LAWS OF MOTION

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LAWS OF MOTION

1. NEWTON'S LAWS OF MOTION

Till the mid of 17th century most of the philosophers thought that some influence was needed to keep a body moving. They thought that a body was in its 'natural state' when it was at rest and some external influence was needed to continuously move a body; otherwise it would naturally stop moving.

Confusions about these issues were solved in 1687 when Newton presented his three laws of motion. According to him influence is needed not for all kind of motion it is needed for accelerated motion only. Before going in details about these three laws, let us summerise these three laws first.

Law 1: Everybody will remain at rest or continue to move with uniform velocity unless and until an external force is applied to it.

Law 2: The rate of change of linear momentum of a body is directly proportional to the external applied force and direction of change in momentum is in direction of applied force.

Law 3: When a body A exerts a force on another body B, B exerts an equal and opposite force on A.

1.1 FRAME OF REFERENCE

Before going in details about Newton's law, let us first define frame of reference. Suppose you are standing on your school bus with one of your friend who is properly seated in his seat. There is another friend of yours standing on bus stop waves his hand to stop the bus. The driver applies brakes and your friend in bus observes you to move forward but your friend outside the bus observes bus and you to stop together. So your two friends one in the bus and other outside the bus observe you. The person in bus finds you initially at rest and then starts moving, while a friend outside the bus observes nothing unusual. Each observer such as your friend in bus or your friend outside bus defines a reference frame. A reference system requires a co-ordinate system (made of origin and co-ordinate axes) and a set of clocks, which enable an observer to measure positions, velocities and accelerations in his or her particular reference frame. Observers in different frame may measure different displacements, velocities and accelerations.

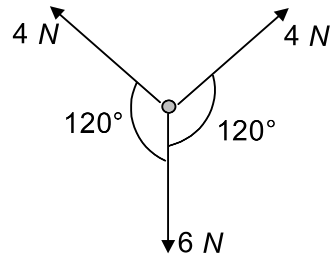
Newton's laws are applicable for a special kind of frame of reference. In the example given earlier, the friend outside the bus is in a frame which observes you moving with bus and then comes to rest. But the friend inside the bus finds you to come in motion without any cause. So we can say that your motion can't be analysed using Newton's law with respect to your friend in bus. The first law of Newton is called **"law of inertia"** and the frame in which this law is applicable is called as inertial frame. In the said example your friend outside the bus defines an inertial frame.

Any reference frame which is not accelerated (either at rest or moving with uniform velocity) is called an inertial frame. Newton's first law is applicable only in an inertial frame. We generally apply Newton's first law with respect to earth by assuming it an inertial frame. In actual practice earth experiences an accelerations of 4.4×10^{-3} m/s^2 towards the sun due to its circular motion around sun. In addition earth rotates about its own axis once every 24 hours, a point on the equator experiences an addition acceleration of 3.37×10^{-2} m/s^2 towards the center of earth. However these accelerations are small compared with g and can often be neglected. In most situations we shall assume that a set of nearby points on earth's surface constitutes an inertial frame. At a later stage we will study about accelerated frame also.

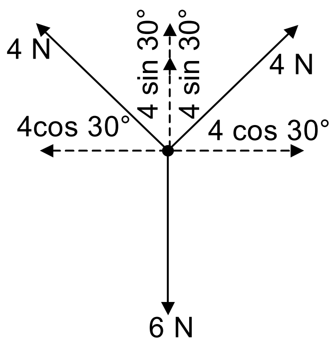
1.2 NEWTON'S FIRST LAW OF MOTION

If a body is observed from an inertial frame which is at rest or moving with uniform velocity then it will remain at rest or continue to move with uniform velocity until an external force is applied on it.
The property due to which a body remains at rest or continue its motion with uniform velocity is called as ***Inertia***.
Force is a push or pull that disturbs or tends to disturb inertia of rest or inertia of uniform motion with uniform velocity of a body.
Hence first law of motion defines inertia, force and inertial frame of reference.

Illustration 1: **The diagram shows the forces that are acting on a particle. Has the particle an acceleration?**



***Solution*:** To check whether the particle will have any acceleration or not, let us see net force is zero or not. Resolving the forces in horizontal and vertical directions.



