}$

(C) $\frac{4}{7}$ (D) $\frac{7}{4}$

50. Two blocks A and B of masses m_1 and m_2 are connected by an inextensible string rest on two smooth planes inclined at angle α and β as shown. The tension in string is-



(A) $(m_1 \sin\alpha - m_2 \sin\beta)\, g$

(B) $(m_1 + m_2)(\sin\alpha - \sin\beta) g$

(C) $\frac{m_1 m_2 g}{m_1 + m_2}(\sin\alpha + \sin\beta)$

(D) $\frac{m_1 m_2 g}{m_1 + m_2}(\sin\alpha - \sin\beta)$

Section K - Two Block system, Two Block on Inclined plane

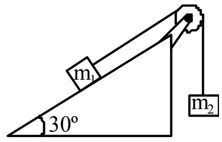
51. A block of mass m_1 = 2 kg on a smooth inclined plane at angle 30º is connected to a second block of mass m_2 = 3 kg by a cord passing over a frictionless pulley as shown in figure. The acceleration of each block is – (Assume g = 10 m/sec^2)

(A) 2 m/sec^2

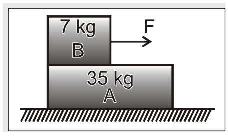
(B) 4 m/sec^2

(C) 6 m/sec^2

(D) 8 m/sec^2



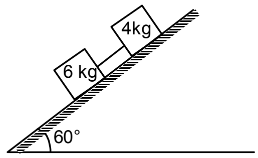
52. Block A of mass 35 kg is resting on a frictionless floor. Another block B of mass 7 kg is resting on it as shown in the figure. The coefficient of friction between the blocks is 0.5 while kinetic friction is 0.4. If a force of 100 N is applied to block B, the acceleration of the block A will be (g = 10 m s^{-2}) :



(A) 0.8 m s^{-2} (B) 2.4 m s^{-2}

(C) 0.4 m s^{-2} (D) 4.4 m s^{-2}

53. Two masses 6 kg and 4 kg are connected by a flexible inextensible string rest on an inclined plane inclined at 60° with the horizontal as shown in figure. The coefficient of friction between the plane and the 6 kg mass is 0.1 and that between the plane and the 4 kg mass is 0.6.



Find the tension in the connecting string.

(A) 2 N (B) 3 N

(C) 5 N (D) 6 N

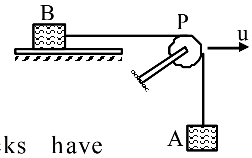
54. Block A and B in the figure are connected by a bar of negligible weight. Mass of each block is 170 kg and μ_A = 0.2 and μ_B = 0.4, where μ_A and μ_B are the coefficients of limiting friction between blocks and plane. Calculate the force developed in the bar (g=10 m/sec^2):

(A) 150 N (B) 75 N

(C) 200 N (D) 250 N

Section A - String Constrained, Wedge Constrained

1. In the figure, the pulley P moves to the right with a constant speed u. The downward speed of A is v_A, and the speed of B to the right is v_B. Then -



(A) $v_B = v_A$

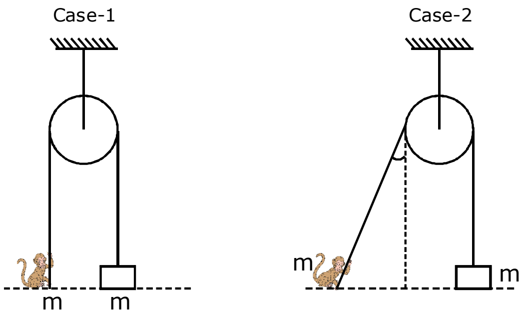
(B) $v_B = u + v_A$

(C) $v_B + u = v_A$

(D) the two blocks have accelerations of the same magnitude

Section B - Newton's Law theory Question

2. In both the cases block & monkey are at the same horizontal level. In both the cases monkey climbs the rope. In case-1 rope remains vertical & in case-2 rope swings during motion. t_1 & t_2 are times taken by monkeys to reach the pulley in case-1 & case-2 respectively. In both cases, monkey applies the same force on the rope.



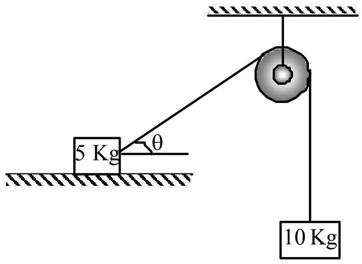
(A) $t_1 = t_2$ (B) $t_1 < t_2$

(C) In case-2, block reaches the pulley earlier than monkey

(D) In case-1, monkey reaches the pulley earlier than block

3. In the arrangement shown pulley is ideal and string is massless. 5 kg block is moving on the smooth surface. When θ is 37º, then acceleration of 5 kg and 10 kg blocks are a_1 and a_2 while tension in string is T then :

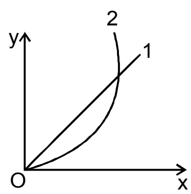
($g = 10\ m/s^2$)



(A) $4a_1 = 5a_2$ (B) $5a_1 = 4a_2$

(C) T = 43.86 N(D) T = 58.14 N

4. A particle is resting on a smooth horizontal floor. At t = 0, a horizontal force starts acting on it. Magnitude of the force increases with time according to law $F = \alpha.t$, where α is a constant. For the figure shown which of the following statements is/are correct?



(A) Curve 1 shows acceleration against time

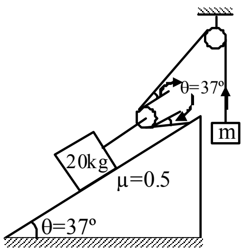
(B) Curve 2 shows velocity against time

(C) Curve 2 shows velocity against acceleration

(D) none of these

Section C - Equillibrium Questions (Normal and Tension), Problems with Acceleration (F=ma)

5. As shown in figure pulley is ideal and strings are massless. If mass m of hanging block is the minimum mass to set the equilibrium of system, then -



(A) m = 2.5 kg

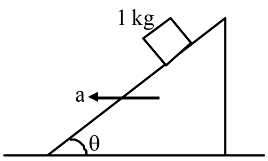
(B) m = 5 kg

(C) force applied by 20 kg block on inclined plane is 179 N

(D) force applied by 20 kg block on inclined plane is 223 N

Section D - Wedge problems

6. A block of mass 1 kg is at rest relative to a smooth wedge moving leftwards with constant acceleration a = 5 m/s². Let N be the normal reaction between the block and the wedge. Then- (g = 10 m/s²)



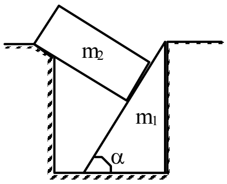
(A) $N = 5\sqrt{5}$ N

(B) N = 15 N

(C) $\tan\theta = \frac{1}{2}$

(D) $\tan\theta = 2$

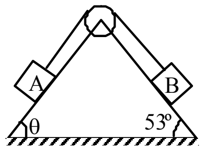
7. A wedge of mass m_1 and a block of mass m_2 are in equilibrium as shown. Inclined surface of the wedge has an inclination α with the horizontal. Each surface is frictionless. The normal reaction on the wedge may be -



