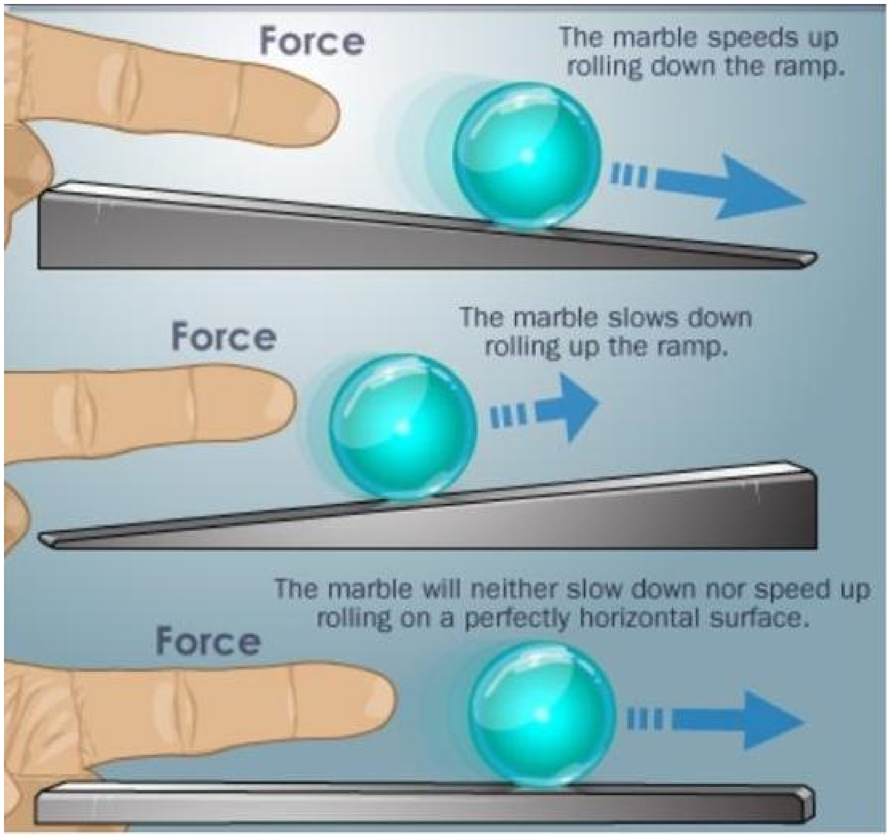
NEWTON'S LAW OF MOTION



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 :

(1) may change only speed
(2) may change only direction of motion.
(3) may change both the speed and direction of motion.
(4) may change size and shape of a body

Unit of force : Newton and $\frac{kg \cdot m}{s^2}$ (MKS System)

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

1 Newton = 10^5 dyne

Kilogram force (kgf)

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

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

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

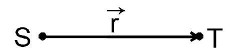
Fundamental Forces

All the forces observed in nature such as muscular force, tension, reaction, friction, elastic, weight, electric, magnetic, nuclear, etc., can be explained in terms of only following four basic interactions:

[A] Gravitational Force

The force of interaction which exists between two particles of masses m_1 and m_2, due to their masses is called gravitational force.

$$\vec{F} = -G\frac{m_1 m_2}{r^3}\vec{r}$$

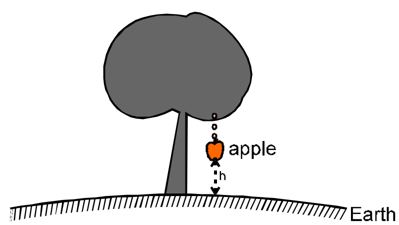


$\vec{r}$ = position vector of test particle 'T' with respect to source particle 'S'. and G = universal gravitational constant $= 6.67 \times 10^{-11}\ Nm^2/kg^2$.

(i) It is the weakest force and is always attractive.

(ii) It is a long range force as it acts between any two particles situated at any distance in the universe.

(iii) It is independent of the nature of medium between the particles.



An apple is freely falling as shown in figure, When it is at a height h, force between earth and apple is given by

$F = \frac{GM_e m}{(R_e + h)^2}$ where M_e – mass of earth, R_e – radius of earth

It acts towards earth's centre. Now rearranging above result,

$$F = m \cdot \frac{GM_e}{R_e^2} \cdot \left(\frac{R_e}{R_e + h}\right)^2$$

$$F = mg\left(\frac{R_e}{R_e + h}\right)^2 \quad \left\{g = \frac{GM_e}{R_e^2}\right\}$$

Here $h << R_e$, so $\frac{R_e}{R_e + h} \simeq 1$

$\therefore \quad F = mg$

This is the force exerted by earth on any particle of mass m near the earth surface. The value of $g = 9.81\ m/s^2 \simeq 10\ m/s^2 \simeq \pi^2\ m/s^2 \simeq 32\ ft/s^2$. It is also called acceleration due to gravity near the surface of earth.

[B] 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

(a) These can be attractive or repulsive.

(b) These are long range forces

(c) These depend on the nature of medium between the charged particles.

(d) All macroscopic forces (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 and repulsions between atoms/molecules.

[C] 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.

[D] Weak Force

It acts between any two elementary particles. Under its action a neutron can change into a proton emitting an electron and a particle called antineutrino. The range of weak force is very small, in fact much smaller than the size of a proton or a neutron.

It has been found that for two protons at a distance of 1 Fermi :

$$F_N : F_{EM} : F_W : F_G :: 1 : 10^{-2} : 10^{-7} : 10^{-38}$$

Classification of forces on the basis of contact :

(A) Field Force:

Force which acts on an object at a distance by the interaction of the object with the field produced by other object is called field force. Examples

(a) Gravitation force

(b) Electromagnetic force

(B) Contact Force:

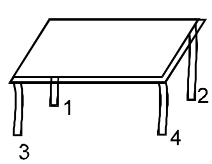
Forces which are transmitted between bodies by short range atomic molecular interactions are called contact forces. When two objects come in contact they exert contact forces on each other.

Examples:

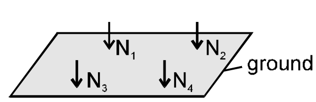
(a) Normal force (N):

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.

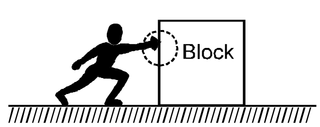
A table is placed on Earth as shown in figure



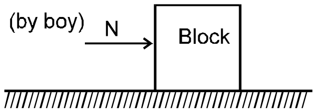
Here table presses the earth so normal force exerted by four legs of table on earth are as shown in figure.



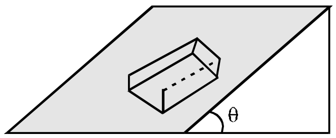
Now a boy pushes a block kept on a frictionless surface.



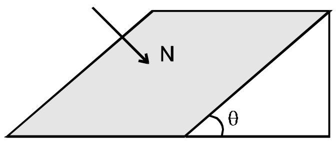
Here, force exerted by boy on block is electromagnetic interaction which arises due to similar charges appearing on finger and contact surface of block, it is normal force.



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.



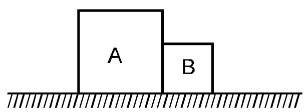
Normal force exerted by block on the surface of inclined plane is shown in figure.



Force acts perpendicular to the surface

SOLVED EXAMPLE

Example 1. Two blocks are kept in contact on a smooth surface as shown in figure. Draw normal force exerted by A on B.



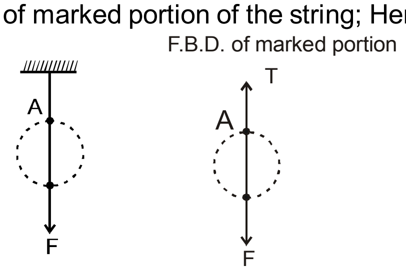
Solution : In above problem, block A does not push block B, so there is no molecular interaction between A and B. Hence normal force exerted by A on B is zero.

Note :

- Normal is a dependent force, it comes in role when one surface presses the other.

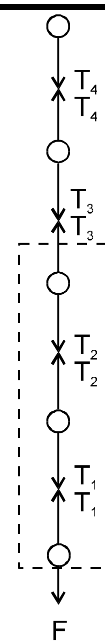
(b) Tension :

Tension in a string is a 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.

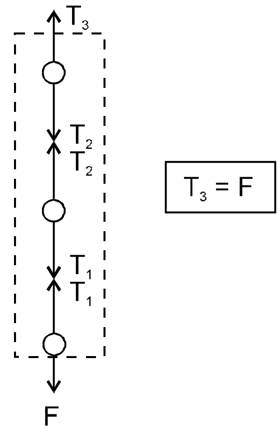


$\Rightarrow$ $T = F$

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



For calculating tension at any segment, we consider two or more than two parts as a system.



Here interaction between segments are considered as internal forces, so they are not shown in F.B.D.

(C) 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.

THIRD LAW OF MOTION :

To every action, there is always an equal and opposite reaction. Newton's law from an 1803 translation from Latin as Newton wrote

"To every action there is always opposed an equal and opposite reaction: to the mutual actions of two bodies upon each other are always equal, and directed to contrary parts."

Important points about the Third Law

(a) The terms 'action' and 'reaction' in the Third Law mean nothing else but 'force'. A simple and clear way of stating the Third Law is as follows : Forces always occur in pairs. Force on a body A by B is equal and opposite to the force on the body B by A.

(b) The terms 'action' and 'reaction' in the Third Law may give a wrong impression that action comes before reaction i.e. action is the cause and reaction the effect. There is no such cause-effect relation implied in the Third Law. The force on A by B and the force on B by A act at the same instant. Any one of them may be called action and the other reaction.

(c) Action and reaction forces act on different bodies, not on the same body. Thus if we are considering the motion of any one body (A or B), only one of the two forces is relevant. It is an error to add up the two forces and claim that the net force is zero.

However, if you are considering the system of two bodies as a whole, $\mathbf{F}_{AB}$ (force on A due to B) and $\mathbf{F}_{BA}$ (force on B due to A) are internal forces of the system (A + B). They add up to give a null force. Internal forces in a body or a system of particles thus cancel away in pairs. This is an important fact that enables the Second Law to be applicable to a body or a system of particles.

SYSTEM :

Two or more than two objects which interact with each other form a system.

Classification of forces on the basis of boundary of system :

(A) Internal Forces:

Forces acting each with in a system among its constituents.

(B) External Forces:

Forces exerted on the constituents of a system by the outside surroundings are called as external forces.

(C) Real Force:

Force which acts on an object due to other object is called as real force. An isolated object (far away from all objects) does not experience any real force.

FREE BODY DIAGRAM

A free body diagram consists of a diagrammatic representations of a single body or a subsystem of bodies isolated from its surroundings showing all the forces acting on it.

Steps for F.B.D.

Step 1: Identify the object or system and isolate it from other objects clearly specify its boundary.

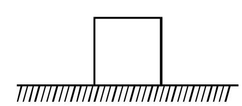
Step 2: First draw non-contact external force in the diagram. Generally it is weight.

Step 3: Draw contact forces which acts at the boundary of the object or system. Contact forces are normal, friction, tension and applied force.

In F.B.D, internal forces are not drawn, only external are drawn.

SOLVED EXAMPLE

Example 2. A block of mass 'm' is kept on the ground as shown in figure.

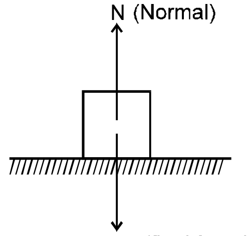


(i) Draw F.B.D. of block.

(ii) Are forces acting on block action–reaction pair.

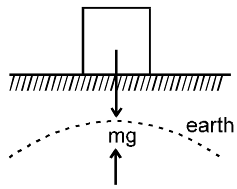
(iii) If answer is no, draw action reaction pair.

Solution : (i) F.B.D. of block

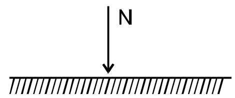


(ii) 'N' and mg are not action-reaction pair. Since pair act on different bodies, and they are of same nature.

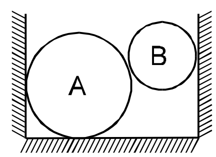
(iii) Pair of 'mg' of block acts on earth in opposite direction.



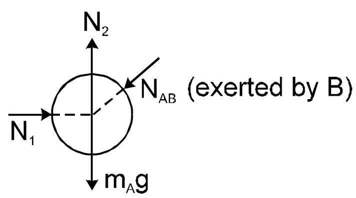
and pair of 'N' acts on surface as shown in figure.



Example 3. Two sphere A and B are placed between two vertical walls as shown in figure. Draw the free body diagrams of both the spheres.

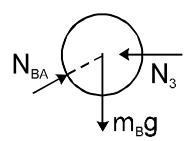


Solution : **F.B.D.** of sphere 'A' :



F.B.D. of sphere 'B' :

(exerted by A)



Note : Here N_{AB} and N_{BA} are the action–reaction pair (Newton's third law).

NEWTON'S LAWS OF MOTION :

First Law of Motion

Each body continues to be in its state of rest or of uniform motion in a straight line unless compelled by some external force to act otherwise.

Newton's first law is really a statement about reference frames in that it defines the types of reference frames in which the laws of Newtonian mechanics hold. From this point of view the first law is expressed as:

If the net force acting on a body is zero, it is possible to find a set of reference frames in which that body has no acceleration.

Newton's first law is sometimes called the law of inertia and the reference frames that it defines are called inertial reference frames.

Newton's law from an 1803 translation from Latin as Newton wrote

" Every body preserves in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon."

Examples of this law :

(a) A bullet fired on a glass window makes a clean hole through it while a stone breaks the whole of it. The speed of bullet is very high. Due to its large inertia of motion, it cuts a clean hole through the glass. When a stone is thrown, it inertia is much lower so it cannot cut through the glass.

(b) A passenger sitting in a bus gets a jerk when the bus starts or stops suddenly.

Second Law of Motion :

The rate of change of momentum of a body is proportional to the applied force and takes place in the direction in which the force acts.

Newton's law from an 1803 translation from Latin as Newton wrote

" The alteration of motion is ever proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed."

Mathematically

$$\vec{F} = \frac{d\vec{p}}{dt}$$

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

where $\vec{p} = m\vec{v}$, $\vec{p}$ = Linear momentum.

In case of two particles having linear momentum $\vec{P}_1$ and $\vec{P}_2$ and moving towards each other under mutual forces, from Newton's second law ;

$$\frac{d}{dt}\left(\vec{p}_1 + \vec{p}_2\right) = \vec{F} = 0$$

$$\frac{d\vec{p}_1}{dt} + \frac{d\vec{p}_2}{dt} = 0$$

$$\vec{F}_1 + \vec{F}_2 = 0$$

$$\vec{F}_2 = -\vec{F}_1$$

which is Newton's third law.

Important points about second law

(a) The Second Law is obviously consistent with the First Law as F = 0 Implies a = 0.

(b) The Second Law of motion is a vector law. It is actually a combination of three equations, one for each component of the vectors :

$$F_x = \frac{dp_x}{dt} = ma_x \qquad F_y = \frac{dp_y}{dt} = ma_y \qquad F_z = \frac{dp_z}{dt} = ma_z$$

This means that if a force is not parallel to the velocity of the body, but makes some angle with it, it changes only the component of velocity along the direction of force. The component of velocity normal to the force remains unchanged.

(b) The Second Law of motion given above is strictly applicable to a single point mass. The force **F** in the law stand for the net external force on the particle and **a** stands for the acceleration of the particle. Any internal forces in the system are not to be included in **F.**

(c) The Second Law of motion is a local relation. What this means is that the force **F** at a point in space (location of the particle) at a certain instant of time is related to **a** at the same point at the same instant. That is acceleration here and now is determined by the force here and now not by any history of the motion of the particle.

Applications of Newton's Laws

(a) When objects are in equilibrium

To solve problems involving objects in equilibrium:

Step 1: Make a sketch of the problem.

Step 2: Isolate a single object and then draw the **free-body diagram** for the object. Label all external forces acting on it.

Step 3: Choose a convenient coordinate system and resolve all forces into rectangular components along x and y direction.

Step 4: Apply the equations $\Sigma F_x = 0$ and $\Sigma F_y = 0$.

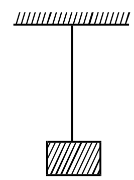
Step 5: Step 4 will give you two equations with several unknown quantities. If you have only two unknown quantities at this point, you can solve the two equations for those unknown quantities.

Step 6: If step 5 produces two equations with more than two unknowns, go back to step 2 and select another object and repeat these steps.

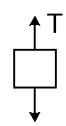
Eventually at step 5 you will have enough equations to solve for all unknown quantities.

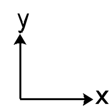
SOLVED EXAMPLE

Example 4. A 'block' of mass 10 kg is suspended with string as shown in figure. Find tension in the string. (g = 10 m/s²)



Solution : F.B.D. of block



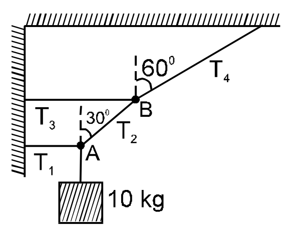


$\Sigma F_y = 0$

$T - 10\,g = 0$

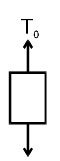
$\therefore$ $T = 100$ N

Example 5. 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)



Solution :

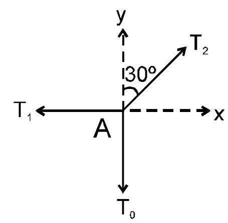
F.B.D. of block 10 kg



$T_0 = 10\,g$

$T_0 = 100$ N

F.B.D. of point 'A'



$\Sigma F_y = O$

$T_2 \cos 30° = T_0 = 100$ N

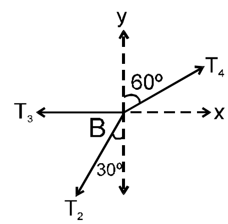
$T_2 = \frac{200}{\sqrt{3}}$ N

$\Sigma F_x = O$

$T_1 = T_2 \sin 30°$

$= \frac{200}{\sqrt{3}} \cdot \frac{1}{2} = \frac{100}{\sqrt{3}}$ N.

F.B.D. of point of 'B'

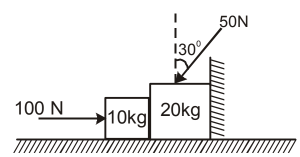


$\Sigma F_y = O \Rightarrow T_4 \cos 60^0 = T_2 \cos 30^0$

and $\Sigma F_x = O \Rightarrow T_3 + T_2 \sin 30^0 = T_4 \sin 60^0$

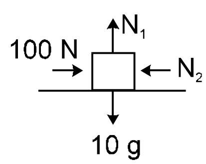
$\therefore \quad T_3 = \frac{200}{\sqrt{3}}$ N, $T_4 = 200$ N

Example 6. 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 blocks.



Solution :

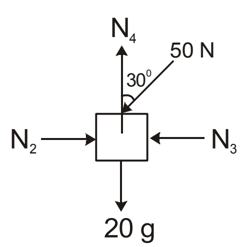
F.B.D. of 10 kg block



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

$N_2 = 100$ N ....(2)

F.B.D. of 20 kg block



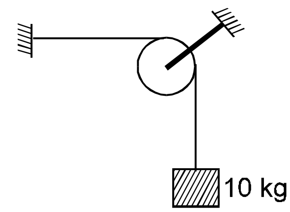
$N_2 = 50 \sin 30° + N_3$

$\therefore \quad N_3 = 100 - 25 = 75$ N ....(3)

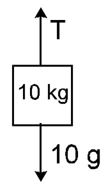
and $\quad N_4 = 50 \cos 30^0 + 20$ g

$N_4 = 243.30$ N

Example 7. Find magnitude of force exerted by string on pulley.

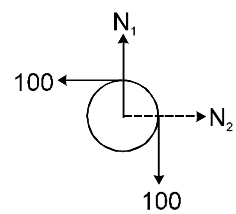


Solution : **F.B.D. of 10 kg block :**



T = 10 g = 100 N

F.B.D. of pulley :



Since string is massless, so tension in both sides of string is same.

Force exerted by string

$$= \sqrt{(100)^2 + (100)^2} = 100\sqrt{2} \text{ N}$$

Note : Since pulley is in equilibrium position, so net forces on it is zero.

Hence force exerted by hinge on it is $100\sqrt{2}$ N.

(b) Accelerating Objects

To solve problems involving objects that are in accelerated motion :

Step 1: Make a sketch of the problem.

Step 2: Isolate a single object and then draw the **free-body diagram** for that object. Label all external forces acting on it. Be sure to include all the forces acting on the chosen body, but be equally carefully not include any force exerted by the body on some other body. Some of the forces may be unknown; label them with algebraic symbols.

Step 3: Choose a convenient coordinate system, show location of coordinate axes explicitly in the free-body diagram, and then determine components of forces with reference to these axes and resolve all forces into x and y components.

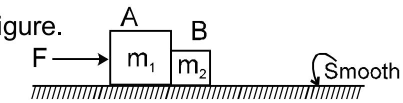
Step 4: Apply the equations $\Sigma F_x = ma_x$ and $\Sigma F_y = m a_y$.

Step 5: Step 4 will give two equations with several unknown quantities. If you have only two unknown quantities at this point, you can solve the two equations for those unknown quantities.