Net force in horizontal direction

$= 4\cos 30° - 4\cos 30°$

$= 0$

Net force in vertically downward direction

$= 6 - 4\sin 30° - 4\sin 30° = 2\text{ N}$

As net force is not zero, so the particle will have acceleration.

1.3 NEWTON'S SECOND LAW OF MOTION

Newton's first law gives definition of force and inertia. Newton's second law of motion defines magnitude of force. Before stating Newton's Second's Law, Let us know about Mass.
If we attempt to change the state of rest or motion with uniform velocity, the object resists this change. Inertia is solely a property of an individual object; it is a measure of response of an object to an external force. If we take two blocks identical in shape and size; one of wood and the other of steel, the same force causes more acceleration in the wooden block. Therefore we say steel block has more inertia than the wooden block.
Mass is measure of inertia of a body. It is an internal property of a body and is independent of the body's surrounding and of the method used to measure it. Its SI unit is kg.
Mass should not be confused with weight. Mass and weight are difference quantities. We will see later, the weight of a body is equal to magnitude of force exerted by the earth on the bodies and varies with location. For example a body, which weighs 60 N on earth weights 10 N on moon. But its mass is 6 kg on earth as well as on moon.
If we push a block of ice on a smooth surface by applying a horizontal force F, the block will move with some acceleration. If we double the force the acceleration doubles, likewise if we make the force $3F$ the acceleration triples. From such observations we conclude that the acceleration of an object is directly proportional to the resultant force acting on it.

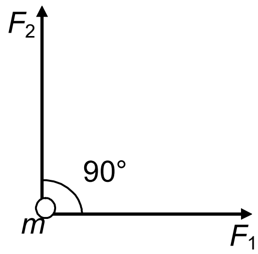
Also if we push a block of ice on a smooth surface by applying a force F, the block moves with an acceleration of a. If we double the mass, the same force causes an acceleration of $a/2$. If we triple the mass of block, the acceleration will be $a/3$.

These observations are summarised, as follows: '*the acceleration of an object is directly proportional to the net force acting on it and is inversely proportional to its mass*'. *Thus we can relate mass, force and acceleration through following mathematical relation*,

$$\sum \vec{F}_{ext} = M\vec{a}. \qquad \ldots (1)$$

It is important to note here that it is a vector relation that is *acceleration is in the direction of net force*.

Illustration 2:



Two forces $\vec{F}_1$ and $\vec{F}_2$ act on a 5.0 kg mass.
If F_1 = 20.0 N and F_2 = 15.0 N, find the acceleration.

***Solution*:**

Acceleration will be in the direction of net force and will have the magnitude given by $\sum \vec{F} = M\vec{a}$

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

$$\therefore \quad |\vec{F}| = \sqrt{20^2 + 15^2} = 25 \text{ N}$$

$$\therefore \quad |\vec{a}| = \frac{|\vec{F}|}{5.0} = 5 \text{ ms}^2$$

If the resultants force is at angle a with $\vec{F}_1$.

$$\tan a = \frac{15}{20} \Rightarrow a = 37°$$

Therefore, acceleration is **5 ms^{-2} at an angle 37°** with the direction of $\vec{F}_1$.

1.4 NEWTON'S THIRD LAW OF MOTION

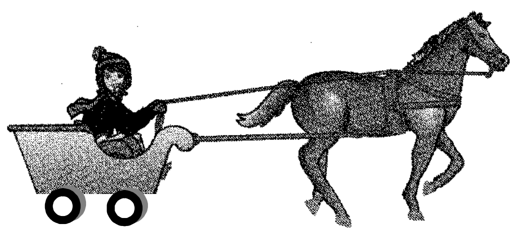
We state this law as, "*To every action there is equal and opposite reaction*".
But what is meaning of action and reaction and which force is action and which force is reaction?
Every force that acts on a body is due to the other bodies in environment. Suppose that a body A experiences a force $\vec{F}_{AB}$ due to other body B. Also body B will experience a force $\vec{F}_{BA}$ due to A. According to Newton third law two forces are equal in magnitude and opposite in direction. Mathematically we write it as

$$\vec{F}_{AB} = -\vec{F}_{BA} \qquad \ldots\ldots(2)$$

Here we can take either $\vec{F}_{AB}$ or $\vec{F}_{BA}$ as action force and the other will be the reaction force. Another important thing is these two forces always acts on different bodies.