(A) $m_2 g \cos\alpha$ (B) $m_2 g \sin\alpha \cos\alpha$

(C) $m_1 g + m_2 g \cos^2\alpha$ (D) $m_1 g + m_2 g \sin\alpha\cos\alpha$

8. As shown in figure two blocks A and B of mass 1kg each are connected by an ideal string that passes over a smooth pulley that is fixed on a smooth fixed wedge as shown. If the ratio of normal reaction on block A and on block B is $\frac{4}{3}$ then –



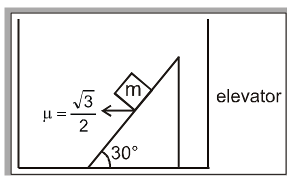
(A) $\cos\theta = \frac{4}{5}$

(B) $\sin\theta = \frac{4}{5}$

(C) acceleration of blocks is $\frac{g}{10}$ m/s²

(D) acceleration of blocks is $\frac{g}{5}$ m/s²

9. A block of mass 1 kg is placed on a rough wedge which is fixed on an elevator going upward with acceleration 2 ms⁻². The block is at rest with respect to the wedge.



Select the correct alternative (take g=10 ms⁻²)

(A) Normal reaction force on the block is $6\sqrt{3}$N

(B) Net reaction force acting on the block is 12 N

(C) Net force on the block is zero

(D) Net force on the block is 2 N

(g=10 ms⁻²)

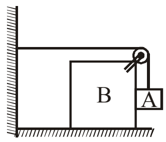
Section E - Pulley Block system

10. In the system shown in the diagram all surfaces are smooth, pulley and strings are ideal. If $\vec{a}_A$ and $\vec{a}_B$ are the accelerations of the two blocks, then just after the system is released from rest, then choose correct statement(s) :

(A) $|\vec{a}_A| = |\vec{a}_B|$

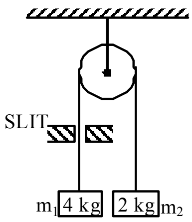
(B) $\vec{a}_A \perp \vec{a}_B$

(C) Acceleration of A relative to B is vertically downwards.



(D) Normal force exerted by B on A is zero.

11. Two masses $m_1 = 4$ kg and $m_2 = 2$ kg 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/s^2)



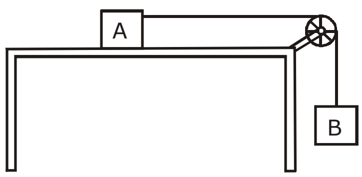
(A) Acceleration of mass m_1 is $\frac{5}{3}$ m/s^2, downwards

(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 position of both the masses are interchanged, then 2 kg mass moves up with an acceleration $\frac{10}{3}$ m/s^2

12. A block A of mass 7 kg is placed on a frictionless table. A thread tied to it passes over a frictionless pulley and carries a body B of mass 3 kg at the other end. The acceleration of the system is (given g = 10 ms^{-2})

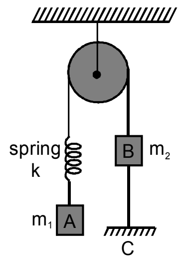


(A) 100 ms^{-2} (B) 3 ms^{-2}

(C) 10 ms^{-2} (D) 30 ms^{-2}

Section F - Spring force and spring cutting problems

13. In the system shown in the figure $m_1 > m_2$. System is held at rest by thread BC. Just after the thread BC is burnt :



(A) acceleration of m_2 will be upwards

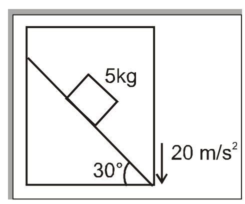
(B) magnitude of acceleration of both blocks will be equal to $\left(\frac{m_1 - m_2}{m_1 + m_2}\right)g$

(C) acceleration of m_1 will be equal to zero

(D) magnitude of acceleration of two blocks will be non-zero and unequal.

Section G - Pseudo force, Weighing Machine

14. A lift starts moving down with 20 m/s^2. Then which of the following is not true ?



(A) Acceleration of 5 kg block along incline is 15 m/s^2

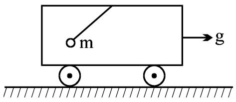
(B) Normal force is $25\sqrt{3}$ and acceleration is 5 m/s^2 along incline

(C) Normal force is zero

(D) Acceleration of 5 kg is 20 m/s^2 downwards

15. Select the correct alternative(s).

(A) A cart moving on a horizontal plane with a constant acceleration g has a mass m attached from its top with a string. Then the constant angle formed by the string with the vertical is 45°.



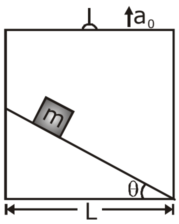
(B) In the above case instead of string if their is spring, then also the constant angle remains the same.

(C) When the same cart moves over a smooth incline of angle 45° with constant speed then the constant angle formed by the string with the line perpendicular to the roof of the cart is 45°.

(D) When the same cart is coming freely down a smooth incline, constant angle formed by the string with the line perpendicular to the roof is 0°.

16. A particle slides down a smooth inclined plane of elevation θ fixed in a elevator going up with an acceleration a_0. The base of the inline has a lenght L.

(A) The acceleration of particle with respect to the incline plane is $(g + a_0) \cos \theta$



(B) The time taken by the particle to reach the bottom $\left(\frac{2L}{(g+a_0)\sin\theta}\right)^{1/2}$.

(C) The acceleration of particle with respect to the incline plane is $(g + a_0) \sin \theta$

(D) The time taken by the particle to reach the bottom $\left(\frac{2L}{(g+a_0)\sin\theta}\right)^{2}$.

Section H - Static friction, Kinetic friction

17. Which of the following is true?

(A) Static friction is always greater than kinetic friction

(B) Friction can not accelerate a body in ground frame

(C) For identical surfaces in contact coefficient of static friction > coefficient of sliding friction

(D) Friction is component of total contact force parallel to surface of contact

Section I - Direction of friction, Pulley Block system on horizontal plane

18. A block of mass 2.5 kg is kept on a rough horizontal surface. It is found that the block does not slide if a horizontal force less than 15 N is applied to it. Also it is if found that it takes 5 second to slide throughout the first 10 m if a horizontal force of 15 N is applied and the block is gently pushed to start the motion. Taking g = 10 m/s^2, then

(A) $\mu_s = 0.60$ (B) $\mu_k = 0.52$

(C) $\mu_k = 0.60$ (D) $\mu_s = 0.52$

19. The contact force exerted by one body on another body is equal to the normal force between the bodies. It can be said that :

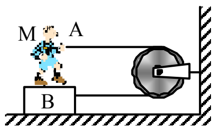
(A) the surface must be frictionless

(B) the force of friction between the bodies 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.