Step 6: If step 5 produces two equations with more than two unknowns, go back to step 2 and select another object and repeat these steps. Eventually at step 5 you will have enough equations to solve for all unknown quantities.

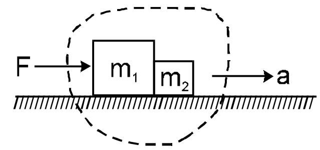
SOLVED EXAMPLE

Example 8. A force F is applied horizontally on mass m_1 as shown in figure. Find the contact force between m_1 and m_2.



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

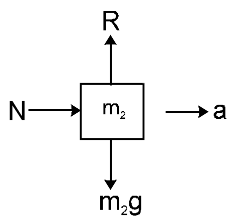
Common acceleration



$$a = \frac{F}{(m_1 + m_2)} \quad .....(1)$$

To find the contact force between 'A' and 'B' we draw F.B.D. of mass m_2.

F.B.D. of mass m_2



$\Sigma F_x = ma_x$

$N = m_2 .a$

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

Example 9. The velocity of a particle of mass 2 kg is given by $\vec{v} = at\hat{i} + bt^2\hat{j}$. Find the force acting on the particle.

Solution : From second law of motion :

$$\vec{F} = \frac{d\vec{P}}{dt} = \frac{d}{dt}(m\vec{v})$$

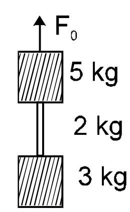
$$= 2.\frac{d}{dt}(at\hat{i} + bt^2\hat{j}) \quad \Rightarrow \quad \vec{F} = 2a\hat{i} + 4bt\hat{j}$$

Example 10. 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 at 2 m/s² by an external force F_0.

(a) What is F_0 ?

(b) What is the net force on rope ?

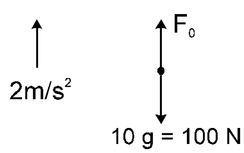
(c) What is the tension at middle point of the rope ? (g = 10 m/s²)



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

F.B.D. of whole system

(a)



$F_0 - 100 = 10 \times 2$

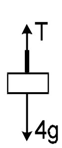
$F = 120$ N .....(1)

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

F = ma = (2) (2)

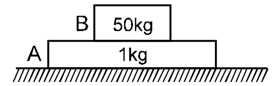
= 4 N .....(2)

(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) ; T = 48 N

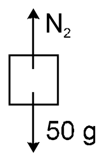
Example 11. A block of mass 50 kg is kept on another block of mass 1 kg as shown in figure. A horizontal force of 10 N is applied on the 1kg block. (All surface are smooth). Find ($g = 10\ m/s^2$)



(a) Acceleration of block A and B.

(b) Force exerted by B on A.

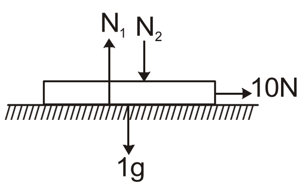
Solution : **(a) F.B.D. of 50 kg**



$N_2 = 50\ g = 500\ N$

along horizontal direction, there is no force $a_B = 0$

(b) F.B.D. of 1 kg block :



along horizontal direction

$10 = 1\ a_A.$

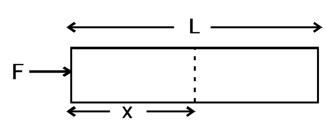
$a_A = 10\ m/s^2$

along vertical direction

$\therefore \quad N_1 = N_2 + 1g$

$= 500 + 10 = 510\ N$

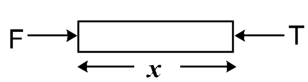
Example 12. A horizontal force is applied on a uniform rod of length L kept on a frictionless surface. Find the tension in rod at a distance 'x' from the end where force is applied.



Solution : Considering rod as a system, we find acceleration of rod

$$a = \frac{F}{M}$$

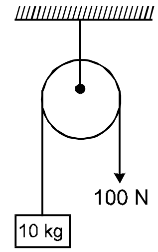
now draw F.B.D. of rod having length 'x' as shown in figure.



Using Newton's second law

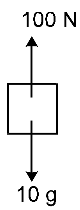
$$F - T = \left(\frac{M}{L}\right) x.a \quad \Rightarrow \quad T = F - \frac{M}{L} x. \frac{F}{M} \quad \Rightarrow \quad T = F\left(1 - \frac{x}{L}\right).$$

Example 13. 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. ($g = 9.8\ m/s^2$)



Solution : Since string is pulled by 100 N force. So tension in the string is 100 N.

F.B.D. of 10 kg block



$$100 - 10\ g = 10\ a$$

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

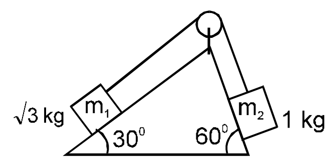
$$a = 0.2\ m/s^2.$$

Example 14. 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

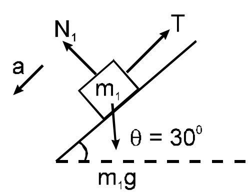
(iii) net force on pulley exerted by string



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

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

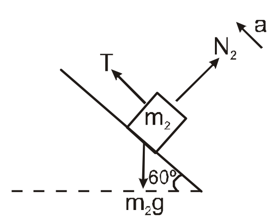
$$\frac{\sqrt{3}}{2}g - T = \sqrt{3}\ a \quad ....(i)$$



F.B.D. of m_2 :

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

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



Adding eq.(i) and (ii) we get a = 0

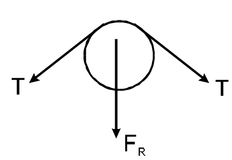
Putting this value in eq.(i) we get

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

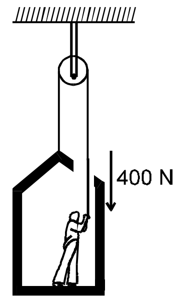
F.B.D. of pulley

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

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



Example 15. A 60 kg painter stands 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.

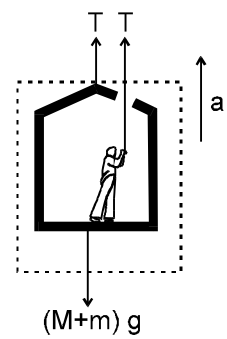


(i) To get started, he pulls the rope down with a force of 400 N. Find the acceleration of the platform as well as that of the painter.

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

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

Solution : 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 pulls the rope.



(i) Applying Newton's Second Law

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

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

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

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

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

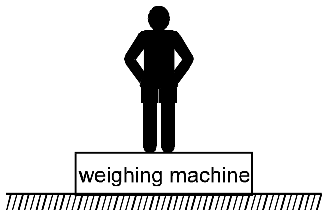
or $\quad F = \dfrac{(M+m)g}{2} = \dfrac{(60+15)(10)}{2} = \mathbf{375\ N}$

WEIGHING MACHINE :

A weighing machine does not measure the weight but measures the force exerted by object on its upper surface.

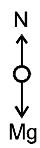
SOLVED EXAMPLE

Example 16. A man of mass 60 Kg is standing on a weighing machine placed on ground. Calculate the reading of machine ($g = 10\ m/s^2$).



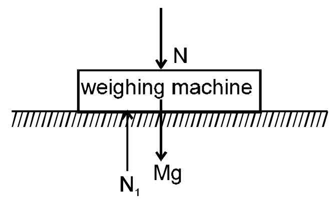
Solution : For calculating the reading of weighing machine, we draw F.B.D. of man and machine separately.

F.B.D. of man



$N = Mg$

F.B.D. of weighing machine



Here force exerted by object on upper surface is N

Reading of weighing machine

$N = Mg$

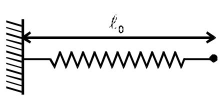
$= 60 \times 10$

$N = 600$ N.

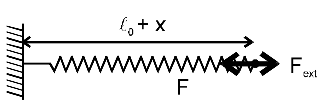
SPRING FORCE :

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.



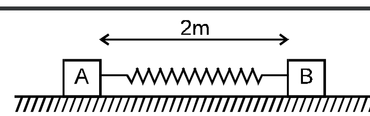
$F = 0$



$F = -kx$

SOLVED EXAMPLE

Example 17. 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 :

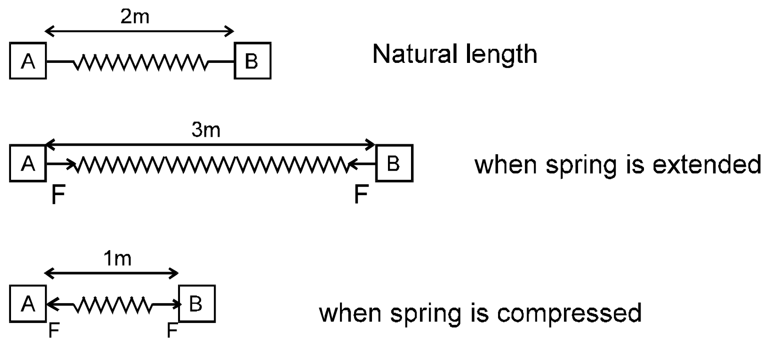
(a) If block 'A' and 'B' both are displaced by 0.5 m in same direction.

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

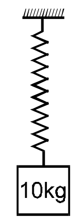
Solution : (a) Since both blocks are displaced by 0.5 m in same direction, so change in length of spring is zero. Hence, spring force is zero.

(b) In this case, change in length of spring is 1 m. In case of extension or compression of spring, spring force is F = Kx = (200) . (1)

F = 200 N

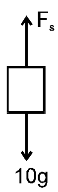


Example 18. Force constant of a spring is 100 N/m. If a 10 kg block attached with the spring is at rest, then find extension in the spring. ($g = 10\ m/s^2$)



Solution : 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 :



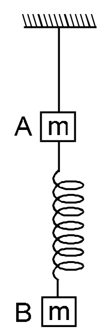
$F_s = 10g$

$\Rightarrow$ Kx = 100

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

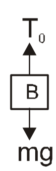
$\Rightarrow$ x = 1m

Example 19. 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.



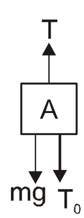
Solution : When block A and B are in equilibrium position

F.B.D of 'B'



$T_0 = mg$ .... (i)

F.B.D of 'A'

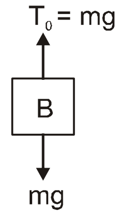


$T = mg + T_0$

$T = 2\ mg$ ....(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 blocks A and B as shown in figure

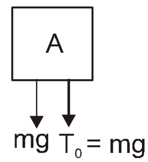
F.B.D. of 'B'



$T_0 - mg = ma_B$

$a_B = 0$

F.B.D. of 'A'



$mg + T_0 = ma_A$

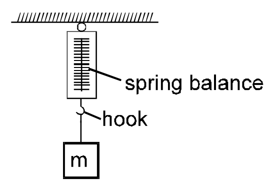
$2mg = ma_A$

$a_A = 2g$ (downwards)

Spring Balance :

It does not measure the weight. It measures the force exerted by the object at the hook.

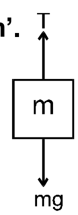
Symbolically, it is represented as shown in figure.



A block of mass 'm' is suspended at hook.

When spring balance is in equilibrium, we draw the F.B.D. of mass m for calculating the reading of balance.

F.B.D. of 'm'.



$mg - T = 0$

$T = mg$

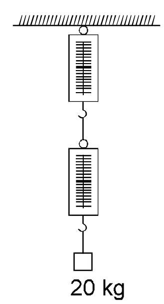
Magnitude of T gives the reading of spring balance.

SOLVED EXAMPLE

Example 20. A block of mass 20 kg is suspended through two light spring balances as shown in figure. Calculate the :

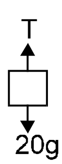
(1) reading of spring balance (1).

(2) reading of spring balance (2).



Solution: For calculating the reading, first we draw F.B.D. of 20 kg block.

F.B.D of 20 kg.



$mg - T = 0$

$T = 20\ g = 200\ N$

Since both balances are light so, both the scales will read 20 kg.

CONSTRAINED MOTION:

String Constraint :

When two objects are connected through a string and if the string have the following properties :

(a) The length of the string remains constant i.e. inextensible string.

(b) Always remains tight, does not slacks.

Then the parameters of the motion of the objects along the length of the string and in the direction of extension have a definite relation between them.

Steps for String Constraint

Step 1. Identify all the objects and number of strings in the problem.

Step 2. Assume variable to represent the parameters of motion such as displacement, velocity acceleration etc.

(i) Object which moves along a line can be specified by one variable.

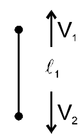
(ii) Object moving in a plane are specified by two variables.

(iii) Objects moving in 3-D requires three variables to represent the motion.

Step 3. Identify a single string and divide it into different linear sections and write in the equation format.

$\ell_1 + \ell_2 + \ell_3 + \ell_4 + \ell_5 + \ell_6 = \ell$

Step 4. Differentiate with respect to time



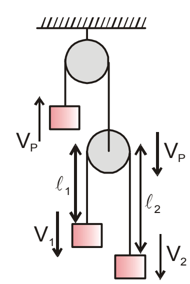
$$\frac{d\ell_1}{dt} + \frac{d\ell_2}{dt} + \frac{d\ell_3}{dt} + ... = 0$$

$\frac{d\ell_1}{dt}$ = represents the rate of increment of the portion 1, end points are always in contact with some object so take the velocity of the object along the length of the string $\frac{d\ell_1}{dt} = V_1 + V_2$

Take positive sign if it tends to increase the length and negative sign if it tends to decrease the length. Here $+V_1$ represents that upper end is tending to increase the length at rate V_1 and lower end is tending to increase the length at rate V_2.

Step 5. Repeat all above steps for different-different strings.

Let us consider a problem given below



Here $\ell_1 + \ell_2$ = constant

$$\frac{d\ell_1}{dt} + \frac{d\ell_2}{dt} = 0$$

$$(V_1 - V_P) + (V_P - V_2) = 0$$

$$V_p = \frac{V_1 + V_2}{2}$$

Similarly,

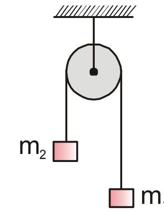
$$a_P = \frac{a_1 + a_2}{2}$$ Remember this result

SOLVED EXAMPLE

Example 21. Two blocks of masses m_1 and m_2 are attached at the ends of an inextensible string which passes over a smooth massless pulley. If $m_1 > m_2$, find :

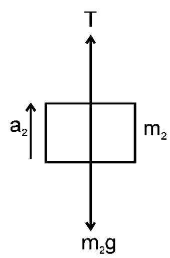
(i) the acceleration of each block

(ii) the tension in the string.

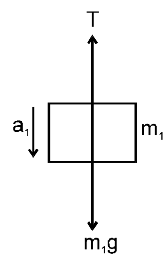


Solution : The block m_1 is assumed to be moving downward and the block m_2 is assumed to be moving upward. It is merely an assumption and it does not imply the real direction. If the values of a_1 and a_2 come out to be positive then only the assumed directions are correct; otherwise the body moves in the opposite direction. Since the pulley is smooth and massless, therefore, the tension on each side of the pulley is same.
The free body diagram of each block is shown in the figure.

F.B.D. of m_2 **F.B.D. of m_1**



F.B.D. of m_2



F.B.D. of m_1

Applying Newton's second Law on blocks m_1 and m_2

Block m_1 $m_1g - T = m_1a_1$ ....(1)

Block m_2 $-m_2g + T = m_2a_2$ ....(2)

Number of unknowns : T, a_1 and a_2 (three)
Number of equations: only two
Obviously, we require one more equation to solve the problem. Note that whenever one finds the number of equations less than the number of unknowns, one must think about the constraint relation. Now we are going to explain the mathematical procedure for this.
How to determine Constraint Relation ?

(1) Assume the direction of acceleration of each block, e.g. a_1 (downward) and a_2 (upward) in this case.

(2) Locate the position of each block from a fixed point (depending on convenience), e.g. centre of the pulley in this case.

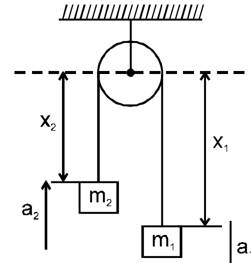
(3) Identify the constraint and write down the equation of constraint in terms of the distance assumed. For example, in the chosen problem, the length of string remains constant is the constraint or restriction.
Thus, $x_1 + x_2$ = constant

Differentiating both the sides w.r.t. time we get $\frac{dx_1}{dt} + \frac{dx_2}{dt} = 0$

Each term on the left side represents the velocity of the blocks.

Since we have to find a relation between accelerations,

therefore we differentiate it once again w.r.t. time.



Position of each block is located w.r.t. centre of the pulley

Thus $\frac{d^2x_1}{dt^2} + \frac{d^2x_2}{dt^2} = 0$

Since, the block m_1 is assumed to be moving downward (x_1 is increasing with time)

$\therefore \quad \frac{d^2x_1}{dt^2} = +a_1$

and block m_2 is assumed to be moving upward (x_2 is decreasing with time)

$\therefore \quad \frac{d^2x_2}{dt^2} = -a_2$

Thus $a_1 - a_2 = 0$

or $a_1 = a_2 = a$ (say) is the required constraint relation.

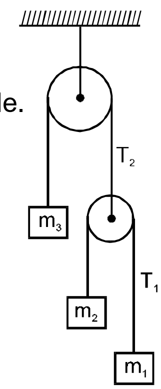
Substituting $a_1 = a_2 = a$ in equations (1) and (2) and solving them, we get

(i) $a = \left[\frac{m_1 - m_2}{m_1 + m_2}\right] g$ (ii) $T = \left[\frac{2m_1m_2}{m_1 + m_2}\right] g$

Example 22. A system of three masses m_1, m_2 and m_3 are shown in the figure. The pulleys are smooth and massless; the strings are massless and inextensible.

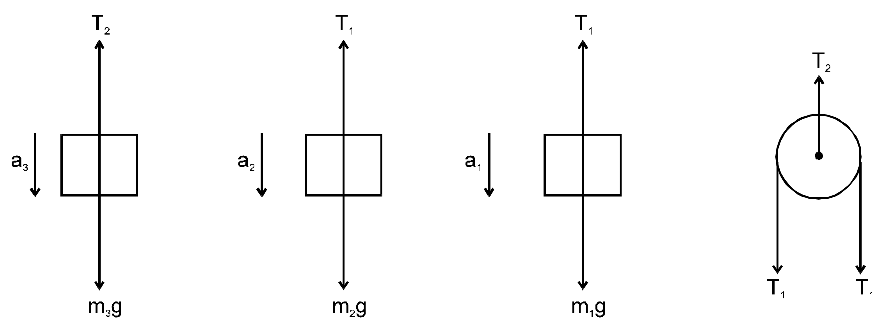
(i) Find the tensions in the strings.

(ii) Find the acceleration of each mass.



Solution : All the blocks are assumed to be moving downward and the free body diagram of each block is shown in figure.

F.B.D. m_3 **F.B.D. m_2** **F.B.D. m_1** **F.B.D. of pulley**



Applying Newton's Second Law to

Block m_1 : $m_1g - T_1 = m_1a_1$ ....(1)

Block m_2 : $m_2g - T_1 = m_2a_2$ ....(2)

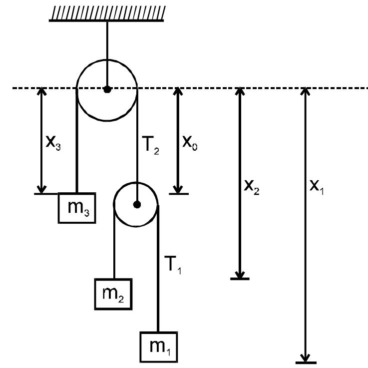
Block m_3 : $m_3g - T_2 = m_3a_3$ ....(3)

Pulley : $T_2 = 2T_1$ ....(4)

Number of unknowns a_1, a_2, a_3, T_1 and T_2 (Five)

Number of equations : Four

The constraint relation among accelerations can be obtained as follows



For upper string $x_3 + x_0 = c_1$

For lower string $x_2 – x_0) + (x_1 – x_0) = c_2$

$$x_2 + x_1 – 2x_0 = c_2$$

Eliminating x_0 from the above two relations,

we get $x_1 + x_1 + 2x_3 = 2c_1 + c_2$ = constant.

Differentiating twice with respect to time,

we get $$\frac{d^2x_1}{dt^2} + \frac{d^2x_2}{dt^2} + 2\frac{d^2x_3}{dt^2} = 0$$

or $a_1 + a_2 + 2a_3 = 0$ ......(5)

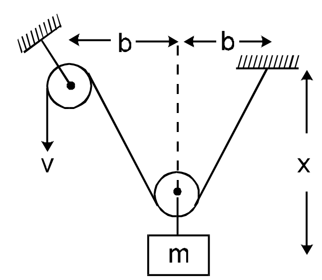
Solving equations (1) to (5), we get

(i) $T_1 = \left[\frac{4m_1m_2m_3}{4m_1m_2 + m_3(m_1 + m_2)}\right]g$; $T_2 = 2T_1$

(ii) $a_1 = \left[\frac{4m_1m_2 + m_1m_3 - 3m_2m_3}{4m_1m_2 + m_3(m_1 + m_2)}\right]g$; $a_2 = \left[\frac{3m_1m_3 - m_2m_3 - 4m_1m_2}{4m_1m_2 + m_3(m_1 + m_2)}\right]g$

$$a_3 = \left[\frac{4m_1m_2 - m_3(m_1 + m_2)}{4m_1m_2 + m_3(m_1 + m_2)}\right]g$$

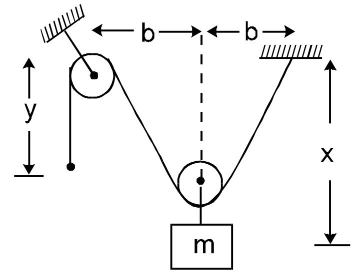
Example 23. The figure shows one end of a string being pulled down at constant velocity v. Find the velocity of mass 'm' as a function of 'x'.