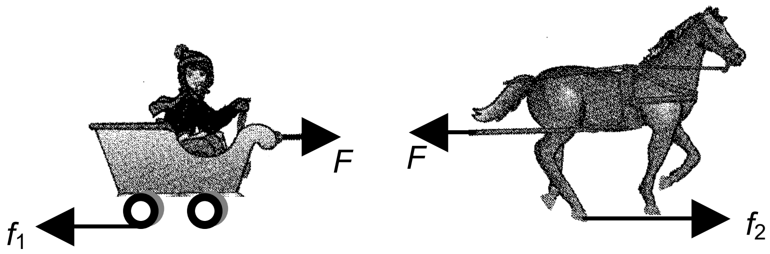
Illustration 3:

A horse pulls a cart with a horizontal force, causing it to accelerate as shown in figure. Newton's third law says that the cart exerts an equal and opposite force on the horse. In view of this, how can the cart accelerate?



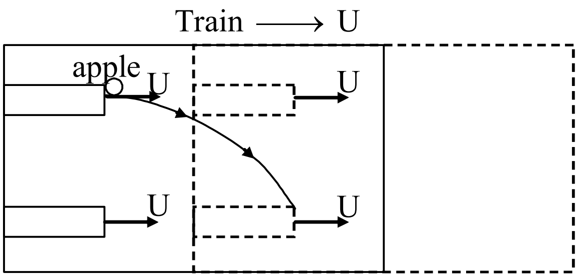
***Solution*:**

The motion of any object is determined by the external forces that acts on it. If resultant of external force is non-zero, the object moves in the direction of resultant force. In this situation, the horizontal forces exerted on the cart are forward force exerted by the horse (F) and the backward contact force (f_1) due to roughness of surface. When forward force exerted on the cart exceeds the backward force, the resultant force on it is in the forward direction. This resultant force causes the cart to accelerate to the right. The horizontal force that acts on the horse are the forward contact force (f_2) due to roughness of surface and the backward force of the cart (F). The resultant of these two forces causes the horse to accelerate.



1.5 NEWTON'S LAW IN DETAIL

I[st] Law Inertia is the property of the body which opposses change in its motion.
The measurement of inertia is mass. Higher is the mass, higher is the inertia.
Hence it is difficult to displace a bus in comparison to cycle.
It has various examples in common life, e.g., motion of aestroids, passenger falling back when bus starts etc. In given figure in moving train, when the apple is dropped it reaches directly in hand of boy below it



II[nd] Law

$\sum \vec{F}_{EXT} = M\vec{a}_{C.M.}$

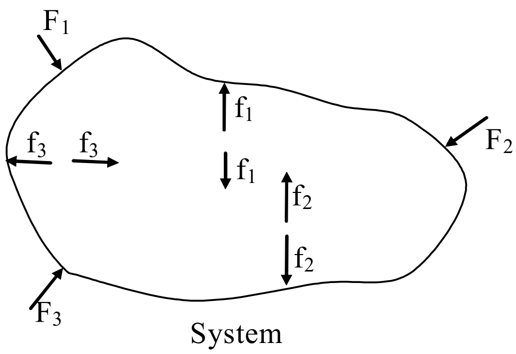
Where :

(a) $\sum \vec{F}_{EXT}$ = vector sum of all external forces acting on the system.

M = Mass of the system

$\overrightarrow{a_{cm}}$ = Acceleration of centre of mass of the system. (Different point on body may have different acceleration).

(b)

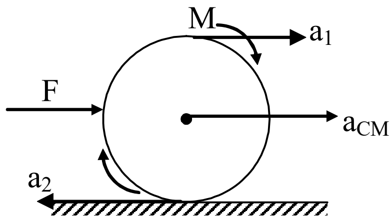


F_1, F_2, F_3 are external froces
f_1, f_2, f_3 are internal forces.

For any system internal forces always exist in pair and they cancel out each other, that is why in Newton's II Law we only consider external force. We can select the system according to our choice.