20. As shown in the figure, M is a man of mass 60 kg standing on a block of mass 40 kg kept on ground. The coefficient of friction between the feet of the man and the block is 0.3 and that between B and the ground is 0.2. If the person pulls the string with 125 N force, then –



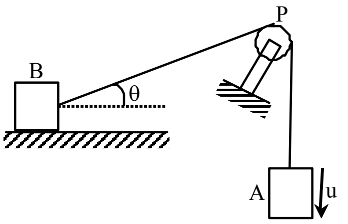
(A) B will slide on ground

(B) A and B will move with acceleration 0.5 m/s^2

(C) the force of friction acting between A and B will be 40 N

(D) the force of friction acting between A and B will be 180 N

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



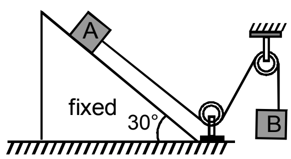
(A) B will never lose contact with the ground

(B) The downward acceleration of A is equal in magnitude to the horizontal acceleration of B.

(C) $v_B = u\cos\theta$ (D) $v_B = u/\cos\theta$

Section J - Pulley Block system on inclined plane

22. Two blocks A and B of equal mass m are connected through a massless string and arranged as shown in figure. Friction is absent everywhere. When the system is released from rest.



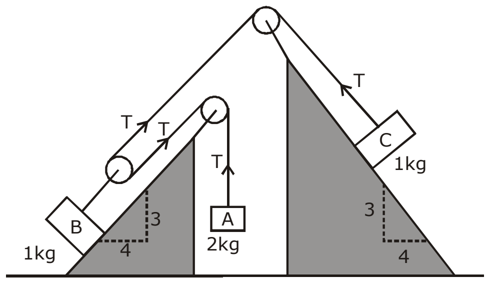
(A) tension in string is $\frac{mg}{2}$

(B) tension in string is $\frac{mg}{4}$

(C) acceleration of A is g/2

(D) acceleration of A is $\frac{3}{4}g$

23. In the system of connected bodies in the adjoining figure. The surface are smooth. Determine the acceleration of each body and the tension in the chord supporting A.



(A) Acceleration of Block C is $\frac{10}{11}$ m/sec^2

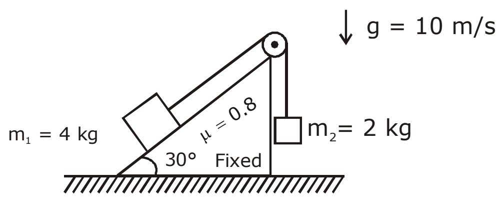
(B) Tension n the string is $\frac{56}{11}$ N

(C) Acceleration of Block B is $\frac{10}{11}$ m/sec^2

(D) Tension n the string is $\frac{28}{11}$ N

Section K - Two Block system, Two Block on Inclined plane

24. Two block of masses m_1 and m_2 are connected through a massless inextensible string. Block of mass m_1 is placed at the fixed rigid inclined surface while the block of mass m_2 hanging at the other end of the string, which is passing through a fixed massless frictionless pulley shown in the figure. The coefficient of static friction between the block and the inclined plane is 0.8. The system of masses m_1 and m_2 is released from rest.



(A) the tension in the string is 20 N after releasing the system

(B) the contact force by the inclined surface on the block is along normal to the inclined surface

(C) the magnitude of contacct force by the inclined surface on the block m_1 is $20\sqrt{3}$ N

(D) none of these

25. A large block A is at rest on a smooth horizontal surface . A small block B having a mass half of that of A is placed over A at one end. B is projected along with velocity u. The coefficient of friction between the blocks is μ.

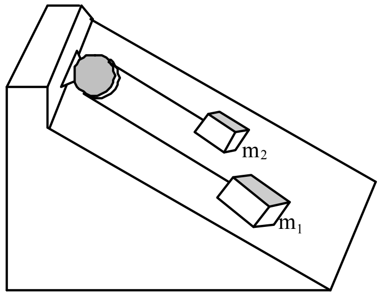
(A) The blocks will reach a common velocity $\mu/3$.

(B) Work done against friction is 2/3 of the initial kinetic energy.

(C) Before the blocks reach a common velocity then acceleration of A relative to B is $\frac{2}{3}\mu g$.

(D) Before the blocks reach a common velocity then acceleration of A relative to B is $\frac{3}{2}\mu g$.

26. Two blocks on a rough incline are connected by a light string that passes over a frictionless light pulley as shown. Assuming $m_1 > m_2$ and taking the coefficient of kinetic friction for each block to be μ we get acceleration of the blocks as–



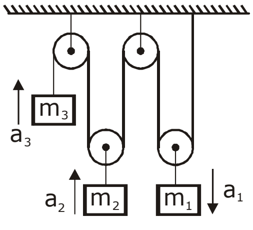
(A) $a = \dfrac{[(m_1 - m_2)\sin\theta - \mu(m_1 + m_2)\cos\theta]g}{(m_1 + m_2)}$ for m_1

(B) $a = \dfrac{[\mu(m_1 + m_2)\cos\theta - (m_1 - m_2)\sin\theta]g}{(m_1 + m_2)}$ for m_2

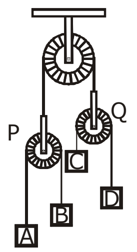
(C) $a = g(\sin\theta - \mu\cos\theta)$ (D) $a = g(\cos\theta - \mu\sin\theta)$

Section A - String Constrained, Wedge Constrained

1. If the blocks are moving as shown in the figure. Given that a_1 = 1 metre/sec^2 and a_2 = 4 metre/sec^2 find value of a_3.



2. In the figure acceleration of A is 1 m/s^2 upward, acceleration of B is 7 m/s^2 upwards and acceleratio of C is 2 m/s^2 upwards. Find the acceleration of D ?



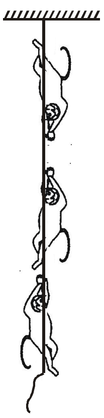
Section B - Newton's Law theory Question

3. A 2 kg block is pulled horizontally by F force which is placed on along smooth horizontal table. It is displaced by 10 metre in 2 seconds. Find the value of F.

Section C - Equillibrium Questions (Normal and Tension), Problems with Acceleration (F=ma)

4. Three monkeys A, B, and C with masses of 10, 15 & 8 kg respectively are climbing up & down the rope suspended from D. at the instant represented, A is descending the rope with an acceleration of 2 m/s^2 & C is pulling himself up with an acceleration of 1.5 m/s^2. Monkeys B is climbing up with a constant speed of 0.8 m/s. Treat the rope and monkeys as a complete system & calculate the tension T in the rope at D.

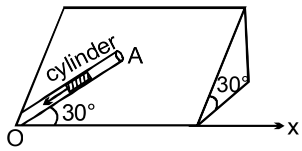
(g = 10 m/s^{-2})



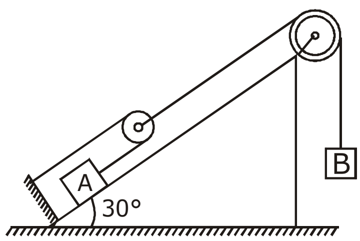
Section D - Wedge problems

5. An inclined plane makes an angle 30º with the horizontal. A groove OA = 5 m cut in the plane makes an angle 30º with OX. A short smooth cylinder is free to slide down the influence of gravity. Find the time taken by the cylinder to due to reach from A to O.