Solution : Using constraint equation

$2\sqrt{x^2 + b^2}$ + y = length of string = constant

Differentiating w.r.t. time :



$$\frac{2}{2\sqrt{x^2 + b^2}} . 2x\left(\frac{dx}{dt}\right) + \left(\frac{dy}{dt}\right) = 0$$

$\Rightarrow$ $\left(\frac{dy}{dt}\right) = v$

$$\left(\frac{dx}{dt}\right) = -\frac{v}{2x}\sqrt{x^2 + b^2}$$

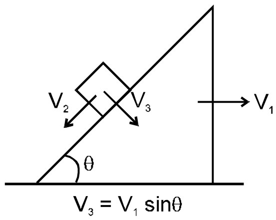
Wedge Constraint :

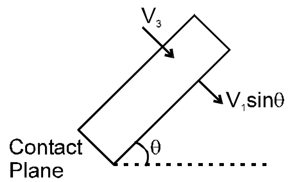
Conditions :

(i) There is a regular contact between two objects.

(ii) Objects are rigid.

The relative velocity perpendicular to the contact plane of the two rigid objects is always zero if there is a regular contact between the objects. Wedge constraint is applied for each contact.



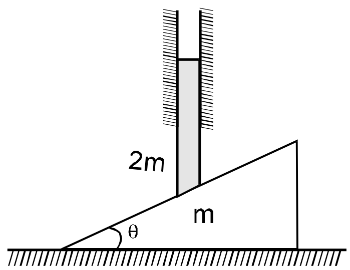


In other words,

Components of velocity along perpendicular direction to the contact plane of the two objects is always equal if there is no deformations and they remain in contact.

SOLVED EXAMPLE

Example 24. A rod of mass 2m moves vertically downward on the surface of wedge of mass as shown in figure. Find the relation between velocity of rod and that of the wedge at any instant.



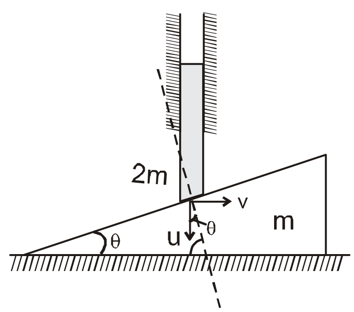
Solution : Using wedge constraint.

Component of velocity of rod along perpendicular to inclined surface is equal to velocity of wedge along that direction.

$u \cos \theta = v \sin \theta$

$\frac{u}{v} = \tan \theta$

$u = v \tan \theta$



NEWTON'S LAW FOR A SYSTEM

$\vec{F}_{ext} = m_1\vec{a}_1 + m_2\vec{a}_2 + m_3\vec{a}_3 + ...$

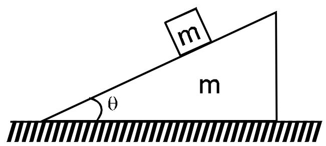
$\vec{F}_{ext} =$ Net external force on the system.

m_1, m_2, m_3 are the masses of the objects of the system and

$\vec{a}_1, \vec{a}_2, \vec{a}_3$ are the acceleration of the objects respectively.

SOLVED EXAMPLE

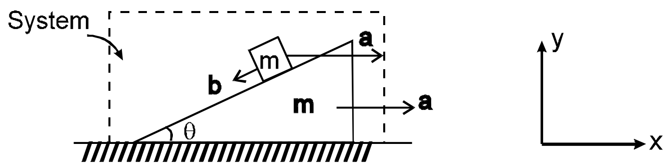
Example 25. The block of mass m slides on a wedge of mass 'm' which is free to move on the horizontal ground. Find the accelerations of wedge and block. (All surfaces are smooth).



Solution : Let . a ⇒ acceleration of wedge

b ⇒ acceleration of block with respect to wedge

Taking block and wedge as a system and applying Newton's law in the horizontal direction

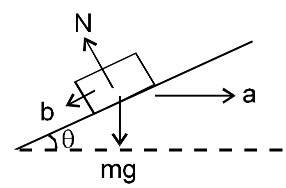


$F_x = m_1\ \vec{a}_{1x} + m_2\, \vec{a}_{2x} = 0$

$0 = ma + m(a - b\cos\theta)$ --------(i)

here 'a ' and 'b' are two unknowns , so for making second equation, we draw F.B.D. of block.

F.B.D of block.



using Newton's second law along inclined plane

$mg\sin\theta = m\,(b - a\cos\theta)$ ------(ii)

Now solving equations (1) and (2) we will get

$$a = \frac{mg\sin\theta\cos\theta}{m(1+\sin^2\theta)} = \frac{g\sin\theta\cos\theta}{(1+\sin^2\theta)}$$

and $$b = \frac{2g\sin\theta}{(1+\sin^2\theta)}$$

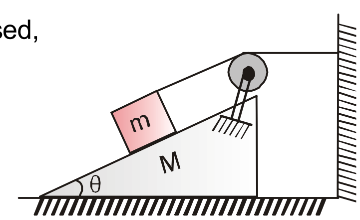
So in vector form :

$$\vec{a}_{\text{wedge}} = a\hat{i} = \left(\frac{g\sin\theta\cos\theta}{1+\sin^2\theta}\right)\hat{i}$$

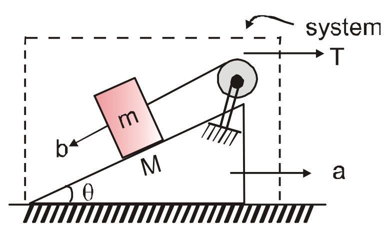
$$\vec{a}_{\text{block}} = (a - b\cos\theta)\,\hat{i} - b\sin\theta\,\hat{j}$$

$$\vec{a}_{\text{block}} = -\frac{g\sin\theta\cos\theta}{(1+\sin^2\theta)}\,\hat{i} - \frac{2g\sin^2\theta}{(1+\sin^2\theta)}\,\hat{j}\,.$$

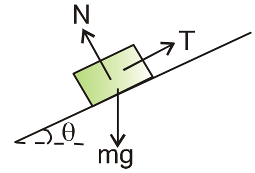
Example 26. For the arrangement shown in figure when the system is released, find the acceleration of wedge. Pulley and string are ideal and friction is absent.



Solution : Considering block and wedge as a system and using Newton' s law for the system along x– direction



$T = Ma + m\,(a - b\cos\theta)$ --------(i)

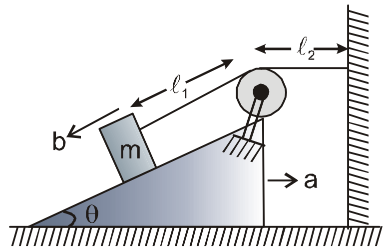


F.B.D of m

along the inclined plane

$mg\sin\theta - T = m\,(b - a\cos\theta)$ -------(ii)

using string constraint equation.



$\ell_1 + \ell_2 =$ constant

$$\frac{d^2\ell_1}{dt^2} + \frac{d^2\ell_2}{dt^2} = 0$$

$b - a = 0$ ....iii)

Solving above equations (i),(ii) & (iii) , we get

$$a = \frac{mg\sin\theta}{M + 2m(1-\cos\theta)}$$

NEWTON'S LAW FOR NON INERTIAL FRAME :

$$\vec{F}_{Real} + \vec{F}_{Pseudo} = m\vec{a}$$

Net sum of real and pseudo force is taken in the resultant force.

$\vec{a}$ = Acceleration of the particle in the non inertial frame

$$\vec{F}_{Pseudo} = -m\,\vec{a}_{Frame}$$

Pseudo force is always directed opposite to the direction of the acceleration of the frame.

Pseudo force is an imaginary force and there is no action-reaction for it. So it has nothing to do with Newton's Third Law.

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.

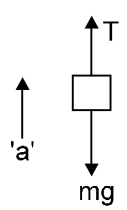
(a) **Inertial reference frame:** Frame of reference either stationary or moving with constant velocity.

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

SOLVED EXAMPLE

Example 27. A lift having a simple pendulum attached with its ceiling is moving upward with constant acceleration 'a'. What will be the tension in the string of pendulum with respect to a boy inside the lift and a boy standing on earth, mass of bob of simple pendulum is m.

Solution : **F.B.D** . of bob (with respect to ground)



$T - mg = ma$

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

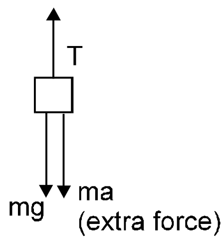
With respect to boy inside the lift, the acceleration of bob is zero.

So he will write above equation in this manner.

$T - mg = m. (0)$.

$\therefore \quad T = mg$

He will tell the value of tension in string is mg. But this is 'wrong' . To correct his result, he makes a free body diagram in this manner, and uses Newton's second law.



$T = mg + ma$ ....(ii)

By using this **extra force**, equations (i) and (ii) give the same result . This **extra force** is called **pseudo force**. This **pseudo force** is used when a problem is solved with a accelerating frame (Non-inertial)

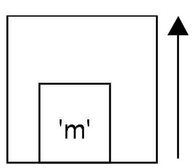
Note : Magnitude of Pseudo force = mass of system × acceleration of frame of reference .

Direction of force:

Opposite to the direction of acceleration of frame of reference, (not in the direction of motion of frame of reference)

SOLVED EXAMPLE

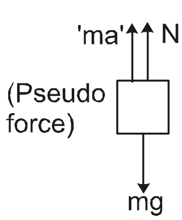
Example 28. A box is moving upward with retardation 'a' <g, find the direction and magnitude of " pseudo force" acting on block of mass 'm' placed inside the box. Also calculate normal force exerted by surface on block



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

pseudo force = ma in upward direction

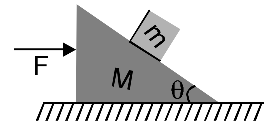
F.B.D of 'm' w.r.t. box (non–inertial)



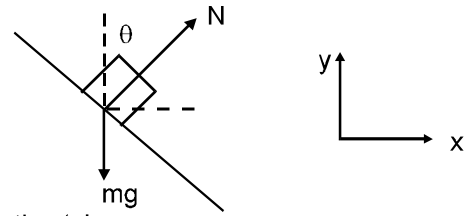
$N + ma = mg$

$N = mg - ma$

Example 29. All surfaces are smooth in the adjoining figure. Find F such that block remains stationary with respect to wedge.



Solution : Acceleration of (block + wedge) is $a = \frac{F}{(M+m)}$



Let us solve the problem by using both frames.

From inertial frame of reference (Ground)

F.B.D. of block w.r.t. ground (Apply real forces) :

with respect to ground block is moving with an acceleration 'a' .

$\therefore \ \Sigma F_y = 0 \Rightarrow N\cos\theta = mg$ ....(i)

and $\Sigma F_x = ma \Rightarrow N\sin\theta = ma$ .....(ii)

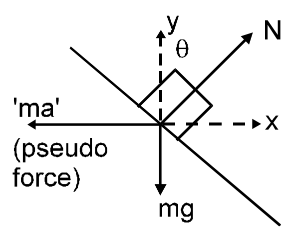
From Eqs. (i) and (ii)

$a = g\tan\theta$

$\therefore \ F = (M + m)\,a \quad = (M + m)\,g\tan\theta$

From non–inertial frame of reference (Wedge) :

F.B.D. of block w.r.t . wedge (real forces + pseudo force)



w.r.t. wedge, block is stationary

$\therefore \ \sum F_y = 0 \Rightarrow N\cos\theta = mg$ ....(iii)

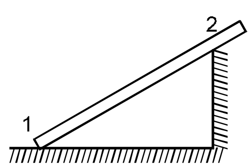
$\sum F_x = 0 \Rightarrow N\sin\theta = ma$ ....(iv)

From Eqs. (iii) and (iv) , we will get the same result

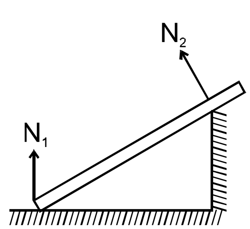
i.e. $F = (M + m)\,g\tan\theta$.

MISCELLANEOUS SOLVED EXAMPLE

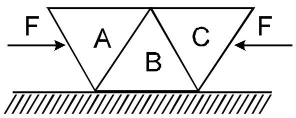
Problem 1. Draw normal forces on the massive rod at point 1 and 2 as shown in figure.



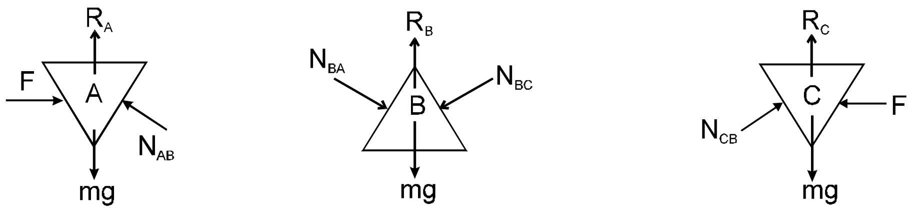
Solution : Normal force acts perpendicular to extended surface at point of contact.



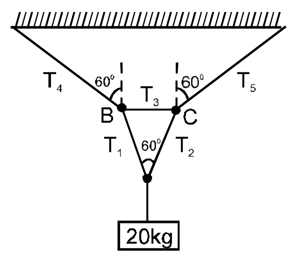
Problem 2. Three triangular blocks A,B and C of equal masses 'm' are arranged as shown in figure. Draw F.B.D. of blocks A,B and C. Indicate action–reaction pair between A,B and B,C.



Solution :

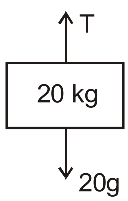


Problem 3. The system shown in figure is in equilibrium, find the tension in each string ; T_1, T_2, T_3, T_4 and T_5.



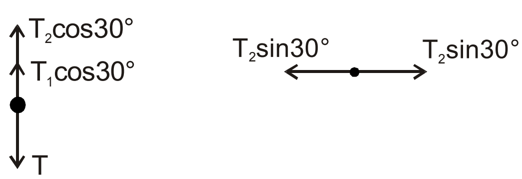
Answer : $T_1 = T_2 = \frac{200}{\sqrt{3}}$ N, $T_4 = T_5 = 200$ N, $T_3 = \frac{200}{\sqrt{3}}$ N.

Solution : **<u>FBD of 20 kg block</u>** →



So, **T = 20 × g = 200 N** .... (1)

<u>From figure</u> →



$\mathbf{T = T_1\cos30° + T_2\cos30°}$ .... (2)

$T_1\sin30° = T_2\sin30°$

$\mathbf{T_1 = T_2}$ .... (3)

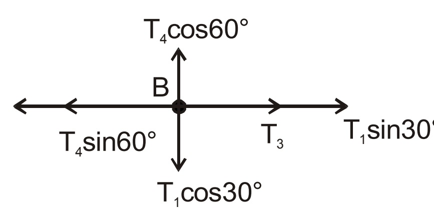
so from equation (3) $T = 2T_1\cos30°$

$\mathbf{T_1 = \frac{200}{\sqrt{3}} = T_2}$ .... (4)

<u>From figure FBD of point B</u> →

In vertical direction

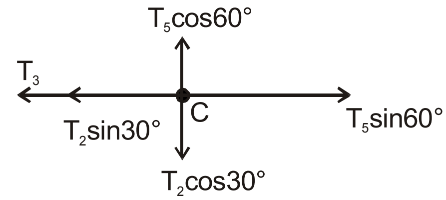
So, $T_4\cos60° = T_1\cos30°$



$T_4 \times \frac{1}{2} = \frac{200}{\sqrt{3}} \times \frac{\sqrt{3}}{2} = 200$ N

So, $\mathbf{T_4 = 200}$ **N**

FBD of point C $\rightarrow$



Equating forces In vertical direction -

$T_5\cos60° = T_2\cos30°$

$$T_5 \times \frac{1}{2} = \frac{200}{\sqrt{3}} \times \frac{\sqrt{3}}{2}$$

T_5 = 200 N

For T_3 $\rightarrow$

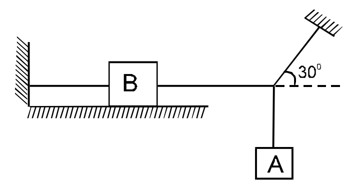
Equating forces in horizontal direction -

$T_3 + T_2\sin30° = T_5\sin60°$

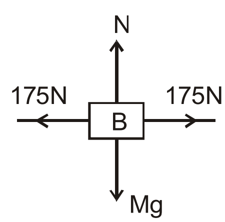
$$T_3 = 200 \times \frac{\sqrt{3}}{2} - \frac{200}{\sqrt{3}} \times \frac{1}{2}$$

$$\mathbf{T_3 = \frac{200}{\sqrt{3}} N}$$

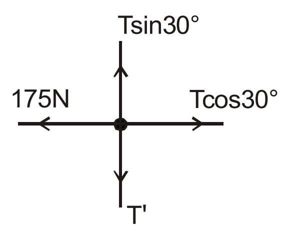
Problem 4. The breaking strength of the string connecting wall and block B is 175 N, find the magnitude of weight of block A for which the system will be stationary. The block B weighs 700 N. (g = 10 m/s²)



Solution : **FBD of block B** $\rightarrow$



FBD of point in figure $\rightarrow$



Equating forces in horizontal direction $\rightarrow$

$T\cos30° = 175$

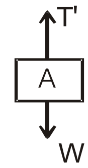
$$T = \frac{175 \times 2}{\sqrt{3}} N$$

In vertical direction $\rightarrow$

$T\sin30° = T'$

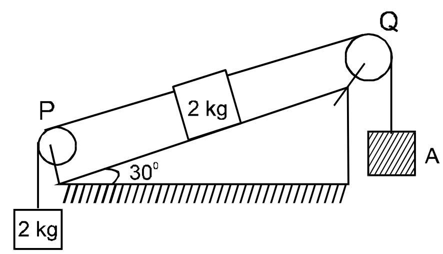
So, $$T' = \frac{175 \times 2}{\sqrt{3}} \times \frac{1}{2} = \frac{175}{\sqrt{3}} N$$

FBD of block A →



So, $\mathbf{T' = W = \frac{175}{\sqrt{3}} N}$

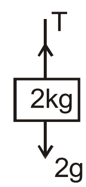
Problem 5. In the arrangement shown in figure, what should be the mass of block A so that the system remains at rest. Also find force exerted by string on the pulley Q. ($g = 10\ m/s^2$)



Answer. m = 3 kg, $30\sqrt{3}$ N.

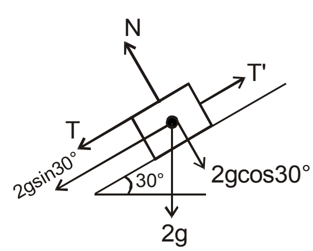
Solution : From figure

FBD of 2 kg block hanging vertically →



T = 20 N .... (1)

FBD of 2kg block on incline plane →

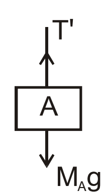


Along the plane →

$T + 2g\sin 30° = T'$

$T' = 20 + 20 \times \frac{1}{2} = 30\ N$

FBD of block A →

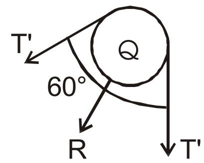


So $T' = M_A g$

$M_A = \frac{T'}{g} = \frac{30}{10} = 3\ kg$

$M_A = 3\ kg$

FBD of pulley Q →



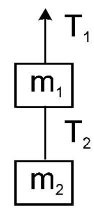
So, $R = 2T'\cos\frac{\theta}{2}$

$R = 2\times30\cos30°$

$R = 2\times30\times\frac{\sqrt{3}}{2}$

$\mathbf{R = 30\sqrt{3}\ N}$

Problem 6. Two blocks with masses $m_1 = 0.2$ kg and $m_2 = 0.3$ kg hang one under other as shown in figure. Find the tensions in the strings (massless) in the following situations : ($g = 10\ m/s^2$)



(a) the blocks are at rest

(b) they move upward at 5 m/s

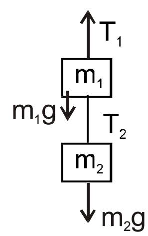
(c) they accelerate upward at 2 m/s^2

(d) they accelerate downward at 2 m/s^2

(e) if maximum allowable tension is 10 N. What is maximum possible upward acceleration ?