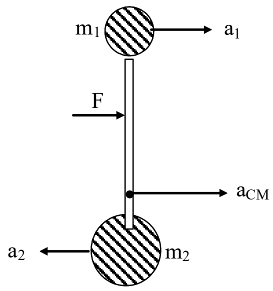
$\therefore \quad \Sigma\overrightarrow{F_{EXT.}} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3$

Example

(i) 

Newtons II Law

$F = Ma_{CM}$

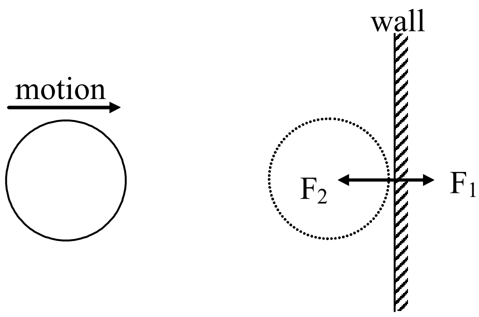
(ii) 

Newton II Law

$F = (m_1 + m_2)a_{CM}$

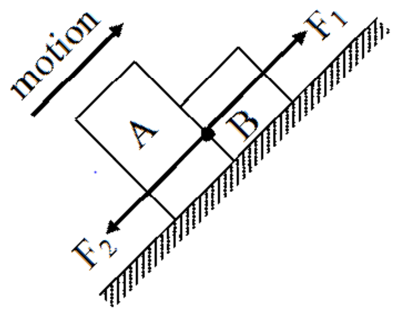
III^rd Law

Action reaction forces always act on two different bodies.

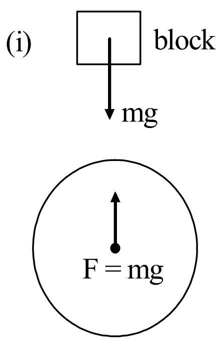
(a) 

Collision

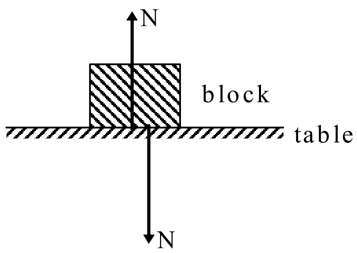
$|\vec{F}_1| = |\vec{F}_2|$, opposite direction

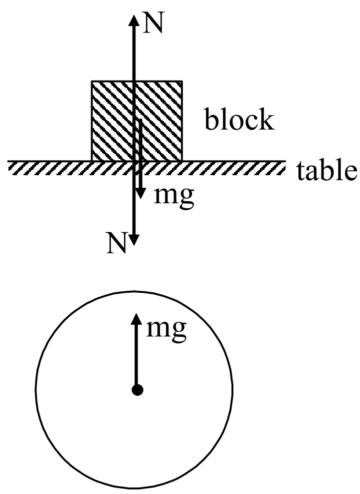
(b) 

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

(c) (i) 

Earth

(ii) 

(d) 

Earth

So we conclude that weight, mg and normal reaction, N are not action-reaction pair.

PRACTICE PROBLEMS

1. Action and reaction
(a) act on two different objects (b) have equal magnitude
(c) have opposite directions (d) all are correct

2. A block of mass m is placed on a 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) mg cos θ (d) mg tan θ

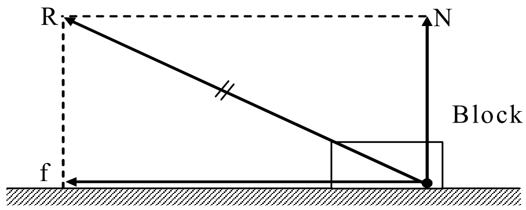
3. The two forces, which when acting at right angles to each other, produce a resultant force of $\sqrt{10}$ N and when at 60°, produce a resultant of $\sqrt{13}$ N. These forces are
(a) $\frac{3}{\sqrt{6}}$ N and $\sqrt{6}$ N (b) 3 N and 1 N
(c) $\sqrt{5}$ N and N (d) 2 N and 1.5 N

2. MECHANICAL FORCES

The type of mechanical forces are
1. Contact force (R)
2. Tension in the string (T)
3. Spring force (F_S)
4. Elastic string force (F_S)
5. Reaction in the rod (R)

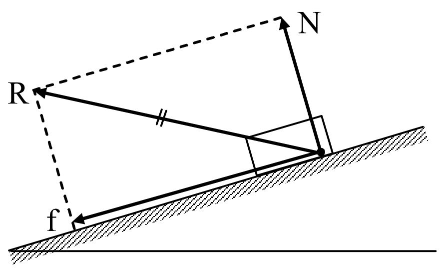
2.1. Contact force (R) - Whenever two bodies are in contact, a force develops between them. This force is called contact force (R). It has two components.