(g = 10 m/s^2)

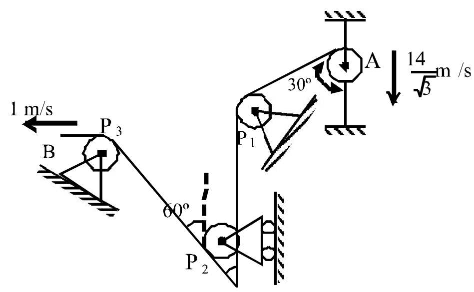


6. In the system shown in figure m_B = 4 kg, and m_A = 2 kg. The pulles are massless and friction is absent everywhere. The acceleration of block A is ?

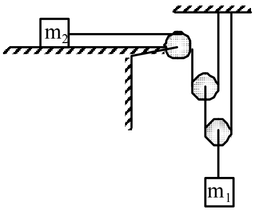


Section E - Pulley Block system

7. Figure shows a string passing through two fixed pulley P_1 and P_3 and a pulley P_2 free to move vertically. One end of string is attached with ring A. Velocity of pulley P_2 at the instant shown is (in m/s) -

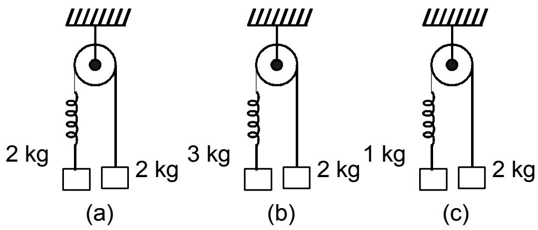


8. Pulleys are ideal and string are massless. The masses of blocks are $m_1 = 4$ kg and $m_2 = 1$ kg as shown. If all surfaces are smooth then the acceleration of m_2 in m/s^2 is ($g = 10\ m/s^2$)

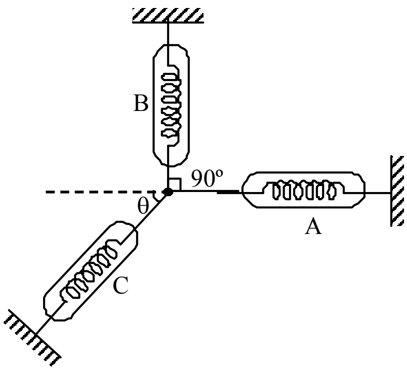


Section F - Spring force and spring cutting problems

9. Same spring is attached with 2 kg, 3 kg and 1 kg blocks in three different cases as shown in figure. If x_1, x_2 and x_3 be the extensions in the spring in these three cases then find the ratio of their extensions.



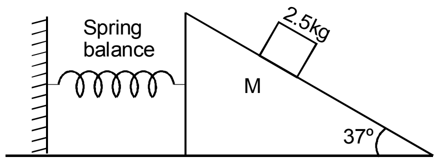
10. Three spring balances are attached to the ring as shown in the figure. There is an angle of 90° between the balance A and balance B. There is a reading of 5 N on balance A and 12 N on the balance B and reading in the balance C is 13 N and angle θ is 33.7° x. Find the value of x.



Section G - Pseudo force, Weighing Machine

11. A block of mass 5 kg is placed on bus moving with acceleration $2m/s^2$. Pseudo force acting on block as seen by a man on ground is -

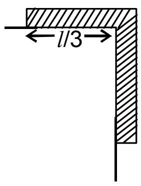
12. Find the reading of spring balance as shown in figure. Assume that mass M is in equilibrium. (All surfaces are smooth)



Section H - Static friction, Kinetic friction

13. A block of mass 1 kg is just fit in a groove in a platform kept horizontally. Groove is along + ve x-axis. The platform is given acceleration $\vec{a} = 2\hat{i} + 3\hat{j}$ m/s^2. If block is not slipping on platform the friction force acting on block (in Newton)

14. Determine the coefficient of friction (μ), so that rope of mass m and length l does not slide down.



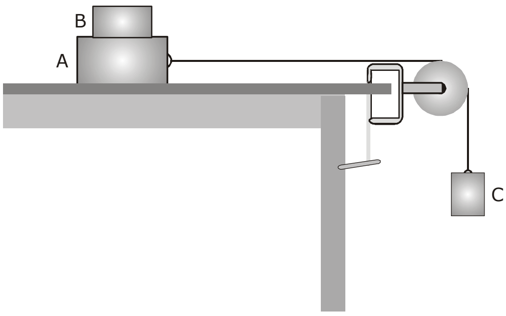
Section I - Direction of friction, Pulley Block system on horizontal plane

15. A block A of mass 2kg rests on another block B of mass 8kg which rests on a horizontal floor. The coefficient of friction between A and B is 0.2 while that between B and floor is 0.5. When a horizontal force F of 25N is applied on the block B, the force of friction between A and B is _________.

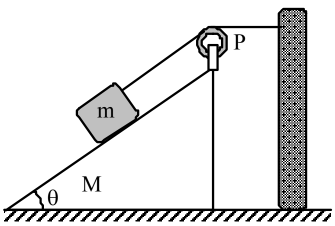
16. A block of mass 2 kg. is lying on a floor. The coefficient of static friction is 0.54. What will be value of frictional force if the applied force is 2.8 N and g = 10 m/s^2:-

Section J - Pulley Block system on inclined plane

17. Block B, of mass m_B = 0.5 kg, rests on block A, with mass m_A = 1.5 kg, which in turn is on a horizontal tabletop (as shown in figure). The coefficient of kinetic friction between block A and the tabletop is μ_k = 0.4 and the coefficient of static friction between block A and block B is μ_S = 0.6 A light string attached to block A passes over a frictionless, massless pulley and block C is suspended from the other end of the string. What is the largest mass m_C (in kg) that block C can have so that blocks A and B still slide together when the system is released from rest ?

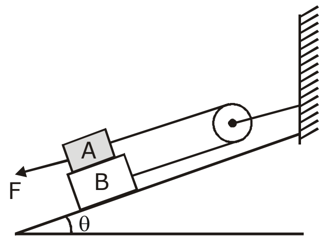


18. In the figure, a bar of mass m is on the smooth inclined face of the wedge of mass M. the inclination to the horizontal being q. The wedge is resting on a smooth horizontal plane. Assuming the pulley P to be smooth and the string is light and inextensible. Find the acceleration of M. Assume that M and m are always in contact.

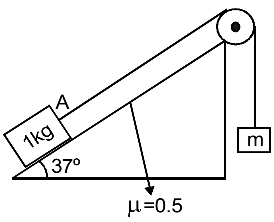


Section K - Two Block system, Two Block on Inclined plane

19. Block A has a mass of 30 kg and block B a mass of 15 kg. The coefficients of friction between all surfaces of contact are μ_S = 0.15 and μ_k = 0.10. Knowing that θ = 30° and that the magnitude of the force F applied to block A is 250 N. Determine (1) acceleration of block A. (2) the tension in the rope.

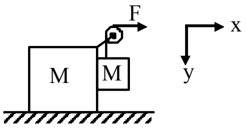


20. In the figure, what should be mass m so that block A slide up with a constant velocity.

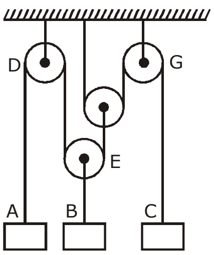


Section A - String Constrained, Wedge Constrained

1. In the situation given, all surfaces are frictionless, pulley is ideal and string is light. If $F = \frac{Mg}{2}$, find the acceleration of both the blocks in vector form.