Ans. (a) 5 N, 3 N (b) 5 N, 3 N (c) 6 N, 3.6 N (d) 4 N, 2.4 N (e) 10 m/s^2

Solution : (a) At rest $a = 0$



$T_2 = m_2g = 0.3\times10 = 3N$

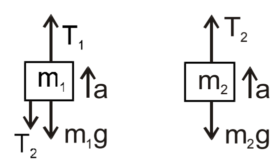
$T_1 = m_1g + T_2$

$T_1 = 0.2\times10 + 3 = 5\ N$

(b) same as above

$a = 0,\ T_2 = 3N,\ T_1 = 5N$

(c) $a = 2m/s^2$ ↑ (upward)



$T_2 - m_2g = m_2a$

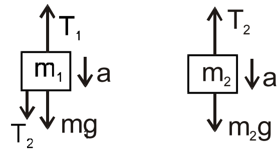
$\Rightarrow T_2 - m_2g = m_2a$

$\Rightarrow T_2 - 0.3\times10 = 0.3\times2$

$\Rightarrow T_2 = 0.6 + 3 = 3.6\ N$

$T_1 - m_1g - T_2 = m_1a \Rightarrow T_1 - 0.2\times10 - 3.6 = 0.2\times2 \Rightarrow T_1 = 0.4 + 5.6 = 6N$

(d) $a = 2\ m/s^2$ (downward)



$m_2g - T_2 = m_2a$

$\Rightarrow 0.3\times10 - T_2 = 0.3\times2$

$\Rightarrow T_2 = 3 - 0.6 = 2.4\ N$

$T_2 + m_1g - T_1 = m_1a$

$\Rightarrow 2.4 + 2 - T_1 = 0.2\times2$

$\Rightarrow T_1 = 4.4 - 0.4 =$ **4 N Ans.**

(e) Chance of breaking is of upper string means $T_1 < 10$ N

For m_1 –

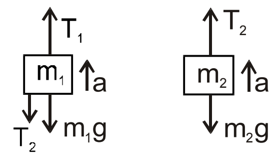
$T_1 - m_1g - T_2 = m_1a$

$10 - 2 - T_2 = 0.2\,a$ .... (1)

For m_2 –

$T_2 - m_2g = m_2a$

$\Rightarrow\ T_2 - 3 = 0.3\,a$ .... (2)



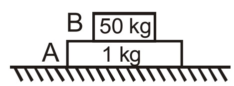
Adding equation (1) and (2)

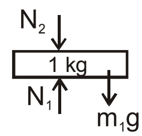
$8 - 3 = 0.5\,a$

$\Rightarrow\ a = \dfrac{5}{0.5} = \mathbf{10\ m/s^2}$

Problem 7. A block of mass 50 kg is kept on another block of mass 1 kg as shown in figure. A horizontal force of 10 N is applied on the 50kg block. (All surface are smooth). Find ($g = 10$ m/s²)
(a) Acceleration of block A and B.
(b) Force exerted by B on A.

Answer : (a) 0.2 m/s², 0 (b) 500 N





Solution : (a) **<u>FBD of A block</u>**

$N_2 = 50 \times 10 = 500$ N

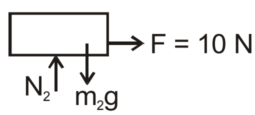
$m_1g = 1 \times 10 = 10$ N

$N_1 = N_2 + m_1g = 500 + 10 = 510$ N

$a_A = 0$ (No horizontal force)

<u>FBD of B block</u>

Vertical $N_2 = m_2g = 500$ N

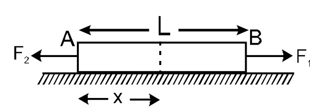


Horizontal force

$F = ma \ \Rightarrow 10 = 50 \times a \ \Rightarrow\ a = \dfrac{1}{5}$ m/s²

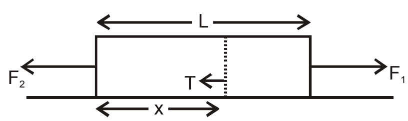
(b) Force exerted By B on A $\rightarrow$
$= N_2 = 500$N (Vertically downwards)

Problem 8. Two forces F_1 and F_2 ($F_2 > F_1$) are applied at the free ends of uniform rod kept on a horizontal frictionless surface. Find tension in rod at a distance x from end 'A',

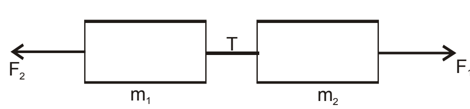


Answer : $T = F_2 - \dfrac{(F_2 - F_1)}{L}.x$

Solution : $a = \dfrac{F_2 - F_1}{m}$



$T - F_1 = m_2a$

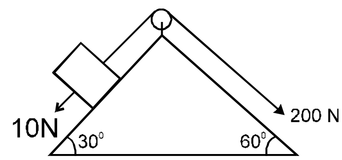


$\Rightarrow \quad T - F_1 = \frac{m}{L}(L-x)\frac{F_2 - F_1}{m} \; (m_2 = \frac{m}{L}(L-x))$

$\Rightarrow \quad T = F_1 + \left(1 - \frac{x}{L}\right)(F_2 - F_1)$

$= F + F_2 - F_1 - \frac{x}{L}(F_2 - F_1) \qquad = F_2 - \frac{x}{L}(F_2 - F_1)$

Problem 9. A 10 kg block kept on an inclined plane is pulled by a string applying 200 N force. A 10 N force is also applied on 10 kg block as shown in figure.
Find : (a) tension in the string.
(b) acceleration of 10 kg block.
(c) net force on pulley exerted by string



Answer : (a) 200 N, (b) 14 m/s^2, (c) $200\sqrt{2}$ N

Solution :

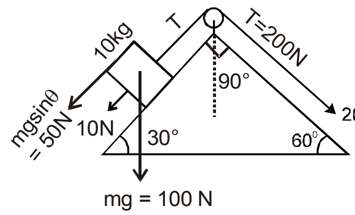
(a) T = **200 N**

(b) $T - 10 - mg\sin\theta = ma$

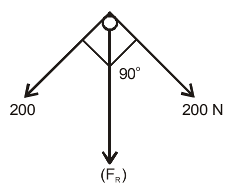
$\Rightarrow \quad T - 10 - 50 = 10a$

$\Rightarrow \quad 200 - 60 = 10a$

$\Rightarrow \quad a = \frac{140}{10} = \mathbf{14\ m/s^2}$



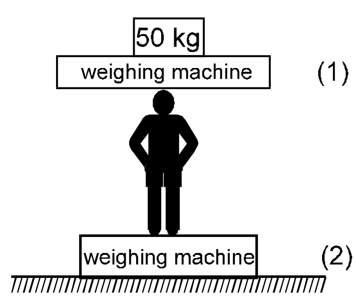
(c)



$(F_R) = \sqrt{(200)^2 + (200)^2}$

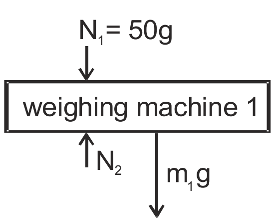
$= \mathbf{200\sqrt{2}\ N}$ **Ans.**

Problem 10. A man of mass 60 kg is standing on a weighing machine (2) of mass 5kg placed on ground. Another similar weighing machine is placed over man's head. A block of mass 50kg is put on the weighing machine (1) . Calculate the readings of weighing machines (1) and (2) (g = 10 m/s^2)

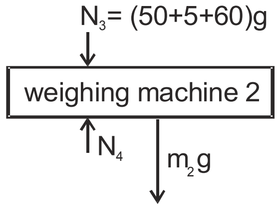


Answer : **500 N, 1150 N**

Solution :



$R_1 = N_1 = 50 \times g = 500$ N
where R_1 = reading in weighing machine 1



$R_2 = N_3$

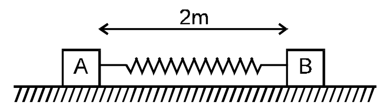
= (50 + 5 +60) g

= 115 × 10

= 1150 N

where R_2 = reading in weighing machine 2

Problem 11. 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) A is kept at rest and B is displaced by 1 m in right direction.

(b) B is kept at rest and A is displaced by 1m in left direction.

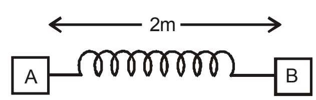
(c) A is displaced by 0.75 m in right direction, and B is 0.25 m in left direction.

Answer : (a) F = 200 N, (b) 200 N, (c) 200 N

Solution : (a) Extension in spring = 1 m.

∴ F_{spring} = Kx

= 200 × 1 = 200 N



(b) Same extension same spring force in both directions -

F_{spring} = 200 N.

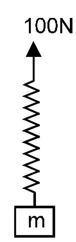
(c) Both displacements of A of B are compressing the spring

total compressing = 0.75 + 0.25 = 1 m.

∴ F_{spring} = k x

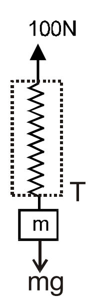
= 200 × 1 = 200 N.

Problem 12. If force constant of spring is 50 N/m. Find mass of the block, if it is at rests in the given situation . (g = 10 m/s²)



Answer m = 10 kg

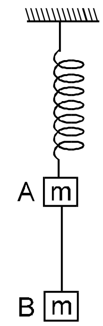
Solution : T = 100 N



⇒ mg = 100 N

$m = \frac{100}{g}$ = 10 kg.

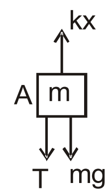
Problem 13. Two blocks 'A' and 'B' of same mass 'm' attached with a light string are suspended by a spring as shown in figure Find the acceleration of block 'A' and 'B' just after the string is cut..



Answer : g (upwards), g (downwards)

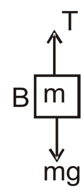
Solution : <u>**When string is not cut**</u> **:**

<u>**FBD of 'A' block**</u>



$kx = mg + T$ ....(i)

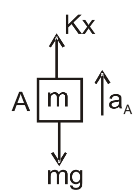
<u>**F. B.D of 'B' block**</u>



$T = mg$ ....(ii)

<u>**When string is cut :**</u>

<u>**FBD of 'A' block**</u>

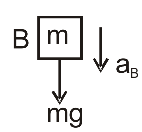


$kx - mg = ma_A$

$2mg - mg = ma_A$

$= a_A = g$ (upwards)

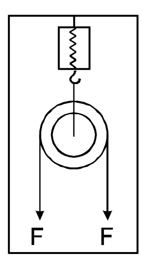
<u>**FBD of 'B' block**</u>



$ma_B = mg$

$a_B = g$ (downwards)

Problem 14. Find the reading of spring balance in the adjoining figure, pulley and strings are ideal.

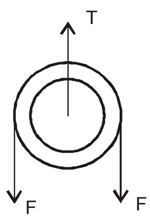


Answer : 2F

Solution : **FBD of spring balance**

R = T ....(i)

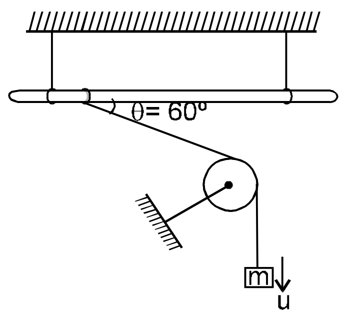
FBD of pulley



T = 2 F ....(ii)

R = 2F

Problem 15. The figure shows mass m moves with velocity u. Find the velocity of ring at that moment. Ring is restricted to move on smooth rod.



Answer : $V_R = \dfrac{u}{\cos\theta}$, $V_R = 2u$

Solution : Velocity along string remains same .

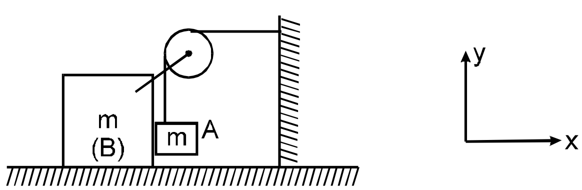
$V_R \cos\theta = u$

$V_R = \dfrac{u}{\cos\theta}$

$\theta = 60^\circ$

$V_R = 2u$

Problem 16. In the system shown in figure, the block A is released from rest. Find :



(i) the acceleration of both blocks 'A' and 'B'.

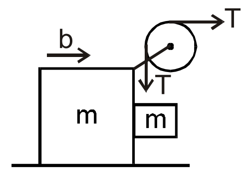
(ii) Tension in the string.

(iii) Contact force between 'A' and 'B'.

Answer : (i) $\frac{g}{3}\hat{i}-\frac{g}{3}\hat{j}$, $\frac{g}{3}\hat{i}$ (ii) $\frac{2mg}{3}$ (iii) $\frac{mg}{3}$.

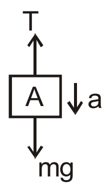
Solution : (i) Let acceleration of blocks in x & y directions are

Taking both blocks as a system



T = 2mb .... (i)

Taking A block :



mg – T = ma ....(ii)

From equations (i) & (ii) ; ma + 2 mb = mg

a + 2 b = g ....(iii)

From string constraint ;

a = b ....(iv)

From equations (iii) & (iv);$a = b = \frac{g}{3}$

hence, acceleration of block A

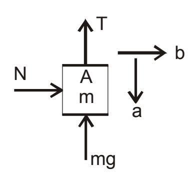
$a_A = b\hat{i} - a\hat{j}$ $a_A = \frac{g}{3}\hat{i} - \frac{g}{3}\hat{j}$

acceleration of block B $a_B = b\hat{i} = \frac{g}{3}\hat{i}$

(ii) $T = 2mb = \frac{2mg}{3}$

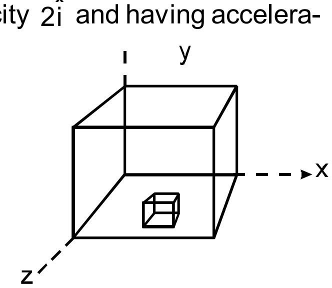
(iii) For contact force between 'A' and 'B'

FBD of block 'A'



N = mb $N = \frac{mg}{3}$

Problem 17. A block of mass 2 kg is kept at rest on a big box moving with velocity $2\hat{i}$ and having acceleration $-3\hat{i}+4\hat{j}$ m/s². Find the value of 'Pseudo force' acting on block with respect to box



Answer : $\vec{F}_{pseudo} = -m\vec{a}_{frame} = -2(-3\hat{i}+4\hat{j})$

$F = 6\hat{i}-8\hat{j}$.

Exercise # 1

PART-I : SUBJECTIVE QUESTIONS

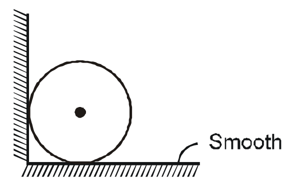
SECTION (A) : TYPE OF FORCES, NEWTON'S THIRD LAW, FREE BODY DIAGRAM :

A-1. Which one out of four fundamental forces is the weakest force between two protons at a distance of 1 Fermi.

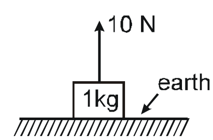
A-2. Suppose you are running fast in a field. When you suddenly find a snake in front of you, you stop quickly. Which force is responsible for your deceleration ?

A-3. A block 'A' exerts a force on 'B' of magnitude 20 N. Calculate the magnitude of force exerted by 'B' on 'A'.

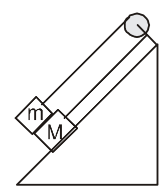
A-4. Draw F.B.D. of the sphere of mass M placed between a vertical wall and ground as shown in figure (All surfaces are smooth).



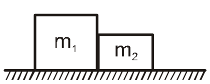
A-5.✍ A block of mass 1 kg placed on ground is pulled by a string by applying 10 N force : (g = 10 m/s^2)
(i) Draw F.B.D. of block.
(ii) Give action–reaction pair involved in the above problem.

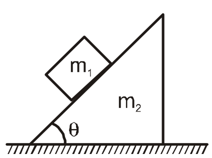


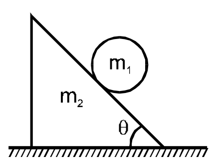
A-6. Draw free body diagrams for masses m and M shown in figure. Identify all action-reaction pairs between two blocks. The pulley is frictionless and massless and all surfaces are smooth.

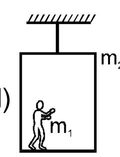


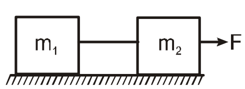
A-7. Draw the FBD for the following individual parts of the systems :
(Pulley are massless and friction less)

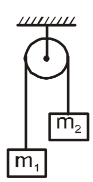
(a) 

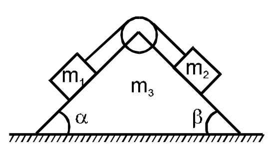
(b) 

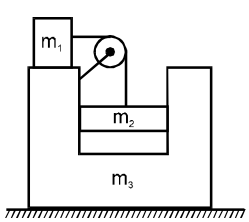
(c) 

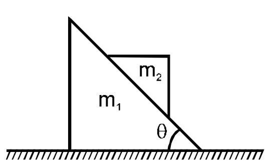
(d) 

(e) 

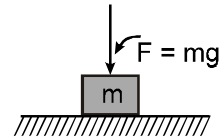
(f) 

(g) 

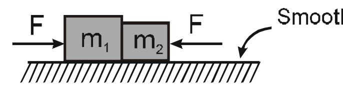
(h) 

(i) 

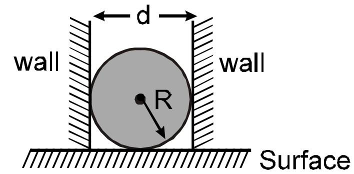
SECTION (B) : CALCULATION OF NORMAL REACTION



B-1. A block of mass 'm' is placed on ground and an additional force F = mg is applied on the block as shown in figure. Calculate contact force between ground and block.

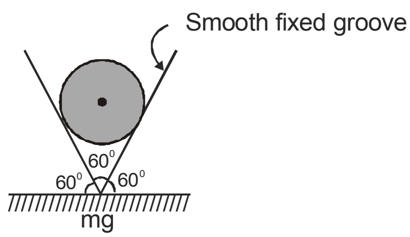


B-2. Two blocks of masses m_1 and m_2 are placed on ground as shown in figure. Two forces of magnitude F act on m_1 and m_2 in opposite directions.
(i) Draw F.B.D. of masses m_1 and m_2.
(ii) Calculate the contact force between m_1 and m_2.
(iii) What will be the value of normal force between m_1 and m_2 .
(iv) Calculate force exerted by ground surface on mass m_1 and m_2

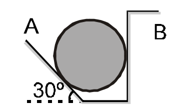


B-3. A sphere of mass 'm', radius 'R' placed between two vertical walls having separation 'd' which is slightly greater than '2R' :
(i) Calculate force exerted by walls on the sphere.
(ii) Calculate force exerted by ground surface on the sphere.

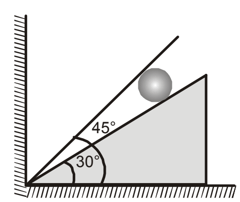
B-4. A cylinder of weight w is resting on a fixed V-groove as shown in figure.



(a) Draw its free body diagram.
(b) Calculate normal reactions between the cylinder and two inclined walls.

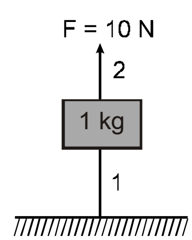


B-5. The 50 kg homogeneous smooth sphere rests on the 30º incline A and bears against the smooth vertical wall B. Calculate the contact forces at A and B.



B-6. A spherical ball of mass m = 5 kg rests between two planes which make angles of 30^0 and 45^0 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.

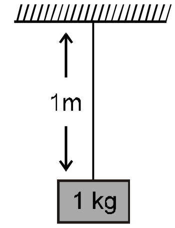
SECTION (C) : CALCULATION OF TENSION



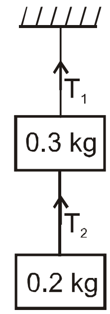
C-1. A string 1 is connected between surface and a block of mass 1 kg which is pulled by another string 2 by applying force F = 10 N as shown in figure. (g = 10 m/s^2)
(i) Calculate tension in string (1).
(ii) Calculate tension in string (2).

C-2. A one meter long massless string fixed with a wall is pulled horizontally by applying a force of magnitude 10 N. Calculate :
(a) the tension at a point 0.5m away from wall.
(b) the tension at a point 0.75 m away from wall.
(c) force exerted by string on the rigid support.

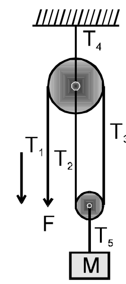
C-3. A block of mass 1 kg is suspended by a string of mass 1 kg, length 1m as shown in figure. ($g = 10\ m/s^2$) Calculate:
(a) the tension in string at its lowest point.
(b) the tension in string at its mid–point.
(c) force exerted by support on string.



C-4. A block of mass 0.3 kg is suspended from the ceiling by a light string. A second block of mass 0.2 kg is suspended from the first block through another string. Find the tensions in the two strings. Take $g = 10\ m/s^2$.

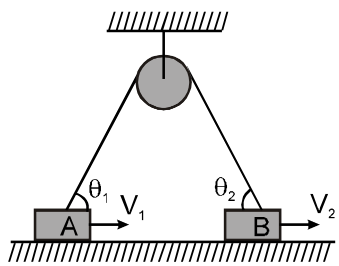


C-5. A mass M is held in place by an applied force F and a pulley system as shown in figure. The pulleys are massless and frictionless.
(a) Find the tension in each section of rope T_1, T_2, T_3, T_4 and T_5.
(b) Find the magnitude of F.