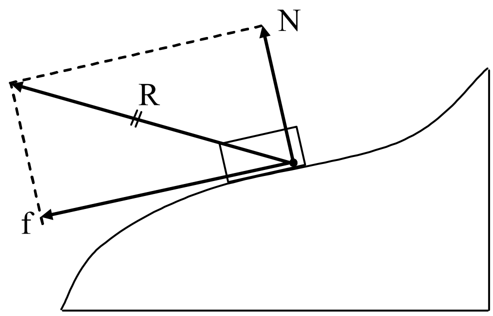
(a) Normal Reaction (N) - It acts along normal (i.e. perpendicular) to contact surface at point of con tact.

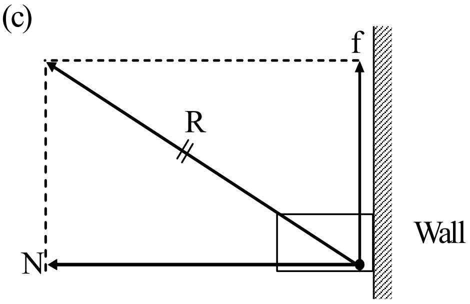


(b) Friction (f) - It acts along tangent to contact surface at point of contact.

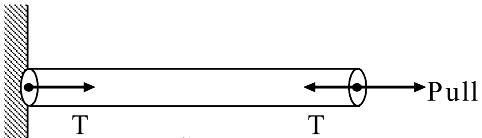
Example

(a)


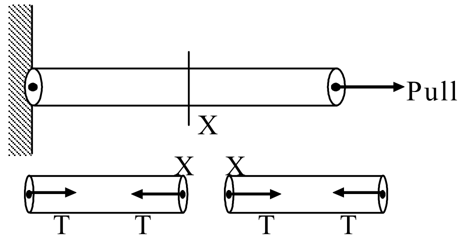
(b)


(c)


2.2. Tension (T) in String - Whenever there is a tendency to stretch the string an opposing force acts. This is called tension (T) in string (i.e., rope). In compression, the string slacks and no force acts. An ideal string is massless, uniform and inextensible. Assume string to be ideal if not stated. In an ideal string the magnitude of tension (T) is same throughout.

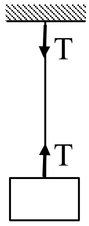


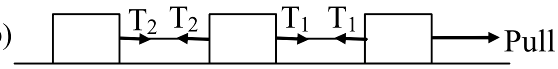
(i)



(ii)

Example

(a)


(b)


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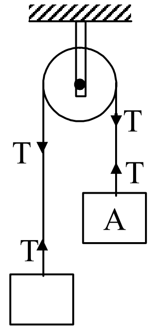
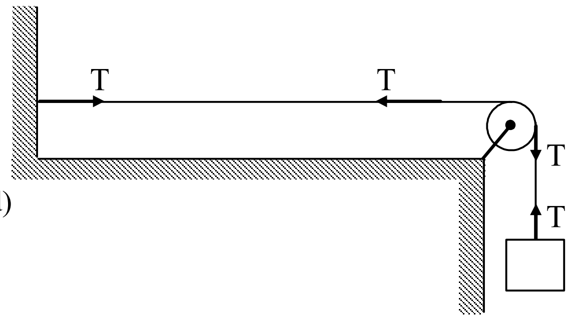


(d)


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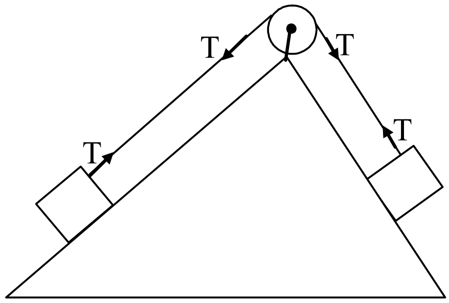
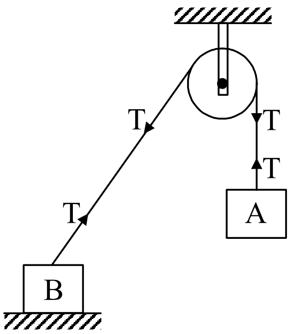
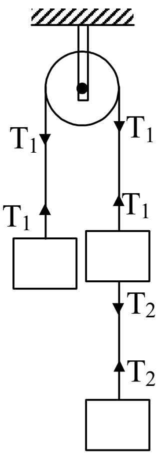
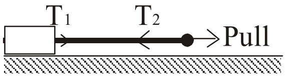