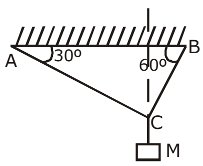


2. Pulleys shown in the system of the figure are massless and friction less. Threads are inextensible. Mass of block A, B and C are $m_1 = 2$ kg, $m_2 = 4$ kg and $m_3 = 2.75$ kg, respectively. Calculate acceleration of A block.

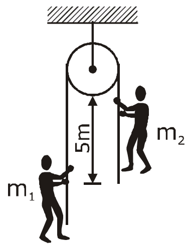


Section C - Equillibrium Questions (Normal and Tension), Problems with Acceleration (F=ma)

3. If mass M is 2 kg what is the tension in string AC? (in N) Answer as multiple of 2.

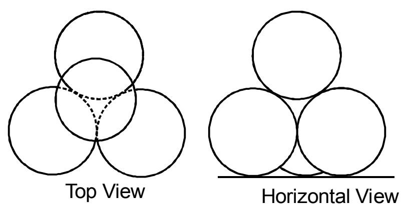


4. Two men of masses m_1 and m_2 hold on the opposite ends of a rope passing over a frictionless pulley. The mass m_1 climbs up the rope with an acceleration of 1.2 m/s^2 relative to the rope. The man m_2 climbs up the rope with an acceleration of 2.0 m/s^2 relative to the rope. Find the tension in the rope if $m_1 = 40$ kg and $m_2 = 60$ kg. Also find the time after which they will be at same horizontal level if they start from rest and are initially separated by 5m.



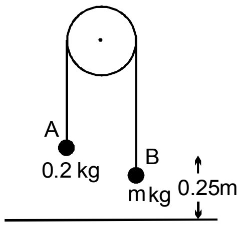
Section D - Wedge problems

5. An ornament for a courtyard at a word's fair is to be made up of four identical, frictionless metal sphere, each weighing $2\sqrt{6}$ Newton. The spheres are to be arranged as shown, with three resting on a horizontal surface and touching each other; the fourth is to rest freely on the other three. The bottom three are kept from separating by spot welds at the points of contact with each other. Allowing for a factor of satety of 3N, how much tension must the spot welds with stand.



Section E - Pulley Block system

6. The diagram shows particles A and B, of masses 0.2 kg and m kg respectively, connected by a light inextensible string which passes over a fixed smooth peg. The system is released from rest, with B at a height of 0.25m above the floor. B descends, hitting the floor 0.5s later. All resistances to motion may be ignored.



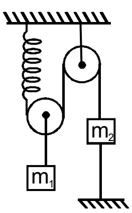
(a) Find the acceleration of B as it descends.

(b) Find the tension in the string while B is descending and find also the value of m.

(c) When B hits the floor it comes to rest immediately, and the string becomes slack. Find the length of time for which B remains at rest on the ground before being jerked into motion again.

Section F - Spring force and spring cutting problems

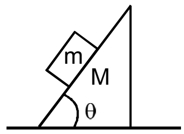
7. In figure shown, pulleys are ideal $m_1 > 2\,m_2$. Initially the system is in equilibrium and string connecting m_2 to rigid support below is cut. Find the initial acceleration of m_2?



Section G - Pseudo force, Weighing Machine

8. A block of mass m lies on wedge of mass M as shown in figure. Answer following parts separately.

(a) With what minimum acceleration must the wedge be moved towards right horizontally so that block m falls freely.



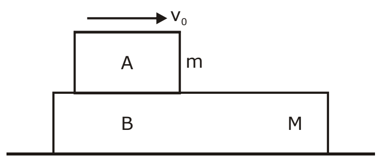
(b) Find the minimum friction coefficient required between wedge M and ground so that it does not move while block m slips down on it.

Section H - Static friction, Kinetic friction

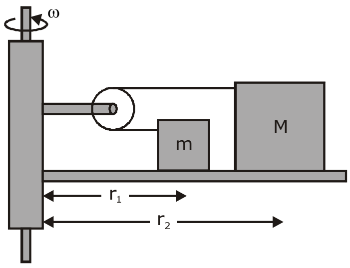
9. A car begins to move at time t = 0 and then accelerates along a straight track with a speed given by $V(t) = 2t^2\ ms^{-1}$ for $0 \le t \le 2$ After the end of acceleration, the car continues to move at a constant speed. A small block initially at rest on the floor of the car begins to slip at t = 1sec. and stops slipping at t = 3sec. Find the coefficient of static and kinetic friction between the block and the floor.

Section I - Direction of friction, Pulley Block system on horizontal plane

10. The masses of the blocks A and B are m and M. Between A and B there is a constant frictional force F, but B can slide frictionlessly on the horizontal surface. A is set in motion with velocity v_0 while B is at rest. What is the distance moved by A relative to B before they move with the same velocity?

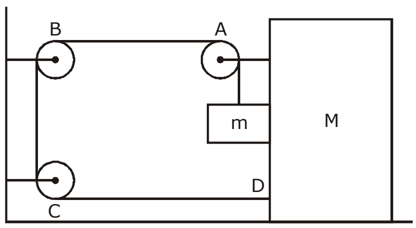


11. Two blocks of masses m and M are connected by a chord passing around a frictionless pulley which is attached to a rotating frame, which rotates about a vertical axis with an angular velocity ω. If the coefficient of friction between the two masses and the surface are μ_1 and μ_2, respectively, determine the value of ω at which the block starts sliding radially (M > m).

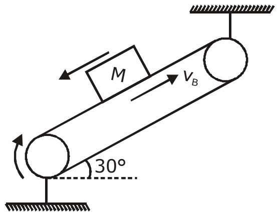


Section J - Pulley Block system on inclined plane

12. In figure, find the acceleration of m assuming that there is friction between m and M, and all other surface are smooth and pulleys light and m = coefficient of friction between m and M.



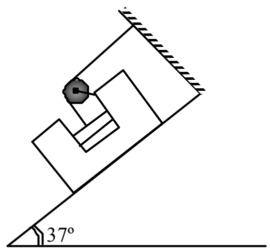
13. A conveyor belt is inclined at 30° with the horizontal. A body of mass M = 1 kg is kept on the conveyor as shown in the figure. The friction force between the body and the conveyor belt depends upon the relative speed of the body with respect to belt as $f = 0.4\,v_{rel}$ N. The belt moves at a constant speed v_B up the conveyor while initially the body has a speed of $2\,ms^{-1}$ relative to the ground in a direction down the conveyor. Take $g = 10\ ms^{-2}$.



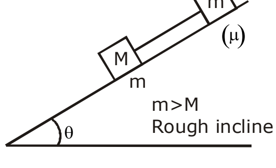
(i) Find the speed of the belt in order to have the body M to be able to eventually approach a final zero velocity relative to ground.
(ii) Find the time when body M attain a speed $1\ ms^{-1}$ relative to ground.