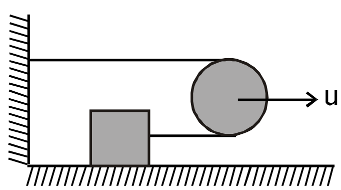


SECTION (D) : CONSTRAINED MOTION

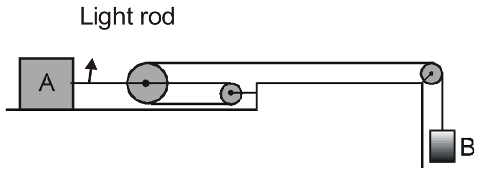
D-1. In the figure shown, blocks A and B move with velocities v_1 and v_2 along horizontal direction. Find the ratio of $\frac{v_1}{v_2}$.



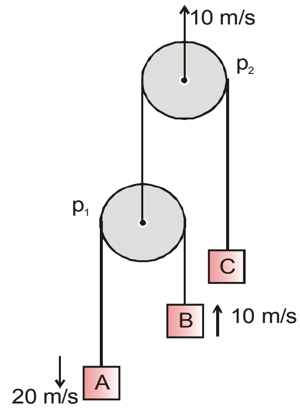
D-2. In the figure shown, the pulley is moving with velocity u. Calculate the velocity of the block attached with string.



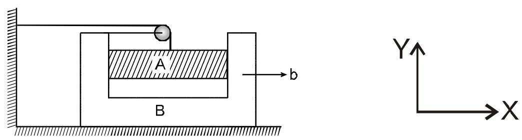
D-3. If block A has a velocity of 0.6 m/s to the right, determine the velocity of block B.



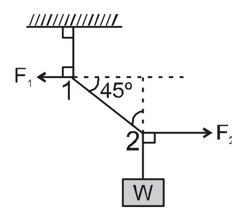
D-4. Velocities of blocks A, B and pulley p_2 are shown in figure. Find velocity of pulley p_1 and block C.



D-5. Find the acceleration of A in term of b.



SECTION (E) : CALCULATION OF FORCE AND ACCELERATION

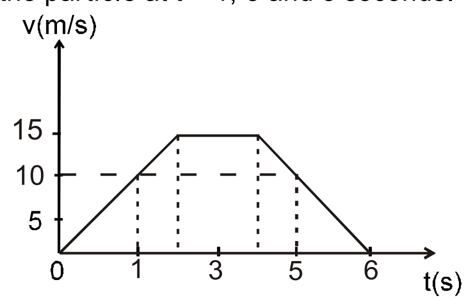


E-1. In the figure the tension in the string between 1 and 2 is 60 N.

(a) Find the magnitude of the horizontal force $\vec{F}_1$ and $\vec{F}_2$ that must be applied to hold the system in the position shown.

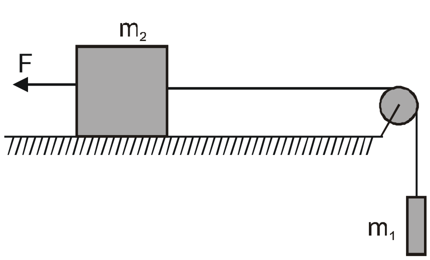
(b) What is the weight of the suspended block ?

E-2. A particle of mass 100 gram moves on a straight line. The variation of speed with time is shown in figure. Find the force acting on the particle at t = 1, 3 and 5 seconds.

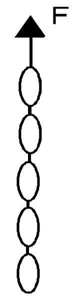


E-3. A 3.0 kg mass is moving in a plane, with its x and y coordinates given by $x = 5t^2 - 1$ and $y = 3t^3 + 2$, where x and y are in meters and t is in second. Find the magnitude of the net force acting on this mass at t = 2 sec.

E-4. A constant force $F = m_1g / 2$ is applied on the block of mass m_2 as shown in figure. The string and the pulley are light and the surface of the table is smooth. Find the acceleration of m_2.



E-5. A chain consisting of five links each with mass 100gm is lifted vertically with constant acceleration of $2 m/s^2$ (↑) as shown. Find : ($g = 10 m/s^2$) :



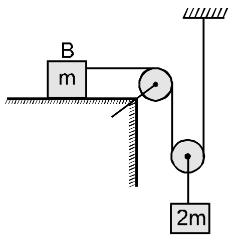
(a) the forces acting between adjacent links

(b) the force F exerted on the top link by the agent lifting the chain

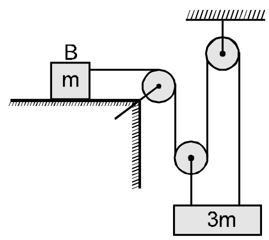
(c) the net force on each link.

E-6. Find out the acceleration of the block B in the following systems :

(a)

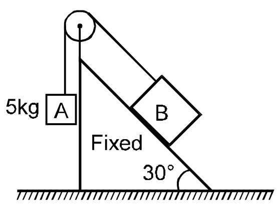


(b)

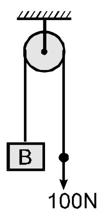


E-7. Find out the mass of block B to keep the system at rest : ($g = 10 m/s^2$)

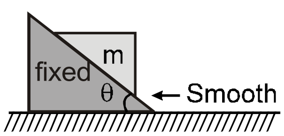
(a)



(b)



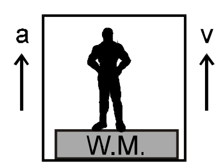
E-8. A block of mass 'm' is placed on inclined plane as shown in figure. Now block is released from rest, calculate normal reaction between block and inclined plane.



SECTION (F) : WEIGHING MACHINE, SPRING RELATED PROBLEMS AND SPRING BALANCE

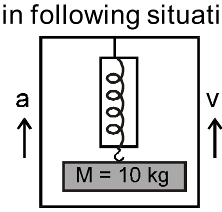
F-1. A man of mass 60 kg is standing on a weighing machine placed in a lift moving with velocity 'v' and acceleration 'a' as shown in figure. Calculate the reading of weighing machine in following situations : ($g = 10 m/s^2$)

(i) $a = 0$, $v = 0$
(ii) $a = 0$, $v = 2$ m/s
(iii) $a = 0$, $v = -2$m/s
(iv) $a = 2m/s^2$, $v = 0$
(v) $a = -2 m/s^2$ $v = 0$
(vi) $a = 2 m/s^2$, $v = 2$ m/s
(vii) $a = 2 m/s^2$, $v = -2$ m/s
(viii) $a = -2 m/s^2$ $v = -2$ m/s

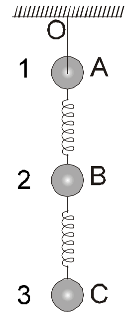


F-2. What will be the reading of spring balance in the figure shown in following situations. ($g = 10 m/s^2$)

(i) $a = 0$, $v = 0$
(ii) $a = 0$, $v = 2$ m/s
(iii) $a = 0$, $v = -2$m/s
(iv) $a = 2m/s^2$, $v = 0$
(v) $a = -2 m/s^2$ $v = 0$
(vi) $a = 2 m/s^2$, $v = 2$ m/s
(vii) $a = 2 m/s^2$, $v = -2$ m/s
(vii) $a = -2 m/s^2$ $v = -2$ m/s



F-3. Three identical balls 1,2,3 are suspended on springs one below the other as shown in the figure. OA is a weightless thread. The balls are in equilibrium

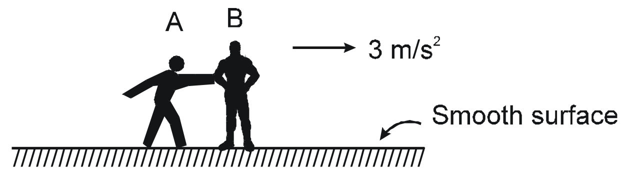


(a) If the thread is cut, the system starts falling. Find the acceleration of all the balls at the initial instant

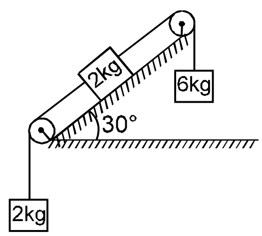
(b) Find the initial accelerations of all the balls if we cut the spring BC, which is supporting ball 3, instead of cutting the thread.

SECTION (G) : NEWTON'S LAW FOR A SYSTEM

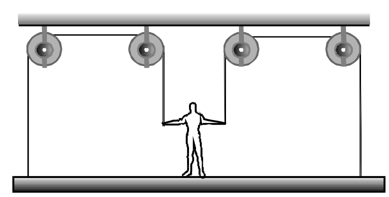
G-1. Man 'A' of mass 60 kg pushes the other man 'B' of mass 75 kg due to which man 'B' starts moving with acceleration 3 m/s^2. Calculate the acceleration of man 'A' at that instant.



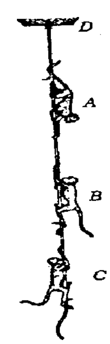
G-2. Find the acceleration of the 6 Kg block in the figure. All the surfaces and pulleys are smooth. Also the strings are inextensible and light. [Take g = 10 m/s^2]



G-3. A painter of mass M stands on a platform of mass m and pulls himself up by two ropes which hang over pulley as shown. He pulls each rope with the force F and moves upward with uniform acceleration 'a'. Find 'a'



G-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 . Monkey B is climbing up with a constant speed of 0.8 m/s . Calculate the tension T in the rope at D. (g = 10 m/s^{-2})

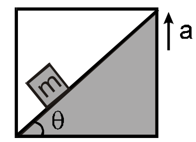


SECTION (H) : PSEUDO FORCE

H-1. An object of mass 2 kg is placed at rest in a frame (S_1) moving with velocity $10\hat{i}+5\hat{j}$ m/s and having acceleration $5\hat{i}+10\hat{j}$ m/s². This object is also seen by an observer standing in a frame (S_2) moving with velocity $5\hat{i}+10\hat{j}$ m/s.

(i) Calculate 'Pseudo force' acting on object. Which frame is responsible for this force.
(ii) Calculate net force acting on object with respect to S_2 frame.
(iii) Calculate net force acting on object with respect to S_1 frame.

H-2. In the adjoining figure, a wedge is fixed to an elevator moving upwards with an acceleration 'a'. A block of mass 'm' is placed over the wedge. Find the acceleration of the block with respect to wedge. Neglect friction.



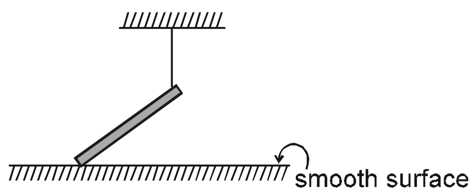
PART - II : OBJECTIVE QUESTIONS

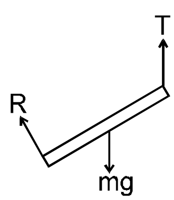
*** Marked Questions may have more than one correct option.**

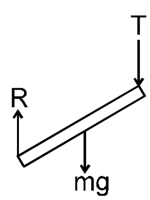
SECTION (A) : TYPE OF FORCES, NEWTON'S THIRD LAW, FREE BODY DIAGRAM :

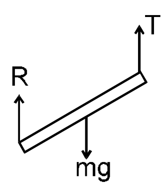
A-1*. Action and reaction pair
(A) act on two different objects
(B) have equal magnitude
(C) have opposite directions
(D) have same directions

A-2. Which figure represents the correct F.B.D. of rod of mass m as shown in figure :



(A) 

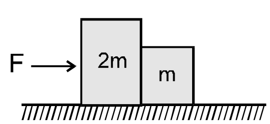
(B) 

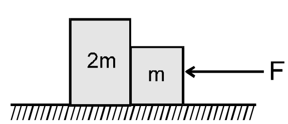
(C) 

(D) None of these

SECTION (B) : CALCULATION OF NORMAL REACTION

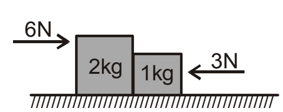
B-1. Two blocks are in contact on a frictionless table. One has mass m and the other 2m. A force F is applied on 2m as shown in the figure. Now the same force F is applied from the right on m. In the two cases respectively, the ratio of force of contact between the two blocks will be :





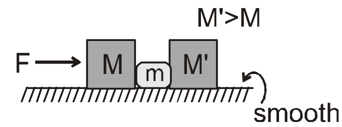
(A) same
(B) 1 : 2
(C) 2 : 1
(D) 1 : 3

B-2. Two forces of 6N and 3N are acting on the two blocks of 2kg and 1kg kept on frictionless floor. What is the force exerted on 2kg block by 1kg block ?



(A) 1N
(B) 2N
(C) 4N
(D) 5N

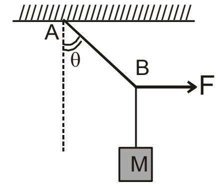
B-3. A constant force F is applied in horizontal direction as shown. Contact force between M and m is N and between m and M' is N' then



(A) N = N'
(B) N > N'
(C) N' > N
(D) cannot be determined

SECTION (C) : CALCULATION OF TENSION

C-1. 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 :

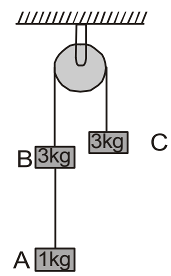


(A) F sin θ
(B) F/sin θ
(C) F cos θ
(D) F/cos θ

C-2. Two persons are holding a light rope tightly at its ends so that it is horizontal. A 15 kg weight is attached to the rope at the mid point which now no longer remains horizontal. The minimum tension required to completely straighten the rope is :

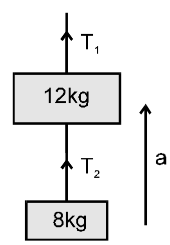
(A) 15 kg
(B) $\frac{15}{2}$ kg
(C) 5 kg
(D) Infinitely large (or not possible)

C-3. In the system shown in the figure, the acceleration of the 1 kg mass and the tension in the string connecting between A and B is :



(A) $\frac{g}{4}$ downwards , $\frac{8g}{7}$
(B) $\frac{g}{4}$ upwards, $\frac{g}{7}$
(C) $\frac{g}{7}$ downwards , $\frac{6}{7}g$
(D) $\frac{g}{2}$ upwards , g

C-4. A body of mass 8 kg is hanging from another body of mass 12 kg. The combination is being pulled by a string with an acceleration of 2.2 m s^{-2}. The tension T_1 and T_2 will be respectively : (use g = 9.8m/s^2)

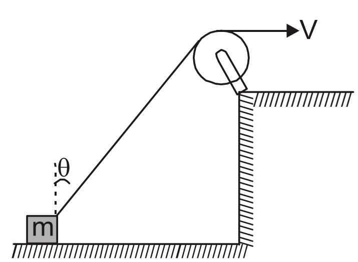


(A) 200 N, 80 N
(B) 220 N, 90 N
(C) 240 N, 96 N
(D) 260 N, 96 N

C-5. 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 on the pulley due to string is nearly
(A) mg (B) 2 mg (C) 4 mg (D) can not be determined

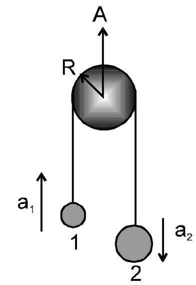
SECTION (D) : CONSTRAINED MOTION

D-1. A block is dragged on smooth plane with the help of a rope which moves with velocity v. The horizontal velocity of the block is :



(A) v
(B) $\frac{v}{\sin\theta}$
(C) v sin θ
(D) $\frac{v}{\cos\theta}$

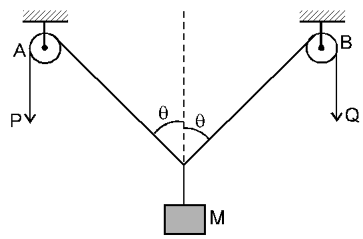
D-2. Two masses are connected by a string which passes over a pulley accelerating upward at a rate A as shown. If a_1 and a_2 be the acceleration of bodies 1 and 2 respectively then :



(A) $A = a_1 - a_2$ (B) $A = a_1 + a_2$

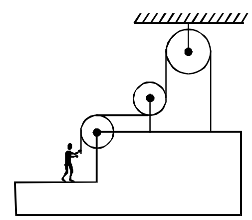
(C) $A = \frac{a_1 - a_2}{2}$ (D) $A = \frac{a_1 + a_2}{2}$.

D-3. In the arrangement shown in fig. the ends P and Q of an unstretchable string move downwards with uniform speed U. Pulleys A and B are fixed. Mass M moves upwards with a speed.



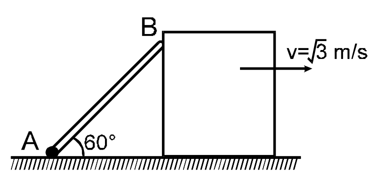
(A) $2\,U\cos\theta$ (B) $U\cos\theta$ (C) $2\,U/\cos\theta$ (D) $U/\cos\theta$

D-4. A system is shown in the figure. A man standing on the block is pulling the rope. Velocity of the point of string in contact with the hand of the man is 2 m/s downwards. The velocity of the block will be: [assume that the block does not rotate]



(A) 3 m/s (B) 2 m/s
(C) 1/2 m/s (D) 1 m/s

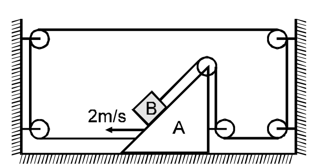
D-5. A rod AB is shown in figure. End A of the rod is fixed on the ground. Block is moving with velocity $\sqrt{3}$ m/s towards right. The velocity of end B of rod when rod makes an angle of 60º with the ground is:



(A) $\sqrt{3}$ m/s (B) 2 m/s

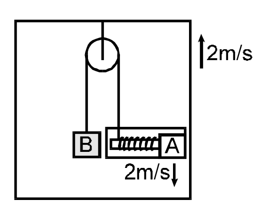
(C) $2\sqrt{3}$ m/s (D) 3 m/s

D-6. System is shown in figure and wedge is moving towards left with speed 2 m/s. Then velocity of the block B will be:



(A) $\sqrt{3}$ m/s (B) 1 m/s
(C) 2 m/s (D) 0 m/s

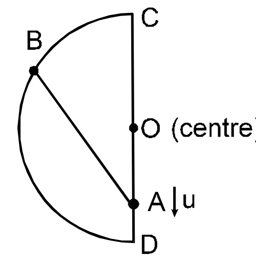
D-7. In the figure shown the velocity of lift is 2 m/s while string is winding on the motor shaft with velocity 2 m/s and block A is moving downwards with a velocity of 2 m/s, then find out the velocity of block B.



(A) 2 m/s ↑ (B) 2 m/s ↓

(C) 4 m/s ↑ (D) 8 m/s ↑

D-8. Two beads A and B move along a semicircular wire frame as shown in figure. The beads are connected by an inelastic string which always remains tight. At an instant the speed of A is u, $\angle BAC = 45°$ and $\angle BOC = 75°$, where O is the centre of the semicircular arc. The speed of bead B at that instant is



(A) $\sqrt{2}u$ (B) u

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

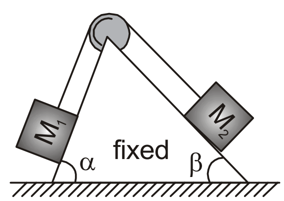
SECTION (E) : CALCULATION OF FORCE & ACCELERTION

E-1. When a constant force is applied to a body, it moves with uniform :
(A) acceleration (B) velocity (C) speed (D) momentum

E-2. An object will continue accelerating until :
(A) resultant force on it begins to decrease
(B) its velocity changes direction
(C) the resultant force on it is zero
(D) the resultant force is at right angles to its direction of motion

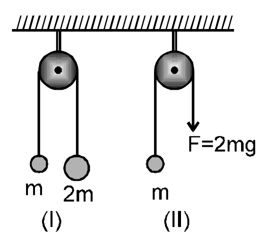
E-3. In which of the following cases the net force is not zero ?
(A) A kite skillfully held stationary in the sky
(B) A ball freely falling from a height
(C) An aeroplane rising upwards at an angle of 45º with the horizontal with a constant speed
(D) A cork lying on the surface of water

E-4. 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. If $M_2 > M_1$ and $\beta > \alpha$ then the acceleration of block M_2 down the inclined will be :



(A) $\frac{M_2 g(\sin\beta)}{M_1 + M_2}$ (B) $\frac{M_1 g(\sin\alpha)}{M_1 + M_2}$ (C) $\left(\frac{M_2 \sin\beta - M_1 \sin\alpha}{M_1 + M_2}\right)g$ (D) zero

E-5. 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 a constant downward force F = 2mg, where g is accel eration 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



E-6. A force produces an acceleration of 4 ms^{-2} in a body of mass m_1 and the same force produces an acceleration of 6 ms^{-2} in another body of mass m_2. If the same force is applied to $(m_1 + m_2)$, then the acceleration will be:
(A) 10 ms^{-2} (B) 2 ms^{-2} (C) 2.4 ms^{-2} (D) 5.4 ms^{-2}

E-7. A body of mass M is acted upon by a force F and the acceleration produced is a. If three coplaner forces each equal to F and inclined to each other at 120º act on the same body and no other forces are acting. The acceleration produced will be:

(A) $\sqrt{2}$ a (B) a/ $\sqrt{3}$ (C) 3a (D) zero

E-8. A fireman wants to slide down a rope. The rope can bear a tension of $\frac{3}{4}$ th of the weight of the man. With what minimum acceleration should the fireman slide down :

(A) $\frac{g}{3}$ (B) $\frac{g}{6}$ (C) $\frac{g}{4}$ (D) $\frac{g}{2}$

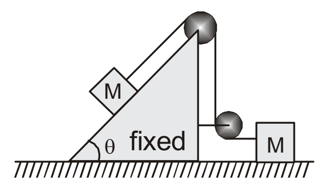
E-9. A force $\vec{F} = 6\hat{i} - 8\hat{j} + 10\hat{k}$ newton produces acceleration 1 m/s² in a body. The mass of the body is (in kg) :

(A) $6\hat{i} - 8\hat{j} + 10\hat{k}$ kg (B) $10\sqrt{2}$ kg (C) 100 kg (D) 10 kg

E-10. A body is moving with a speed of 1 m/s and a constant force F is needed to stop it in a distance x. If the speed of the body is 3 m/s the force needed to stop it in the same distance x will be

(A) 1.5 F (B) 3F (C) 6 F (D) 9F

E-11. 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:

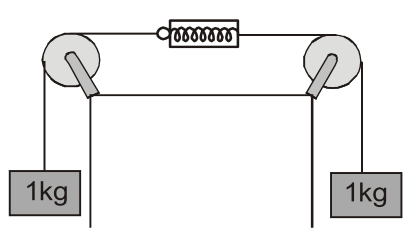


(A) $\frac{2}{3}$ Mg sin θ (B) $\frac{3}{2}$ Mg sin θ

(C) $\frac{Mg\sin\theta}{2}$ (D) 2 Mg sin θ

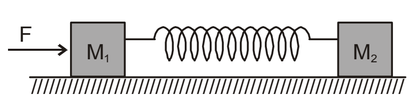
SECTION (F) : WEIGHING MACHINE, SPRING RELATED PROBLEMS AND SPRING BALANCE

F-1. In the given figure, what is the reading of the spring balance ?