Section K - Two Block system, Two Block on Inclined plane

14. A block B is kept on an inclined plane. Another block A is inserted in a slot in the block B through a light string. One end of the string is fixed to a support and other end of the string is attached to A. All the surfaces are smooth. Masses of A and B are same. The acceleration of block B is found to be 4/n. Find value of n.



15. If figure, the tension in the rope (rope is light) is



1. The upper half of an inclined plane with inclination ϕ is perfectly smooth, while the lower half is rough. A body starting from rest at the top will again come to rest at the bottom, if the coefficient of friction for the lower half is given by **[AIEEE 2005]**

(A) 2 sin ϕ (B) 2 cos ϕ

(C) 2 tan ϕ (D) tan ϕ

2. A smooth block is released at rest on a 45° incline and then slides a distances d. The time taken to slide is **n** time as much to slide on rough incline than on a smooth incline. The coefficient of friction is **[AIEEE 2005]**

(A) $\mu_k = 1 - \frac{1}{n^2}$ (B) $\mu_k = \sqrt{1 - \frac{1}{n^2}}$

(C) $\mu_s = 1 - \frac{1}{n^2}$ (D) $\mu_s = \sqrt{1 - \frac{1}{n^2}}$

3. A particle of mass 0.3 kg is subjected to a force F = – kx with k = 15 Nm^{-1}. What will be its initial acceleration, if it is released from a point 20 cm away from the origin ? **[AIEEE 2005]**

(A) 3 ms^{-2} (B) 15 ms^{-2}

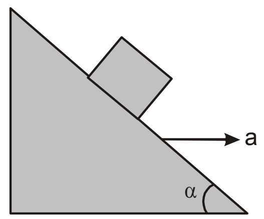
(C) 5 ms^{-2} (D) 10 ms^{-2}

4. Consider a car moving on a straight road with a speed of 100 ms^{-1}. The distance at which car can be stopped, is $[\mu_k = 0.5]$. **[AIEEE 2005]**

(A) 800 m (B) 1000 m

(C) 100 m (D) 400 m

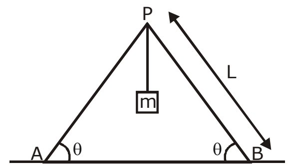
5. A block is kept on a frictionless inclined surface with angle of inclination α. The incline is given an acceleration **a** to keep the block stationary. Then **a** is equal to **[AIEEE 2005]**



(A) $\frac{g}{\tan\alpha}$ (B) g cosec α

(C) g (D) g tan α

6. Two identical ladders are arranged as shown in the figure. Mass of each ladder is M and length L. The system is in equilibrium. Find direction and magnitude of frictional force acting at A or B. **[AIEEE 2005]**

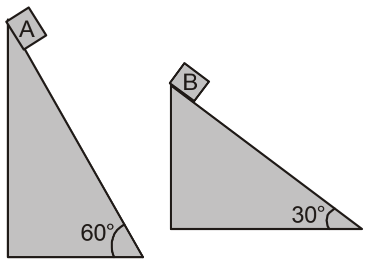


7. A block of mass m is connected to another block of mass M by a spring (massless) of spring constant k. The blocks are kept on a smooth horizontal plane. Initially the blocks are at rest and the spring is unstreched. Then a constant force F starts acting on the block of mass M to pull it. Find the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

(A) $\frac{mF}{M}$ (B) $\frac{(M+m)F}{m}$

(C) $\frac{mF}{(m+M)}$ (D) $\frac{MF}{(m+M)}$

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



(A) 4.9 ms^{-2} in horizontal direction

(B) 9.8 ms^{-2} in vertical direction

(C) Zero

(D) 4.9 ms^{-2} in vertical direction

9. The minimum force required to start pushing a body up a rough (frictional coefficient μ) 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 θ from the horizontal such tan θ= 2μ, then the ratio $\frac{F_1}{F_2}$ is **[AIEEE 2011]**

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

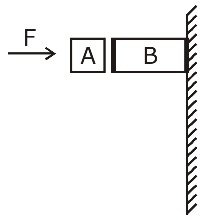
10. A block of mass m is placed on a surface with a vertical cross section given by $y = \frac{x^3}{6}$. If the coefficient of friction is 0.5, the maximum height above the ground at which the block can be placed without slipping is : **[AIEEE 2014]**

(A) $\frac{1}{3}$ m (B) $\frac{1}{2}$ m

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

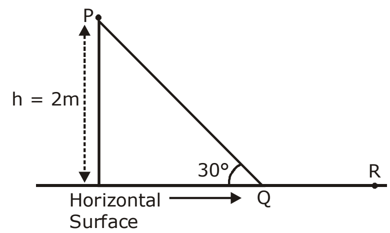
11. Given the figure are two blocks A and B of weight 20 N and 100 N, respectively. These are being pressed against a wall by a force F as shown. If the coefficient of friction between the blocks is 0.1 and between block B and the wall is 0.15, the frictional force applied by the wall on block B is :

[AIEEE 2015]



(A) 120 N (B) 150 N
(C) 100 N (D) 80 N

12. A point particle of mass m, moves along the uniformly rough track PQR as shown in the figure. The coefficient of friction, between the particle and the rough track equals m The particle is released, from rest, from the point P and it comes to rest at a point R. The energies, lost by the ball, over the parts, PQ and QR, of the track, are equal to each other, and no energy is lost when particle changes direction from PQ to QR.



The values of the coefficient of friction m and the distance x(=QR), are, respectively close to :

(A) 0.2 and 3.5 m

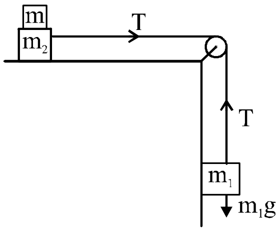
(B) 0.29 and 3.5 m

(C) 0.29 and 6.5 m

(D) 0.2 and 6.5 m

[AIEEE 2016]

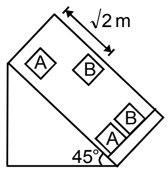
13. Two masses m_1 = 5 kg and m_2 = 10 kg, connected by an inextensible string over a frictionless pulley, are moving as shown in the figure. The coefficient of frictioin of horizontal surface is 0.15. The minimum weight m that should be put on top of m_2 to stop the motion is : **[AIEEE 2018]**



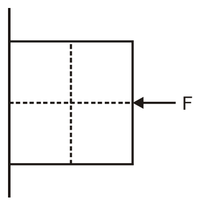
(A) 10.3 kg
(B) 18.3 kg
(C) 27.3 kg
(D) 43.3 kg

1. Two blocks A and B of equal masses are released from an inclined plane of inclination 45° at t = 0. Both the blocks are initially at rest. The coefficient of kientic friction between the block A and the inclined plane is 0.2 while it is 0.3 for block B. **[JEE 2004]**

Initially, the block A is $\sqrt{2}$ m behind the block B. When and where their front faces will come in line. [Take g = 10m/s^2].



2. A block of mass m is at rest under the action of force F against a wall as shown in fiugre. Which of the following statement is incorrect? **[2005, 2M]**



(A) f = mg (where f is the friction force)

(B) F = N (where N is the normal force)

(C) F will not produce torque

(D) N' will not produce torque

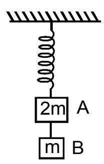
3. Two blocks A and B masses 2m and m, respectively, are connected by a massless and inextensible string. The whole system is suspended by a massless spring as shown in the figure. The magnitudes of acceleration of A and B, immediately after the string is cut, are respectively. **[JEE 2006]**

(A) g, g

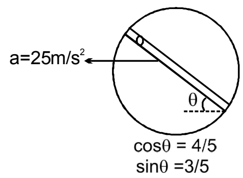
(B) g, g/2

(C) g/2, g

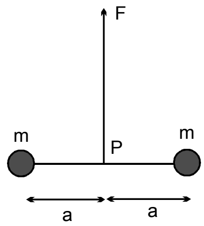
(D) g/2, g/2



4. A circular disc with a groove along its diameter is placed horizontally. A block of mass 1 kg is placed as shown. The co-efficient of friction between the block and all surfaces of groove in contact is $\mu = 2/5$. The disc has an acceleration of 25 m/s^2. Find the acceleration of the block with respect to disc. **[JEE 2006]**



5. Two particles of mass m each are tied at the ends of a light string of length 2a. The whole system is kept on a frictionless horizontal surface with the string held tight so that each mass is at a distance 'a' from the center P (as shown in the figure). Now, the mid-point of the string is pulled vertically upwards with a small but constant force F. As a result, the particles move towards each other on the surfaces. The magnitude of acceleration, when the separation between them becomes 2x, is **[JEE 2007]**



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

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

(C) $\dfrac{F}{2m}\dfrac{x}{a}$

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

6. **STATEMENT-1**

A cloth Covers a table. Some dishes are kept on it. The cloth can be pulled out without dislodging the dishes from the table **[JEE 2007]**

because

STATEMENT-2

For every action there is an equal and opposite reaction

(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

7. **STATEMENT-1**

It is easier to pull a heavy object than to push it on a level ground.

and

STATEMENT-2

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

(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

[JEE 2008]

8. A block of base 10 cm × 10 cm and height 15 cm is kept on an inclined plane. The coefficient of friction between them is $\sqrt{3}$. The inclination θ of this inclined plane from the horizontal plane is gradually increased from 0°. Then **[JEE 2009]**

(A) at θ = 30°, the block will start sliding down the plane

(B) the block will remain at rest on the plane up to certain θ and then it will topple

(C) at θ = 60°, the block will start sliding down the plane and continue to do so at higher angles

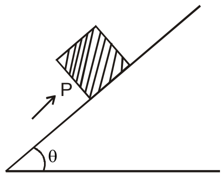
(D) at θ = 60°, the block will start sliding down the plane and on further increasing θ, it will topple at certain θ

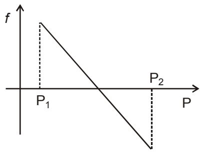
9. A piece of wire is bent in the shape of a parabola $y=kx^2$ (y-axis vertical) with a bead of mass m on it. The bead can slide on the wire without friction. It stays at the lowest point of the parabola when the wire is at rest. The wire is now accelerated parallel to the x-axis with a constant acceleration a. The distance of the new equilibrium position of the bead, where the bead can stay at rest with respect to the wire, from the y-axis is : **(JEE 2009)**

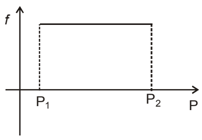
(A) $\frac{a}{gk}$ (B) $\frac{a}{2gk}$

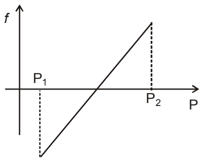
(C) $\frac{2a}{gk}$ (D) $\frac{a}{4gk}$

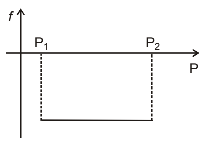
10. A block of mass m is on an inclined plane of angle θ. The coefficient of friction betwen the block and the plane is μ and tan θ > μ. The block is held stationary by applying a force P parallel to the plane. The direction of force pointing up the plane is taken to the positive. As P is varied from $P = mg(\sin\theta - \mu\cos\theta)$ to $P_z = mg(\sin\theta + \mu\cos\theta)$, the frictional force f versus P graph will look like **[JEE 2010]**



(A)


(B)


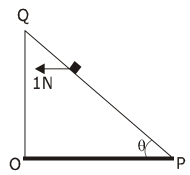
(C)


(D)


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

12. A small block of mass of 0.1 kg lies on a fixed inclined plane PQ which makes an angle θ with the horizontal. A horizontal force of 1 N acts on the block through its center of mass as shown in the figure. The block remains stationary if (take $g = 10\ m/s^2$)

[JEE 2012]



(A) θ = 45°

(B) θ > 45° and a frictional force acts on the block towards P.

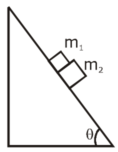
(C) θ > 45° and a frictional force acts on the block towards Q.

(D) θ < 45° and a frictional force acts on the block towards Q.

13. A block of mass m_1 = 1 kg another mass m_2=2kg 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 static and dinamic friction between the block m_2 and the plane are equal to μ=0.3. In List II expressions for the friction on block m_2 are given. Match the correct expression of the friction in List II with the angles given in List I, and choose the correct option. The acceleration due to gravity is denoted by g.

[JEE ADVANCED 2014]

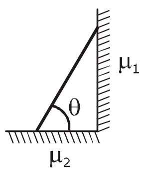
[आवश्यक आँकड़े : tan(5.5°) ≈ 0.1; tan(11.5°)≈ 0.2; tan(16.5°) ≈ 0.3]



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. $\mu(m_1+m_2)\, g \cos q$

(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

14. In the figure, a ladder of mass m is shown leaning against a wall. It is in static equilibrium making an angle θ with the horizontal floor. The coefficient of friction between the wall and the ladder is μ_1 and that between the floor and the ladder is μ_2. The normal reaction of the wall on the ladder is N_1 and that of the floor is N_2. If the ladder is about to slip, then **[JEE Advance 2014]**



(A) $\mu_1 = 0$ $\mu_2 \neq 0$ and $N_2 \tan\theta = \frac{mg}{2}$

(B) $\mu_1 \neq 0$ $\mu_2 = 0$ and $N_1 \tan\theta = \frac{mg}{2}$

(C) $\mu_1 \neq 0$ $\mu_2 \neq 0$ and $N_2 = \frac{mg}{1+\mu_1\mu_2}$

(D) $\mu_1 = 0$ $\mu_2 \neq 0$ and $N_1 \tan\theta = \frac{mg}{2}$

15. A uniform wooden stick of mass 1.6 kg and length ℓ rests in an inclined manner on a smooth, vertical wall of height h(<ℓ) such that a small portion of the stick extends beyond the wall. The reaction force of the wall on the stick is perpendicular to the stick. The stick makes an angle of 30° with the wall and the bottom of the stick is on a rough floor. The reaction of the wall on the stick is equal in magnitude to the reaction of the floor on the stick. The ratio h/ℓ and the frictional force f at the bottom of the stick are (g = 10 ms^{-2}) **[JEE ADVANCED 2016]**