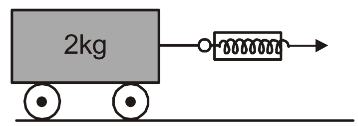
(A) 10 N (B) 20 N (C) 5 N (D) zero

F-2. Two blocks of masses M_1 and M_2 are connected to each other through a light spring as shown in figure. If we push mass M_1 with force F and cause acceleration a_1 in right direction. What will be the magnitude of acceleration in M_2?



(A) F/M_2 (B) $F/(M_1 + M_2)$ (C) a_1 (D) $(F - M_1a_1)/M_2$

F-3. A massless spring balance is attached to 2 kg trolley and is used to pull the trolley along a flat surface as shown in the fig. The reading on the spring balance remains at 10 kg during the motion. The acceleration of the trolley is (Use g = 9.8 ms^{-2})

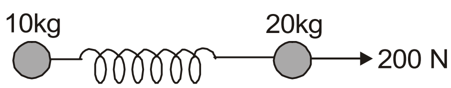


(A) 4.9 ms^{-2} (B) 9.8 ms^{-2} (C) 49 ms^{-2} (D) 98 ms^{-2}

F-4. The ratio of the weight of a man in a stationary lift & when it is moving downward with uniform acceleration 'a' is 3 : 2 . The value of 'a' is : (g = acceleration. due to gravity)
(A) (3/2) g (B) g (C) (2/3) g (D) g/3

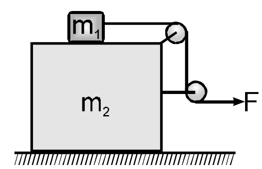
SECTION (G) : NEWTON'S LAW FOR A SYSTEM

G-1. 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 acceleration of the 20 kg mass is :



(A) 2 ms^{-2} (B) 4ms^{-2} (C) 10ms^{-2} (D) 20ms^{-2}

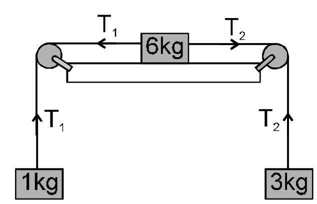
G-2. In the arrangement shown in the figure all surfaces are frictionless, pulley and string are light. The masses of the block are m_1 = 20 kg and m_2 = 30 kg. The accelerations of masses m_1 and m_2 will be if F = 180 N is applied according to figure.



(A) $a_{m_1} = 9 m/s^2, a_{m_2} = 0$ (B) $a_{m_1} = 9 m/s^2, a_{m_2} = 9$ m/s^2

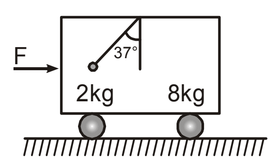
(C) $a_{m_1} = 0, a_{m_2} = 9 m/s^2$ (D) None of these

G-3. Three masses of 1 kg , 6 kg and 3 kg are connected to each other with threads and are placed on table as shown in figure. What is the accel eration with which the system is moving ? Take g = 10m s^{-2}.
(A) Zero (B) 1 m s^{-2}
(C) 2 m s^{-2} (D) 3 m s^{-2}

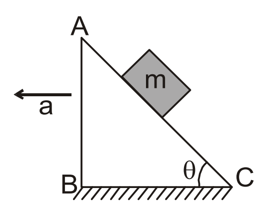


SECTION (H) : PSEUDO FORCE

H-1*. A trolley of mass 8 kg is standing on a frictionless surface inside which an object of mass 2 kg is suspended. A constant force F starts acting on the trolley as a result of which the string stood at an angle of 37^0 from the vertical (bob at rest relative to trolley) Then :
(A) acceleration of the trolley is 40/3 m/sec^2. (B) force applied is 60 N
(C) force applied is 75 N (D) tension in the string is 25 N



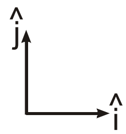
H-2. A block of mass m resting on a wedge of angle θ as shown in the figure. The wedge is given an acceleration a towards left. What is the minimum value of **a** due to external agent so that the mass m falls freely ?
(A) g (B) g cos θ
(C) g cot θ (D) g tan θ



H-3. An object kept on a smooth inclined plane of inclination θ with horizontal can be kept stationary relative to the incline by giving a horizontal acceleration to the inclined plane, equal to :
(A) g sin θ (B) g cos θ (C) g tan θ (D) none of these.

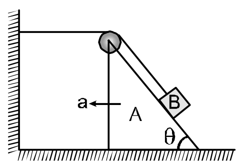
PART-III : MATCH THE COLUMN

1. In column- I gives four different situations are given column-II corresponding result are given. Match the statement in column-I with the correct result in column-II :



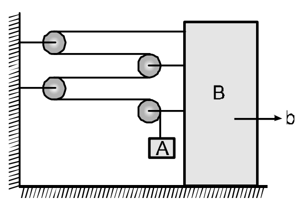
Column I **Column II**

(A) The acceleration of B w.r.t ground.



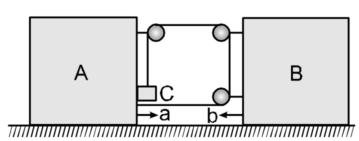
(p) $4b\,\hat{j}$

(B) The acceleration of A w.r.t. ground.



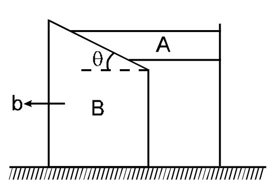
(q) $\vec{a}_A = -b\tan\theta\ \hat{j}$

(C) The acceleration of C w.r.t. ground



(r) $(a\cos\theta - a)\,\hat{i} - a\sin\theta\,\hat{j}$

(D) The acceleration of wedge A



(s) $a\,\hat{i} - 2(a+b)\,\hat{j}$

2. Column-I gives four different situations involving two blocks of mass m_1 and m_2 placed in different ways on a smooth horizontal surface as shown. In each of the situations horizontal forces F_1 and F_2 are applied on blocks of mass m_1 and m_2 respectively and also $m_2F_1 < m_1F_2$. Match the statements in column I with corresponding results in column-II

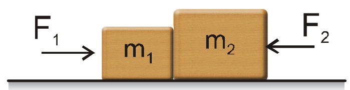
Column I

(A) 

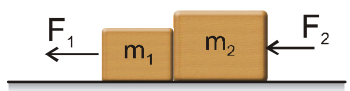
. Both the blocks are connected by massless inelastic string. The magnitude of tension in the string is

(B) 

. Both the blocks are connected by massless inelastic string. The magnitude of tension in the string is

(C) 

. The magnitude of normal reaction between the blocks is

(D) 

. The magnitude of normal reaction between the blocks is

Column II

(p) $\frac{m_1 m_2}{m_1+m_2}\left(\frac{F_1}{m_1}-\frac{F_2}{m_2}\right)$

(q) $\frac{m_1 m_2}{m_1+m_2}\left(\frac{F_1}{m_1}+\frac{F_2}{m_2}\right)$

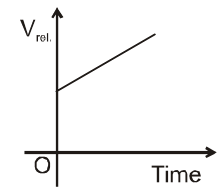
(r) $\frac{m_1 m_2}{m_1+m_2}\left(\frac{F_2}{m_2}-\frac{F_1}{m_1}\right)$

(s) $m_1 m_2\left(\frac{F_1+F_2}{m_1+m_2}\right)$

Exercise # 2

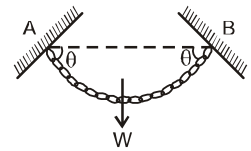
PART - I : OBJECTIVE QUESTIONS

1. A particle is observed from two frames S_1 and S_2. The graph of relative velocity of S_1 with respect to S_2 is shown in figure . Let F_1 and F_2 be the pseudo forces on the particle when seen from S_1 and S_2 respectively . Which one of the following is not possible ?



(A) $F_1 = 0$, $F_2 \neq 0$ (B) $F_1 \neq 0$, $F_2 = 0$
(C) $F_1 \neq 0$, $F_2 \neq 0$ (D) $F_1 = 0$, $F_2 = 0$

2. A flexible chain of weight W hangs between two fixed points A and B at the same level. The inclination of the chain with the horizontal at the two points of support is θ. What is the tension of the chain at the endpoint.

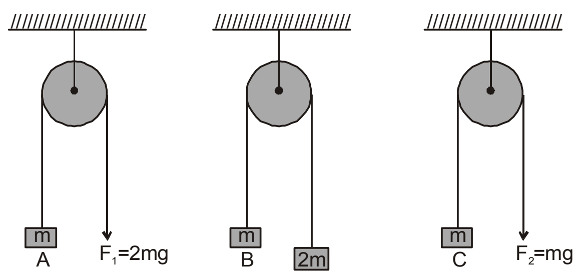


(A) $\frac{W}{2}$ cosec θ (B) $\frac{W}{2}$ sec θ
(C) W cos θ (D) $\frac{W}{3}$ sin θ

3. A ball weighing 10 gm hits a hard surface vertically with a speed of 5m/s and rebounds with the same speed. The ball remain in contact with the surface for 0.01 sec. The average force exerted by the surface on the ball is :

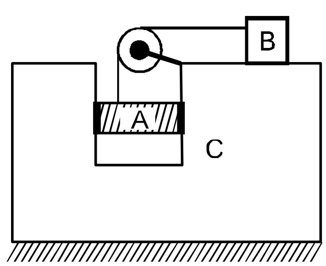
(A) 100 N (B) 10 N (C) 1 N (D) 150 N

4. 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 .



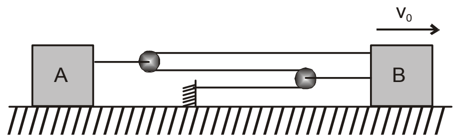
(A) $a_1 = a_2 = a_3$ (B) $a_1 > a_2 > a_3$ (C) $a_1 = a_2$, $a_2 > a_3$ (D) $a_1 > a_2$, $a_2 = a_3$

5. In the system shown in figure $m_A = 4m$, $m_B = 3m$ and $m_C = 8m$. Friction is absent everywhere. String is light and inextensible. If the system is released from rest find the acceleration of block B



(A) $\frac{g}{8}$ (leftward) (B) $\frac{g}{2}$ (leftward) (C) $\frac{g}{6}$ (rightward) (D) $\frac{g}{4}$ (rightward)

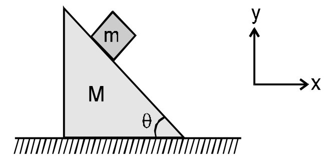
6. Block B moves to the right with a constant velocity v_0. The velocity of block A relative to B is :



(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

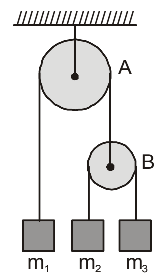
7. Consider the shown arrangement. Assume all surfaces to be smooth. If 'N' represents magnitude of normal reaction between block and wedge then acceleration of 'M' along horizontal equals:



(A) $\frac{N\sin\theta}{M}$ along + ve-x-axis (B) $\frac{N\cos\theta}{M}$ along-ve x-axis

(C) $\frac{N\sin\theta}{M}$ along – ve x-axis (D) $\frac{N\sin\theta}{m+M}$ along –ve x-axis

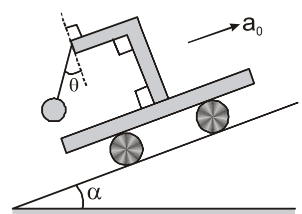
8. In the arrangement shown in figure , pulleys are massless and frictionless and threads are light and inextensible. Block of mass m_1 will remain at rest if :



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

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

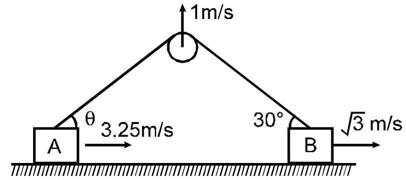
9. A pendulum of mass m hangs from a support fixed to a trolley. The direction of the string when the trolley rolls up a plane of inclination α with acceleration a_0 is (String and bob remain fixed with respect to trolley) :



(A) $\theta = \tan^{-1}\alpha$ (B) $\theta = \tan^{-1}\left(\frac{a_0}{g}\right)$

(C) $\theta = \tan^{-1}\left(\frac{g}{a_0}\right)$ (D) $\theta = \tan^{-1}\left(\frac{a_0 + g\sin\alpha}{g\cos\alpha}\right)$

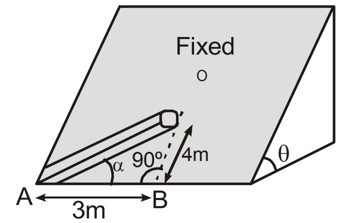
10. In the figure shown, find out the value of θ at this instant
[assume string to be tight]



(A) $\tan^{-1}\frac{3}{4}$ (B) $\tan^{-1}\frac{4}{3}$

(C) $\tan^{-1}\frac{3}{8}$ (D) none of these

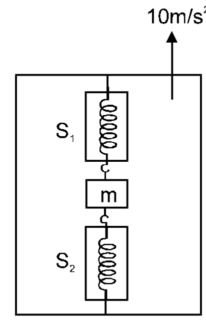
11. There is an inclined surface of inclination $\theta = 30^\circ$. A smooth groove is cut into it forming angle α with AB. A steel ball is free to slide along the groove. If the ball is released from the point O at top end of the groove, the speed when it comes to A is: [$g = 10\ m/s^2$]



(A) $\sqrt{40}\,m/s$ (B) $\sqrt{20}\,m/s$

(C) $\sqrt{10}\,m/s$ (D) $\sqrt{15}\,m/s$

12. Reading shown in two spring balances S_1 and S_2 is 90 kg and 30 kg respectively when lift is accelerating upwards with acceleration 10 m/s^2. The mass is stationary with respect to lift. Then the mass of the block will be :



(A) 60 kg

(B) 30 kg

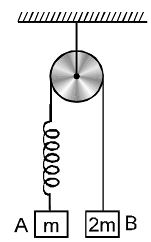
(C) 120 kg

(D) None of these

13. Five persons A, B, C, D & E are pulling a cart of mass 100 kg on a smooth surface and cart is moving with acceleration 3 m/s^2 in east direction. When person 'A' stops pulling, it moves with acceleration 1m/s^2 in the west direction. When only person 'B' stops pulling, it moves with acceleration 24 m/s^2 in the north direction. The magnitude of acceleration of the cart when only A & B pull the cart keeping their directions same as the old directions, is :

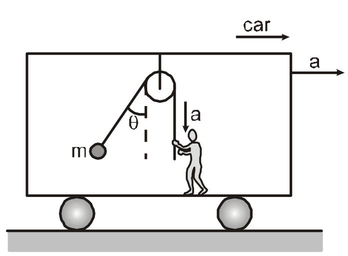
(A) 26 m/s^2 (B) $3\sqrt{71}$ m/s^2 (C) 25 m/s^2 (D) 30 m/s^2

14. In the figure a block 'A' of mass 'm' is attached at one end of a light spring and the other end of the spring is connected to another block 'B' of mass 2m through a light string. 'A' is held and B is in static equilibrium. Now A is released. The acceleration of A just after that instant is 'a'. In the next case, B is held and A is in static equilibrium. Now when B is released, its acceleration immediately after the release is 'b'. The value of a/b is : (Pulley, string and the spring are massless)



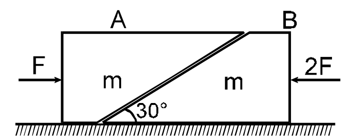
(A) 0 (B) $\frac{1}{2}$ (C) 2 (D) undefined

15. A bob is hanging over a pulley inside a car through a string. The second end of the string is in the hand of a person standing in the car . The car is moving with constant acceleration 'a' directed horizontally as shown in figure . Other end of the string is pulled with constant acceleration ' a ' (relative to car) vertically. The tension in the string is equal to



(A) $m\sqrt{g^2 + a^2}$ (B) $m\sqrt{g^2 + a^2} - ma$ (C) $m\sqrt{g^2 + a^2} + ma$ (D) $m(g + a)$

16. Two blocks 'A' and 'B' each of mass 'm' are placed on a smooth horizontal surface. Two horizontal forces F and 2F are applied on the two blocks 'A' and 'B' respectively as shown in figure. The block A does not slide on block B. Then the normal reaction acting between the two blocks is:



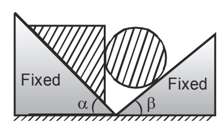
(A) F (B) F/2 (C) $\frac{F}{\sqrt{3}}$ (D) 3F

17. What will be the displacement of a block in first 0.2s if the block is kept on the floor of an elevator at rest. suddenly elevator starts descending with an acceleration of 13 m/s^2. Take g = 10 m/s^2.

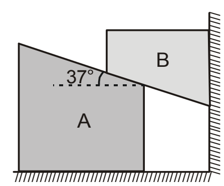
(A) 26 cm (B) 6cm (C) 46cm (D)20cm

PART - II : SUBJECTIVE QUESTIONS

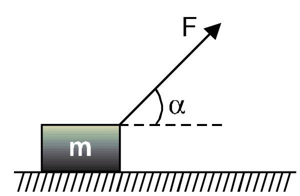
1. A cylinder and a wedge of same masses with a vertical face, touching each other, move along two smooth inclined planes forming the same angle α and β respectively with the horizontal. Determine the force of normal N (in newton) exerted by the wedge on the cylinder, neglecting the friction between them. If m = $\frac{1}{\sqrt{3}}$ kg, $\alpha = 60^0$, $\beta = 30^0$ and g = 10 m/s^2



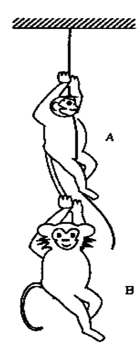
2. The masses of blocks A and B are same and equal to m. Friction is absent everywhere.the magnitude of accelerations of the blocks A is $\frac{12x}{25}$ then find the value of x.



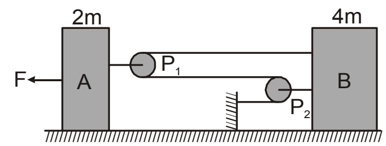
3. At the moment t = 0 the force F = at N is applied to a small body of mass m resting on a smooth horizontal plane (a is constant). The permanent direction of this force forms an angle α with the horizontal (as shown in the figure). then the distance traversed by the body up to this moment of its breaking off the plane is $\frac{m^2 g^3 \cos\alpha}{pa^2 \sin^3\alpha}$ m. then find value of p.



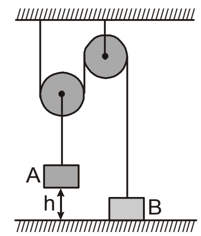
4. The monkey A shown in the figure climbing on a rope while monkey B holding tail of the monkey A which is climbing on a rope. The masses of the monkeys A and B are 7 kg and 3 kg respectively. If A can tolerate a tension of 45 N in its tail, If maximum force applied by monkey A on the rope in order to carry the monkey B with it is 30x N then find the value of x.Take g =10 m/s^2.



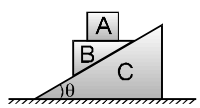
5. The acceleration of the block B in the figure, assuming the surfaces and the pulleys P_1 and P_2 are all smooth and pulleys and string are light is $\frac{3F}{xm}$ then value of x is.



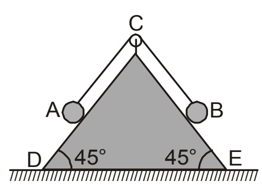
6. In the arrangement shown in figure, the mass of the body A is n = 4 times that of body B. The height h=20 cm. At a certain instant, the body B is released and the system is set in motion. What is the maximum height(in cm) , the body B will go up? Assume enough space above B and A sticks to ground. (A and B are of small size) (g = 10 m/s^2)



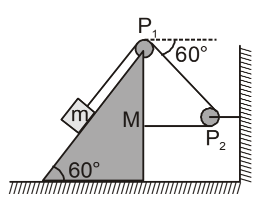
7. In the figure shown all blocks are of equal mass 'm'. All surfaces are smooth. the acceleration of blocks C is $\frac{2g\sin\theta\cos\theta}{1+x\sin^2\theta}$ then find the value of x.