(A) $\frac{h}{\ell} = \frac{\sqrt{3}}{16}$, f=$\frac{16\sqrt{3}}{3}$N

(B) $\frac{h}{\ell} = \frac{3}{16}$, f=$\frac{16\sqrt{3}}{3}$N

(C) $\frac{h}{\ell} = \frac{3\sqrt{3}}{16}$, f=$\frac{8\sqrt{3}}{3}$N

(D) $\frac{h}{\ell} = \frac{3\sqrt{3}}{16}$, f=$\frac{16\sqrt{3}}{3}$N

16. A solid horizontal surface is covered with a thin layer of oil. A rectangular block of mass m=0.4kg is at rest on this surface. An impulse of 1.0 N s is applied to the block at time to t = 0 so that it starts moving along the x-axis with a velocity $v(t) = v_0 e^{-t/\tau}$, where v_0 is a constant and τ = 4 s. The displacement of the block, in metres, at t = τ is.................. Take e^{-1} = 0.37 ? **[JEE ADVANCED 2018]**

ANSWER KEYS

Exercise - 1 Objective Problems | JEE Main

1.	A	**2.**	A	**3.**	B	**4.**	C	**5.**	D	**6.**	B	**7.**	D
8.	A	**9.**	B	**10.**	B	**11.**	C	**12.**	A	**13.**	B	**14.**	C
15.	A	**16.**	A	**17.**	B	**18.**	C	**19.**	B	**20.**	B	**21.**	C
22.	C	**23.**	A	**24.**	C	**25.**	D	**26.**	A	**27.**	A	**28.**	C
29.	A	**30.**	B	**31.**	B	**32.**	C	**33.**	A	**34.**	A	**35.**	C
36.	C	**37.**	B	**38.**	B	**39.**	C	**40.**	A	**41.**	C	**42.**	B
43.	C	**44.**	B	**45.**	C	**46.**	D	**47.**	C	**48.**	A	**49.**	A
50.	B	**51.**	B	**52.**	A	**53.**	A	**54.**	B	**55.**	B	**56.**	A
57.	C	**58.**	C	**59.**	A	**60.**	A	**61.**	C	**62.**	D	**63.**	A
64.	B	**65.**	C	**66.**	C	**67.**	C	**68.**	C	**69.**	C	**70.**	B
71.	C	**72.**	D	**73.**	D	**74.**	D	**75.**	A	**76.**	C	**77.**	B
78.	A	**79.**	D	**80.**	A								

Exercise - 2 (Level-I) Objective Problems | JEE Main

1.	A	**2.**	A	**3.**	A	**4.**	B	**5.**	A	**6.**	A	**7.**	C
8.	B	**9.**	B	**10.**	B	**11.**	C	**12.**	C	**13.**	A	**14.**	A
15.	B	**16.**	A	**17.**	C	**18.**	B	**19.**	C	**20.**	B	**21.**	C
22.	C	**23.**	B	**24.**	B	**25.**	C	**26.**	B	**27.**	B		
28.	**(i)**	A	**(ii)**	A	**(iii)**	A	**(iv)**	C	**(v)**	B	**(vi)**	C	
	(vii)	C	**(viii)**	B									
29.	**(i)**	A	**(ii)**	A	**(iii)**	C	**(iv)**	D	**(v)**	B	**(vi)**	D	
	(vii)	B	**(viii)**	B									
30.	B	**31.**	B	**32.**	B	**33.**	A	**34.**	D	**35.**	A	**36.**	C
37.	D	**38.**	C	**39.**	A	**40.**	A	**41.**	B	**42.**	D	**43.**	A
44.	C	**45.**	A	**46.**	C	**47.**	D	**48.**	C	**49.**	B	**50.**	D
51.	B	**52.**	A	**53.**	D	**54.**	A						

Exercise - 2 (Level-II) Multiple Correct | JEE Advanced

1.	B	**2.**	B,C	**3.**	A,C	**4.**	A,B,C	**5.**	A,C
6.	A,C	**7.**	A,B,C	**8.**	A,C	**9.**	A,B,D	**10.**	A,C
11.	A,C	**12.**	B	**13.**	AC	**14.**	A,B,D	**15.**	ABCD
16.	BC	**17.**	C,D	**18.**	A,B	**19.**	B,D	**20.**	A,B
21.	A,D	**22.**	B,D	**23.**	AB	**24.**	A,B,C	**25.**	A,B,D
26.	A,B								

Exercise - 3 | Level-I — Subjective | JEE Advanced

1.	6 metre/sec^2	**2.**	10 m/sec^2	**3.**	10 N	**4.**	332.5 N	**5.**	2 sec
6.	10/3 m/s^2	**7.**	4	**8.**	8				
9.	$x_2 > x_1 > x_3$ $x_1 : x_2 : x_3 : 15 : 18 : 10$					**10.**	2	**11.**	0
12.	12 N	**13.**	2	**14.**	$\mu = 2$	**15.**	0	**16.**	2.8 N
17.	5	**18.**	**a =** $\frac{mg\sin\theta}{M+2m(1-\cos\theta)}$			**19.**	$m_A g \sin\theta + F - T - f = m_A a$ (i)		
20.	1 kg								

Exercise - 3 | Level-II — Subjective | JEE Advanced

1.	$\vec{a}_A = \frac{g}{4}\hat{i} + \frac{g}{2}\hat{j}$, $\vec{a}_B = \frac{g}{4}\hat{i}$	**2.**	1	**3.**	5				
4.	556.8 N , 1.47 sec			**5.**	2 N	**6.**	**(a)** 2 ms^{-2}, **(b)** 2.4 N 0.3 **(c)** 0.2 s		
7.	$\left(\frac{m_1 - 2m_2}{2m_2}\right)g$	**8.**	(a) a = g cotθ, (b) $\mu_{min} = \frac{m\sin\theta\cos\theta}{m\cos^2\theta + M}$						
9.	$\mu_s = 0.4$, $\mu_k = 0.3$			**10.**	$\frac{mMv_0^2}{2F(m+M)}$	**11.**	$\left[\frac{g(\mu_1 m + \mu_2 M)}{Mr_2 - mr_1}\right]^{1/2}$		
12.	$\frac{2\sqrt{5}\,mg}{m + 5m + 2\mu m}$	**13.**	i. 2.5 ms^{-1} ; ii. 2.5 ln 2			**14.**	3	**15.**	0

Exercise - 4 | Level-I — Previous Year | JEE Main

1.	C	**2.**	A	**3.**	D	**4.**	B	**5.**	D
6.	$f = \left(\frac{M+m}{2}\right)g\cot\theta$			**7.**	C	**8.**	D	**9.**	D
10.	C	**11.**	**A**	**12.**	**B**	**13.**	**C**		

Exercise - 4 | Level-II — Previous Year | JEE Advanced

1.	11.313 m	**2.**	D	**3.**	B	**4.**	10 m/s^2	**5.**	B
6.	B	**7.**	B	**8.**	B	**9.**	B	**10.**	A
11.	10. 5N	**12.**	A,C	**13.**	D	**14.**	C, D	**15.**	D
16.	**6.30**								