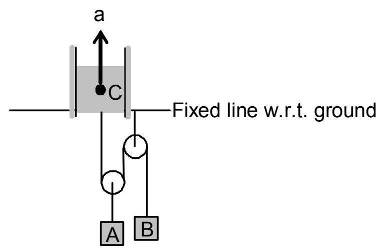
8. Two particles A and B of masses 3 kg and 2 kg are connected by a light inextensible string . The particles are in contact with the smooth faces of a wedge DCE of mass 10 kg resting on a smooth horizontal plane. When the system is moving freely, find the acceleration of the wedge (in cm/s^2).



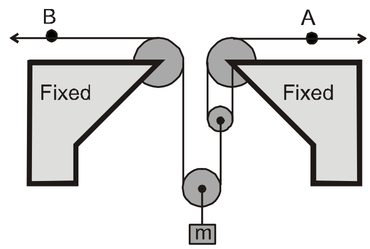
9. In the arrangement shown in the fig, the block of mass m = 2 kg lies on the wedge of mass M = 8 kg. the Initial acceleration of the wedge if the surfaces are smooth and pulley & strings are massless is $\frac{30\sqrt{3}}{x}$ m/s^2 then x is.



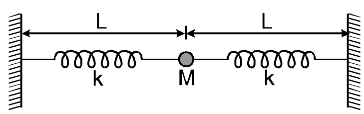
10. The block C shown in the figure is ascending with an acceleration $a = 3\ m/s^2$ by means of some motor not shown here.the bodies A and B of masses 10 kg and 5 kg respectively, assuming pulleys and strings are massless and friction is absent every where then find the acceleration of body A(in m/s^2).



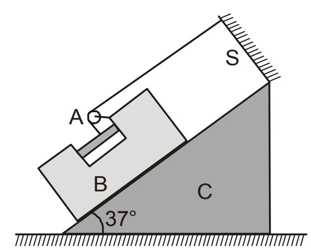
11. For the pulley system , each of the cables at A and B is given velocity of 4m/s in the direction of the arrow. Determine the upward velocity v of the load m (in m/s).



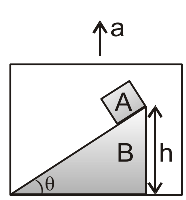
12. A ball of mass M is suspended from two identical springs each with spring constant k and undeformed length L. The ball is held in line with two springs as shown in the figure. When the ball begins to fall, find the magnitude of the acceleration of the ball at the instant when it has fallen through a vertical distance x(in m/s^2) if M = 250g,K = 130 N/m , L = 12cm , x = 5cm and $g = 10m/s^2$.



13. In the figure shown C is a fixed wedge. A block B is kept on the inclined surface of the wedge C. Another block A is inserted in a slot in the block B as shown in figure. A light inextensible string passes over a light pulley which is fixed to the block B through a light rod. One end of the string is fixed and other end of the string is fixed to A.S is a fixed support on the wedge. All the surfaces are smooth. Masses of A and B are same. Then the magnitude of acceleration of A is $\frac{\sqrt{x}}{3}$ m/s^2.Then x is (sin 37° = 3/5)

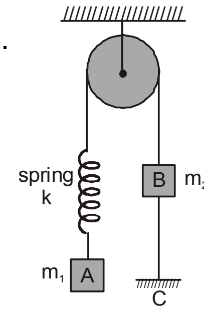


14. A lift is moving upwards with a constant acceleration a = g. A small block A of mass ' m ' is kept on a wedge B of the same mass ' m '. The height of the vertical face of the wedge is ' h '. A is released from the top most point of the wedge. Find the time taken by A to reach the bottom of B. All surfaces are smooth and B is also free to move. If h=4m, $\theta = 30^0$ and $g = 10m/s^2$.



PART - III : ONE OR MORE THAN ONE CORRECT OPTIONS

1. 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 :



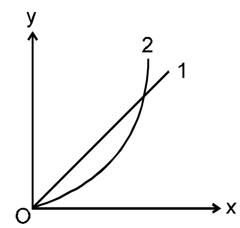
(A) acceleration of m_2 will be upwards

(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.

2. 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 ?



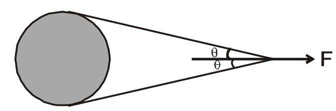
(A) Curve 1 shows acceleration against time

(B) Curve 2 shows velocity against time

(C) Curve 2 shows velocity against acceleration

(D) none of these

3. A light string is wrapped round a cylindrical log of wood which is placed on a horizontal surface with it's axis vertical and it is pulled with a constant force F as shown in the figure.(Friction is absent everywhere)



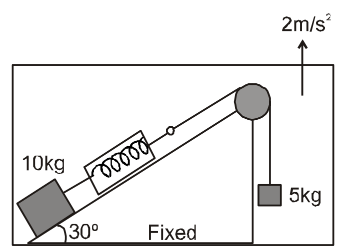
(A) tension T in the string increases with increase in θ

(B) tension T in the string decreases with increase in θ

(C) tension T > F if $\theta > \pi/3$

(D) tension T > F if $\theta > \pi/4$

4. According to figure the reading of the spring balance will be : (all contacts are smooth) [g = 10 m/s²]



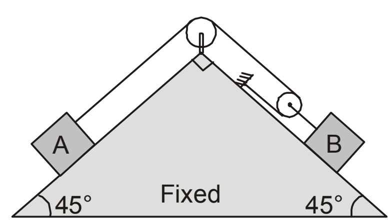
(A) 6 kg f

(B) 5 kg f

(C) 60 N

(D) 60 kg f

5. Two blocks A and B of mass 10 kg and 40 kg are connected by an ideal string as shown in the figure. Neglect the masses of the pulleys and effect of friction. (g = 10 m/s²)



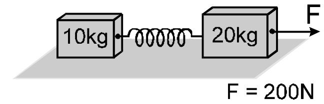
(A) The acceleration of block A is $\frac{5}{\sqrt{2}}$ ms^{-2}

(B) The acceleration of block B is $\frac{5}{2\sqrt{2}}$ ms^{-2}

(C) The tension in the string is $\frac{125}{\sqrt{2}}$ N

(D) The tension in the string is $\frac{150}{\sqrt{2}}$ N

6. Two blocks of masses 10 kg and 20 kg are connected by a light spring as shown. A force of 200 N acts on the 20 kg mass as shown. At a certain instant the acceleration of 10 kg mass is 12 ms^{-2} towards right direction.



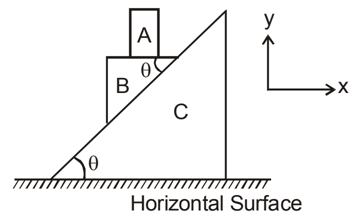
(A) At that instant the 20 kg mass has an acceleration of 12 ms^{-2}.

(B) At that instant the 20 kg mass has an acceleration of 4 ms^{-2}.

(C) The stretching force in the spring is 120 N.

(D) The collective system moves with a common acceleration of $\frac{20}{3}$ ms^{-2} when the extension in the connecting spring is the maximum.

7. In the figure shown all the surface are smooth. All the blocks A, B and C are movable X-axis is horizontal and y-axis vertical as shown. Just after the system is relased from the position as shown.



(A) Acceleration of 'A' relative to ground is in negative y-direction

(B) Acceleration of 'A' relative to B is in positive x-direction

(C) The horizontal acceleration of 'B' relative to ground is in negative x-direction.

(D) The acceleration of 'B' relative to ground directed along the inclined surface of 'C' is greater than g sin θ.

8. A particle stays at rest as seen from a frame. We can conclude that

(A) The frame is inertial.

(B) Resultant force on the particle is zero.

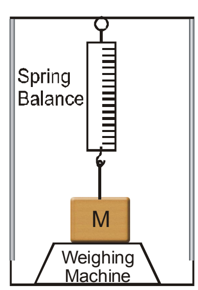
(C) If the frame is inertial then the resultant force on the particle is zero.

(D) If the frame is noninertial then there is a nonzero resultant force.

PART - IV : COMPREHENSION

Comprehension # 1

Figure shows a weighing machine kept in a lift. Lift is moving upwards with acceleration of 5 m/s². A block is kept on the weighing machine. Upper surface of block is attached with a spring balance. Reading shown by weighing machine and spring balance is 15 kg and 45 kg respectively. Answer the following questions. Asume that the weighing machine can measure weight by having negligible deformation due to block, while the spring balance requires larger expansion : (take g = 10 m/s²)



1. Mass of the object in kg and the normal force acting on the block due to weighing machine are :

(A) 60 kg, 450 N (B) 40 kg, 150 N (C) 80 kg, 400 N (D) 10 kg, zero

2. If lift is stopped and equilibrium is reached. Reading of weighing machine and spring balance will be :

(A) 40 kg, zero (B) 10 kg, 20 kg (C) 20 kg, 10 kg (D) zero, 40 kg

3. Find the acceleration of the lift such that the weighing machine shows its true weight.

(A) $\frac{45}{4}$ m/s^2 (B) $\frac{85}{4}$ m/s^2 (C) $\frac{22}{4}$ m/s^2 (D) $\frac{60}{4}$ m/s^2

Comprehension # 2

A small block of mass 1 kg starts moving with constant velocity 2 m/s on a smooth long plank of mass 10 kg which is also pulled by a horizontal force F = 10 t N where t is in seconds and F is in newtons. (the initial velocity of the plank is zero).

4. Displacement of 1 kg block with respect to plank at the instant when both have same velocity is

(A) $4\frac{4}{3}$m (B) 4 m (C) $\frac{8}{3}$m (D) 2 m

5. The time ($t \neq 0$) at which displacement of block and plank with respect to ground is same will be :

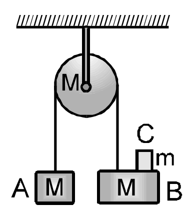
(A) 12 s (B) $2\sqrt{3}$ s (C) $3\sqrt{3}$ s (D) $\sqrt{3}/2$ s

6. Relative velocity of plank with respect to block when acceleration of plank is 4 m/s^2 will be -

(A) Zero (B) 10 m/s (C) 6 m/s (D) 8 m/s

Comprehension # 3

For the following system shown assume that pulley is frictionless, string is massless (m remains on M) :



7. Find the acceleration of the block A.

(A) $\frac{Mg}{2M+m}$ (B) $\frac{mg}{2M+m}$ (C) $\frac{mg}{2m+M}$ (D) $\frac{2mg}{3m+M}$

8. Find normal reaction on m is (force on C due to B)

(A) $\frac{3Mmg}{M+2m}$ (B) $\frac{3Mmg}{4M+m}$ (C) $\frac{3Mmg}{M+m}$ (D) $\frac{2Mmg}{2M+m}$

9. Find the force on the ceiling

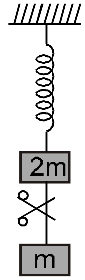
(A) $\frac{2Mmg}{2M+m}$ (B) $\frac{(3M+5m)Mg}{M+2m}$ (C) $\frac{(6M+5m)Mg}{M+2m}$ (D) $\frac{(3M+5m)mg}{2M+m}$

Exercise # 3

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

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

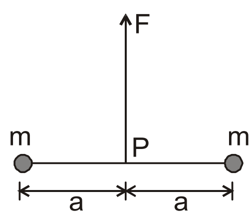
1. System shown in figure is in equilibrium and at rest. The spring and string are massless Now the string is cut. The acc7eleration of mass 2m and m just after the string is cut will be : **[JEE 2006, 3/184]**



(A) g/2 upwards , g downwards (B) g upwards, g/ 2 downwards

(C) g upwards , 2g downwards (D) 2g upwards , g downwards

2. Two particles of mass m each are tied at the ends of a light string of length 2a. The whole system is kept on a frictionless horizontal surface with the string held tight so that each mass is at a distance 'a' from the centre P (as shown in the figure). Now, the mid-point of the string is pulled vertically upwards with a small but constant force F. As a result, the particles move towards each other on the surface. The magnitude of acceleration, when the separation between them becomes 2x, is **[JEE 2007, 3/81]**



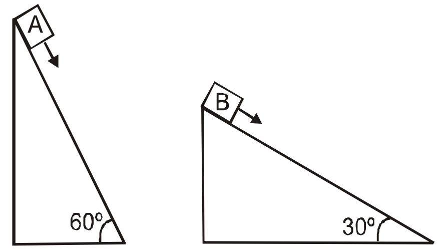
(A) $\frac{F}{2m}\frac{a}{\sqrt{a^2-x^2}}$ (B) $\frac{F}{2m}\frac{x}{\sqrt{a^2-x^2}}$ (C) $\frac{F}{2m}\frac{x}{a}$ (D) $\frac{F}{2m}\frac{\sqrt{a^2-x^2}}{x}$

3. 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, 3/160, –1]**

(A) $\frac{a}{gk}$ (B) $\frac{a}{2gk}$ (C) $\frac{2a}{gk}$ (D) $\frac{a}{4gk}$

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

1. Two fixed frictionless inclined planes making an angle 30º and 60º with the vertical are shown in the figure. Two blocks A and B are placed on the two planes respectively. What is the relative vertical acceleration of A with respect to B? **[AIEEE-2010, 4/144, –1]**

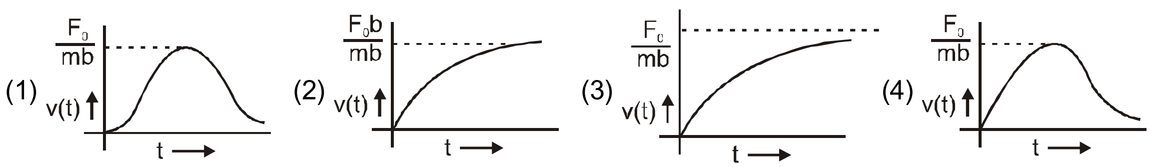


(1) 4.9 ms^{-2} in horizontal direction
(2) 9.8 ms^{-2} in vertical direction
(3) Zero
(4) 4.9 ms^{-2} in vertical direction

2. If a spring of stiffness 'k' is cut into two parts 'A' and 'B' of length $\ell_A : \ell_B = 2 : 3$, then the stiffness of spring 'A' is given by : **[AIEEE 2011, 11 May; 4/120, –1]**

(1) $\frac{3k}{5}$ (2) $\frac{2k}{5}$ (3) k (4) $\frac{5k}{2}$

3. A particle of mass m is at rest at the origin at time t = 0. It is subjected to a force $F(t) = F_0e^{-bt}$ in the x direction. Its speed v(t) is depicted by which of the following curves ? **[AIEEE 2012 ; 4/120, –1]**



4. A particle of mass m is moving in a straight line with momentum p. Starting at time t = 0, a force F = kt acts in the same direction on the moving particle during time interval T so that its momentum changes from p to 3p. Here k is a constant. The value of T is :- **[JEE Main 2019, Jan.]**

(1) $2\sqrt{\frac{p}{k}}$ (2) $\sqrt{\frac{2p}{k}}$ (3) $\sqrt{\frac{2k}{p}}$ (4) $2\sqrt{\frac{k}{p}}$

5. A mass of 10 kg is suspended by a rope of length 4 m, from the ceiling. A force F is applied horizontally at the mid-point of the rope such that the top half of the rope makes an angle of 45° with the vertical. Then F equals: (Take g= 10 ms^{-2} and the rope to be massless) **[JEE Main 2020, Jan.]**

(1) 100 N (2) 90 N (3) 75 N (4) 70 N

Answers

Exercise # 1

PART - I

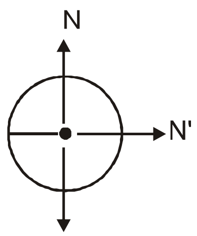
SECTION (A) :

A-1. Gravitational.

A-2. Frictional force, which is a type of electromagnetic force.

A-3. 20 N

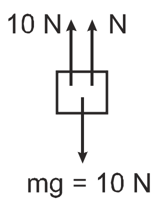
A-4.



Vertical wall does not exert force on sphere

(N' = 0).

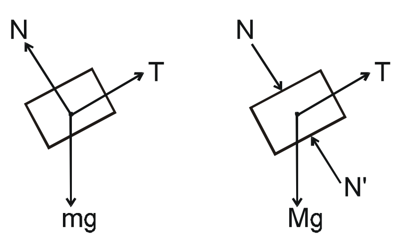
A-5. (i)



(N = 0).

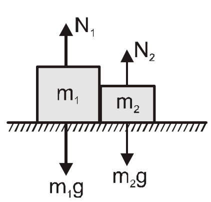
(ii) Gravitational between earth and block .

A-6.

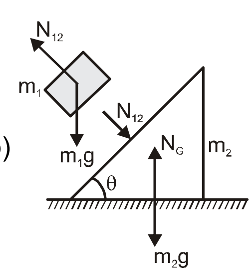


Normal reaction

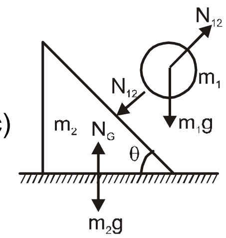
A-7. (a)



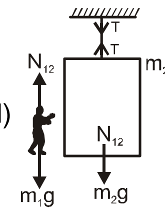
(b)



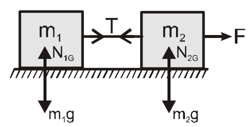
(c)



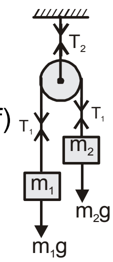
(d)



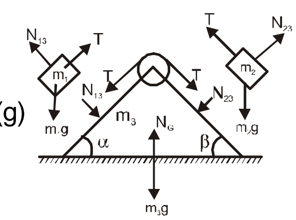
(e)



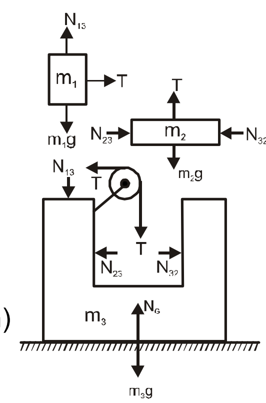
(f)



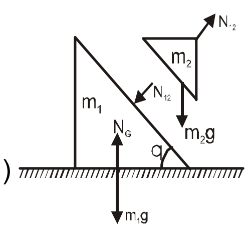
(g)



(h)



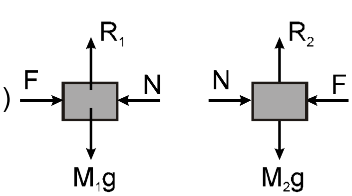
(i)



SECTION (B):

B-1. 2 mg

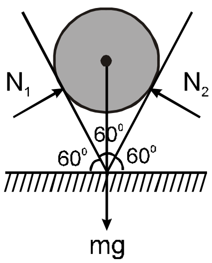
B-2. (i)



(ii) N = F (iii) F (iv) m_1g, m_2g.

B-3. (i) zero (ii) mg

B-4. (a)



(b) equal magnitude w .

B-5. $N_A = \frac{1000}{\sqrt{3}}$ N, $N_B = \frac{500}{\sqrt{3}}$ N

B-6. $N_{45} = \frac{50\sqrt{2}}{\sqrt{3}-1} = 96.59$ N; $N_{30} = \frac{100}{\sqrt{3}-1} = 136.6$ N

SECTION (C):

C-1. (i) zero, (ii) 10 N

C-2. (a) 10 N, (b) 10 N, (c) 10 N.

C-3. (a) 10 N, (b) 15 N, (c) 20 N.

C-4. $T_1 = 5$N, $T_2 = 2$N

C-5. (a) $T_1 = T_2 = T_3 = \frac{Mg}{2}$, $T_5 = Mg$ and $T_4 = \frac{3Mg}{2}$

(b) $F = \frac{Mg}{2}$

SECTION (D):

D-1. $\frac{\cos\theta_2}{\cos\theta_1}$ **D-2.** 2u

D-3. $V_B = 3V_A = 1.8$ m/s in downward direction.

D-4. $V_{P_1} = 5$ m/s downward

$V_C = 25$ m/s upward

D-5. $b\hat{i} + b\hat{j}$

SECTION (E):

E-1. (a) $|\vec{F}_1| = |\vec{F}_2| = 30\sqrt{2}$ N (b) $W = 30\sqrt{2}$ N

E-2. 1 N along the motion, zero and 1 N opposite to the motion.

E-3. $|F| = \sqrt{(30)^2 + (108)^2} = 112.08$ N

E-4. $\frac{m_1 g}{2(m_1 + m_2)}$

E-5. (a) 4.8 N, 3.6 N, 2.4N, 1.2 N (b) F = 6 N

(c) 0.2 N

E-6. (a) 2g/3 (b) 3g/4

E-7. (a) $m_B = 10$ kg (b) $m_B = 10$ kg

E-8. $mg\cos\theta$.

SECTION (F)

F-1. (i) 600 N, (ii) 600 N,

(iii) 600 N, (iv), 720 N,

(v) 480 N, (vi) 720 N,

(vii) 720 N, (viii) 480 N

F-2. (i) 100 N, (ii) 100 N,

(iii) 100 N, (iv) 120 N,

(v) 80 N, (vi) 120 N,

(vii) 120 N, (viii) 80 N.

F-3. (a) 3 g↓, 0, 0, (b) 0, g ↑, g ↓

SECTION (G)

G-1. $\frac{15}{4}$ m/s², opposite direction.

G-2. a = 3 m/s² **G-3.** $a = \frac{4F}{M+m} - g$.

G-4. 322 N

SECTION (H)

H-1. (i) $F = -10\hat{i} - 20\hat{j}$ N,

Due to acceleration of frame s_1

(ii) $10\hat{i} + 20\hat{j}$ N (iii) zero.

H-2. $(g + a)\sin\theta$

PART - II

SECTION (A):

A-1. (A),(B),(C) **A-2.** (C)

SECTION (B)

B-1. (B) **B-2.** (C) **B-3.** (B)

SECTION (C)

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

SECTION (D)

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

SECTION (E)

E-1. (A) **E-2.** (C) **E-3.** (B) **E-4.** (C)
E-5. (C) **E-6.** (C) **E-7.** (D) **E-8.** (C)
E-9. (B) **E-10.** (D) **E-11.** (C)

SECTION (F)

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

SECTION (G)

G-1. (B) **G-2.** (A) **G-3.** (C)

SECTION (H)

H-1. (C),(D) **H-2.** (C) **H-3.** (C)

PART - III

1. (A) $\rightarrow$ r ; (B) $\rightarrow$ p ; (C) $\rightarrow$ s ; (D) $\rightarrow$ q

2. (A) $\rightarrow$ q ; (B) $\rightarrow$ r ; (C) $\rightarrow$ q : (D) $\rightarrow$ r

Exercise # 2

PART - I

1. (D) **2.** (A) **3.** (B) **4.** (B)
5. (B) **6.** (B) **7.** (C) **8.** (B)
9. (D) **10.** (A) **11.** (A) **12.** (B)
13. (C) **14.** (C) **15.** (C) **16.** (D)
17. (D)

PART - II

1. 5 **2.** 10 **3.** 6 **4.** 5
5. 17 **6.** 60 **7.** 3 **8.** 40
9. 23 **10.** 1 **11.** 3 **12.** 6
13. 32 **14.** 1

PART - III

1. (A), (C) **2.** (A), (B), (C)
3. (A), (C) **4.** (A), (C)
5. (A), (B), (D) **6.** (B), (C)
7. (A),(B), (C), (D) **8.** (C), (D)

PART - IV

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

Exercise # 3

PART - I

1. (A) **2.** (B) **3.** (B)

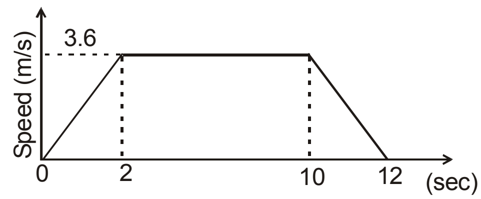
PART - II

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

Ranker Problems

SUBJECTIVE QUESTIONS

1. A lift is going up. The total mass of the lift and the passengers is 150 kg. The variation in the speed of the lift is given in the graph. ($g = 9.8\ m/s^2$)



(a) What will be the tension in the rope pulling the lift at t equal to

(i) 1 sec

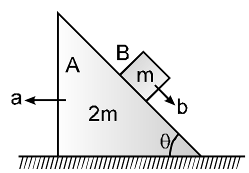
(ii) 6 sec and

(iii) 11 sec ?

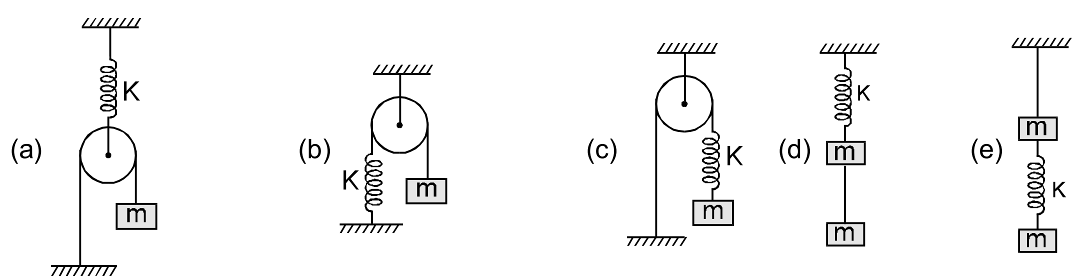
(b) What is the height through which the lift takes the passengers ?

(c) What will be the average velocity and average acceleration during the course of entire motion?

2. The system shown in figure is released from rest calculate the value of acclerations 'a' and 'b'. (where b is w.r.t. to A)

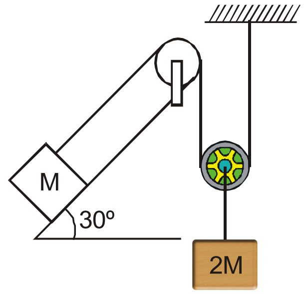


3. Find the tension in the string and the extension in the spring at equilibrium. Where pulley, strings and springs are ideal.

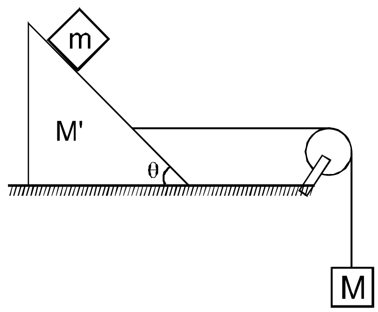


4. A pendulum bob of mass 50 g is suspended from the ceiling of an elevator. Find the tension in the string if the elevator (a) goes up with acceleration $1.2\ m/s^2$, (b) goes up with deceleration $1.2\ m/s^2$ (c) goes up with uniform velocity, (d) goes down with acceleration $1.2\ m/s^2$, (e) goes down with deceleration $1.2\ m/s^2$ and (f) goes down with uniform velocity.

5. As shown in figure, all the surfaces are frictionless and the pulleys and the string are light. find the acceleration of block M and 2M.

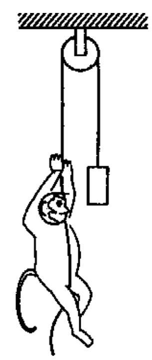


6. What will be the value M of the hanging block as shown in the figure which will prevent the smaller block from slipping over the triangular block. All the surface are frictionless and the string and the pulley are light.

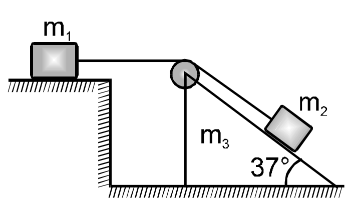


7. A monkey of mass 15 kg is climbing on a rope with one end fixed to the ceiling .If it wishes to go up with an acceleration of 1 m/s^2 , how much force should it apply to the rope? If the rope is 5m long and the monkey starts from rest, how much time will it take to reach the ceiling ?

8. Figure shown a monkey is climbing on a rope that goes over a smooth light pulley and a block of equal mass hanging on the other end. Show that the monkey and the block move in the same direction with equal acceleration, whatever force the monkey exerts on the rope If intially both were at rest, their separation will not change as time passes.



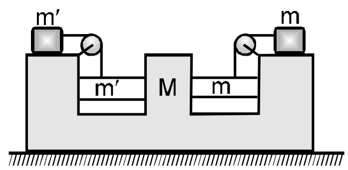
9. In the arrangement shown in Fig, a wedge of mass m_3 = 3.45 kg is placed on a smooth horizontal surface. A small and light pulley is connected on its top edge, as shown. A light, flexible thread passes over the pulley. Two blocks having mass m_1= 1. 3 kg & m_2= 1.5 kg are connected at the ends of the thread. m_1 is on smooth horizontal surface and m_2 rests on inclined surface of the wedge. Base length of wedge is 2 m and inclination is 37^0. m_2 is initially near the top edge of the wedge. If the whole system is released from rest. Calculate:



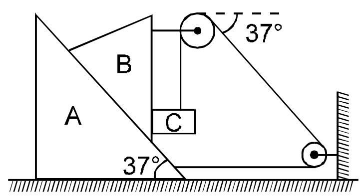
(i) velocity of wedge when m_2 reaches its bottom

(ii) velocity of m_2 at that instant and tension in the thread during motion of m_2. All the surfaces are smooth. [g = 10 ms^{-2}]

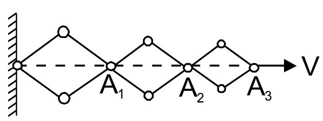
10. Neglecting friction every where, find the acceleration of M. Assume $m > m'$.



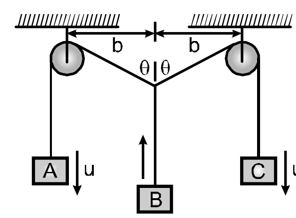
11. A system is shown in figure. All contact surfaces are smooth and string is tight & inextensible. Wedge 'A' moves towards right with speed 10 m/s & velocity of 'B' relative to 'A' is in downward direction along the incline having magnitude 5m/s. Find the horizontal and vertical component of velocity of Block 'C'.



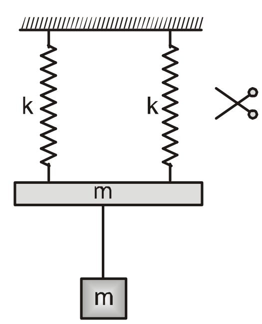
12. A hinged construction consists of three rhombus with the ratio of sides (5 : 3 : 2). Vertex A_3 moves in the horizontal direction with velocity V. Velocity of A_2 will be :



13. In the figure shown the blocks A & C are pulled down with constant velocities u . Acceleration of block B is :



14. System shown in figure is in equilibrium. The magnitude of change in tension in the string just before and just after, when one of the spring is cut. Mass of both the blocks is same and equal to m and spring constant of both springs is k. (Neglect any effect of rotation)



Answers

(RANKER PROBLEMS)

1. (a) (i) 1740 N (ii) 1470 N (iii) 1200 N (b) 36 m (c) Average velocity = 3 m/s; Average acceleration = 0

2. $a = \frac{b\cos\theta}{3}$ $b = \frac{3g\sin\theta}{3-\cos^2\theta}$

3. (a) $T = mg$, $x = \frac{2mg}{K}$; (b) $T_1 = mg$, $T_2 = 2mg$, $x = \frac{mg}{K}$; (c) $T_1 = mg$, $T_2 = 2mg$, $x = \frac{mg}{K}$;

(d) $T = mg$, $x = \frac{2mg}{K}$; (e) $T = 2mg$, $x = \frac{mg}{K}$

4. (a) 0.55 N (b)0.43 N (c) 0.49 N (d) 0.43 N (e) 0.55 N (f) 0.49 N

5. g /3 up the plane for M

g /6 downward for 2M

6. $\frac{M'+m}{\cot\theta-1}$

7. 165 N, $\sqrt{10}$ s

8. Hence separation remains same.

9. (i) 2 ms^{-1} (ii) $\sqrt{13}$ ms^{-1}, 3.9 Newton

10. $a = \frac{(m-m')g}{2M+3m+3m'}$

11. Horizontal component of velocity is 14 m/sec and vertical component of velocity is 26 m/sec.

12. 0.8V

13. $\frac{u^2}{b}\tan^3\theta$

14. $\frac{mg}{2}$

Self Assessment Test

JEE (ADVANCED) PAPER

SECTION-1 : ONE OPTION CORRECT (Maximum Marks - 12)

1. A block of mass m is placed on a smooth wedge of inclination θ . The whole system is accelerated horizontally so that the block does not slip on the wedge. The force exerted by the wedge on the block has a magnitude.

(A) mg (B) mg/cos θ (C) mgcos θ (D) mgtan θ

2. A block of mass M is placed on a fixed smooth inclined plane of inclination θ with the horizontal. The force exerted by the plane on the block has a magnitude

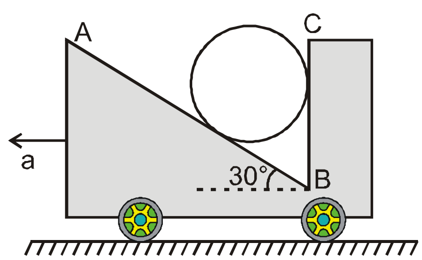
(A) Mg (B) Mg/cos θ (C) Mgcos θ (D) Mgtan θ

3. A force of magnitude F_1 acts on a particle so as to accelerate it from rest to a velocity v. The force F_1 is then replaced by another force of magnitude F_2 which decelerates it to rest.

(A) F_1 must be the equal to F_2 (B) F_1 may be equal to F_2

(C) F_1 must be unequal to F_2 (D) None of these

4. 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} increase.

(C) N_{AB} remains constant and N_{BC} increases. (D) N_{AB} increases and N_{BC} remains constant.

SECTION-2 : ONE OR MORE THAN ONE CORRECT (Maximum Marks - 32)

5. A reference frame attached to the earth

(A) is an inertial frame by definition

(B) cannot be an inertial frame because the earth is revolving around the sun.

(C) is an inertial frame because Newton's laws are applicable in this frame.

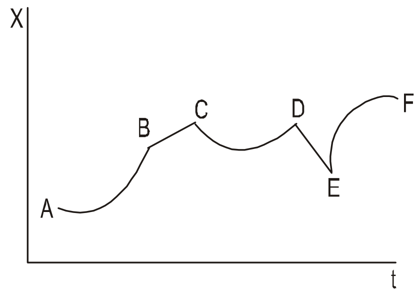
(D) cannot be an inertial frame because the earth is rotating about its axis.

6. A particle is found to be at rest when seen from a frame S_1 and moving with a constant velocity when seen from another frame S_2. Markout the possible options.

(A) Both the frames are inertial (B) Both the frames are noninertial.

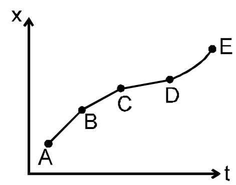
(C) S_1 is inertial and S_2 is noninertial. (D) S_1 is noninertial and S_2 is inertial.

7. Figure shows the displacement of a particle going along the X-axis as a function of time. Find the region where force acting on the particle is zero



(A) AB (B) BC (C) CD (D) DE

8. Figure shows the displacement of a particle going along the x–axis as a function of time :



(A) the force acting on the particle is zero in the region AB

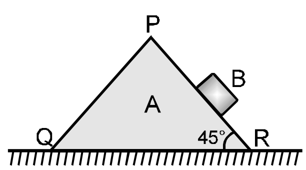
(B) the force acting on the particle is zero in the region BC

(C) the force acting on the particle is zero in the region CD

(D) the force is zero no where .

9. A block B of mass 0.6 kg slides down the smooth face PR of a wedge A of mass 1.7 kg which can move freely on a smooth horizontal surface.

The inclination of the face PR to the horizontal is 45º. Then :



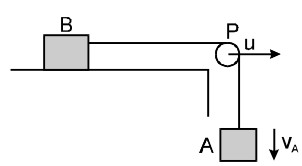
(A) the acceleration of A is 3 g/20

(B) the vertical component of the acceleration of B is 23 g/40

(C) the horizontal component of the acceleration of B is 17 g/40

(D) none of these

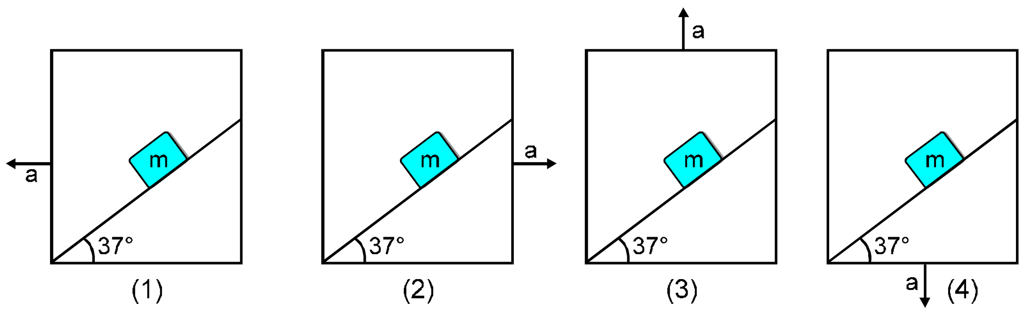
10. In the Figure, the pulley P moves to the right with a constant speed u. The downward speed of A is $v_{A,}$ and the speed of B to the right is $v_{B.}$



(A) $v_B = v_A$ (B) $v_B = u + v_A$

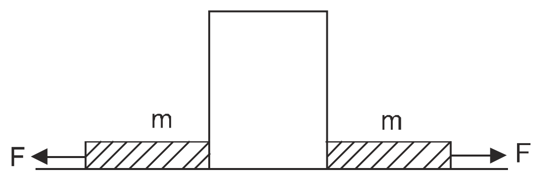
(C) $v_B + u = v_A$ (D) the two blocks have accelerations of the same magnitude

11. A block of mass m is placed on a wedge. The wedge can be accelerated in four manners marked as (1), (2), (3) and (4) as shown. If the normal reactions in situation (1), (2), (3) and (4) are N_1, N_2, N_3 and N_4 respectively and acceleration with which the block slides down on the wedge in situations are b_1, b_2, b_3 and b_4 respectively then :



(A) $N_3 > N_1 > N_2 > N_4$ (B) $N_4 > N_3 > N_1 > N_2$ (C) $b_2 > b_3 > b_4 > b_1$ (D) $b_2 > b_3 > b_1 > b_4$

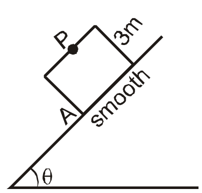
12. A heavy block kept on a frictionless surface and being pulled by two ropes of equal mass m as shown in figure. At t = 0, the force on the left rope is withdrawn but the force on the right end continues to act. Let F_1 and F_2 be the magnitudes of the forces by the right rope and the left rope on the block respectively. Then choose incorrect option.



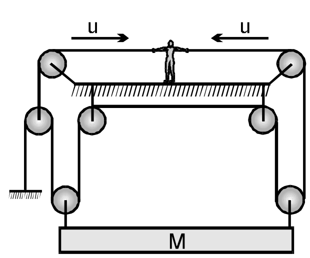
(A) $F_1 = F_2 = F$ for $t < 0$
(B) $F_1 = F_2 = F + mg$ for $t < 0$
(C) $F_1 = F$, $F_2 = F$ for $t > 0$
(D) $F_1 < F$, $F_2 = F$ for $t > 0$

SECTION-3 : NUMERICAL VALUE TYPE (Maximum Marks - 18)

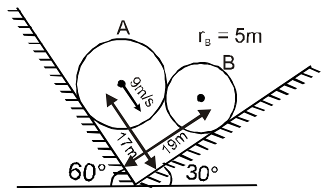
13. A cuboidal car of height 3 m is slipping on a smooth inclined plane. A bolt relesed from the roof of car from centre of roof (P) then find the distance (in meter) from centre of roof where bolt hits the floor with respect to car.



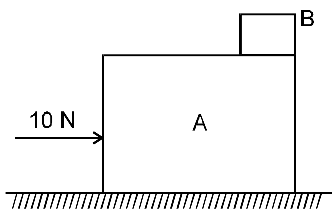
14. System is shown in the figure and man is pulling the rope from both sides with constant speed ' u = 20m/s'. Then find the speed of the block (in m/s) (M moves vertical):



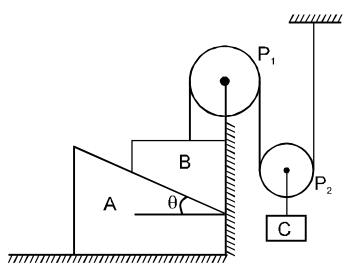
15. System is shown in the figure. Velocity of sphere A is 9 m/s. Then find the speed(in m/s) of sphere B.



16. A small block B is placed on another block A of mass 5 kg and length 20 cm. Intially the block B is near the right end of block A (figure). A constant horizontal force of 10 N is applied to the block A. All the surfaces are assumed frictionless. Find the time (in sec) elapsed before the block B separates from A.



17. In the figure shown P_1 and P_2 are massless pulleys. P_1 is fixed and P_2 can move. Masses of A, B and C are $\frac{9m}{64}$, 2m and m respectively . All contacts are smooth and the string is massless. $\theta = \tan^{-1}\left(\frac{3}{4}\right)$. Find the acceleration of block C in m/s^2.



18. A person is standing on a weighing machine placed on the floor of an elevator. The elevator stars going up with some acceleration, moves with uniform velocity for a while and finally decelerates to stop. The maximum and the minimum weights recorded are 80.5 kg and 59.5 kg. Assuming that the magnitudes of the acceleration and the deceleration are the same, find the true weight(in kg) of the person Take g = 10 m/s^2.

Answers

SAT (SELF ASSESSMENT TEST)

1.	(B)	**2.**	(C)	**3.**	(B)	**4.**	(C)
5.	(B), (D)	**6.**	(A), (B)	**7.**	(B), (D)	**8.**	(A), (B), (C)
9.	(A), (B), (C)	**10.**	(B), (D)	**11.**	(A), (C)	**12.**	(B),(C),(D)
13.	03.00	**14.**	15.00	**15.**	12 .00	**16.**	00.45
17.	03.00	**18.**	70.00				