(f)


(g)


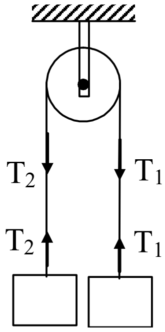
String with different tension

1. If string has mass the tension will vary along its length.



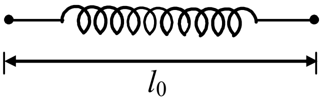
(T_2 = pulling force)

2. If string passes over non ideal pulley then the tension at the two sides of the pulley will be different.

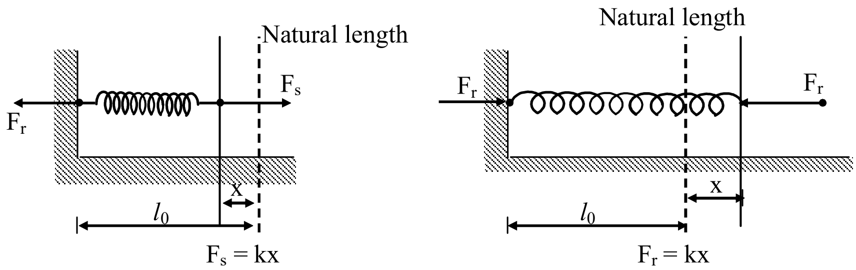


2.3. Spring Force (F_s) - Let us leave the spring free, it acquires it's natural state or free state. The length in this state is called natural length or free length (l_0).
Whenever there is compression or extension from free state in spring, an opposing force arises, which is called spring force (F_s). It acts at both ends of spring.

(a)



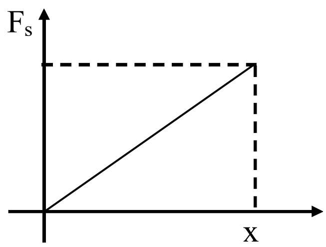
(b)



Hook's Law - "Upto a certain limit, the spring force" (F_s)is directly proportioal to compression or extension (x) produced in the spring." This limit is called proportionality limit.

$F_s \propto x$

$F_s = kx$



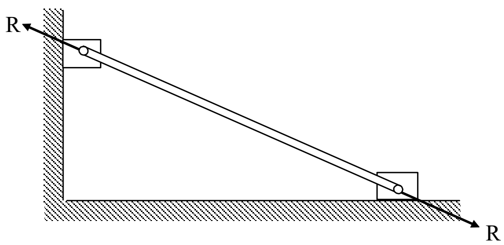
Let us take above two figure.

2.4. Elastic string force - It example is hair rubber band etc. In extension it's identical to spring. In compression, it applies no force.

2.5. Reaction in rod (R) - It applies an opposing force in both cases of compression or extension.

An ideal rod is uniform massless and rigid. It's length cannot be changed. For ideal rod, the reaction at the two ends is equal.

(a)



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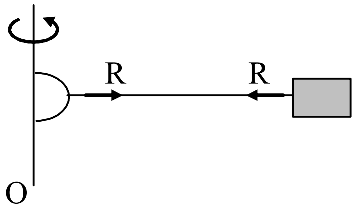
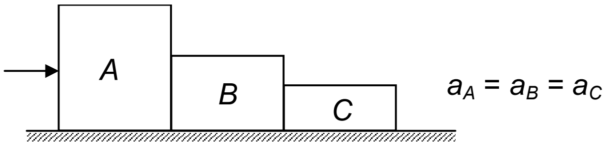


2.6. COMMONLY USED FORCES

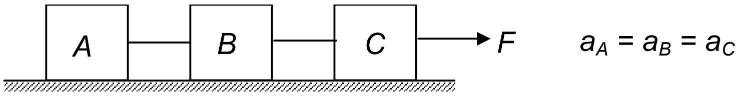
(i) Weight of a body: It is the force with which Earth attracts a body towards its center. If *M* is mass of body and *g* is acceleration due to gravity, weight of the body is *Mg*. We take its direction vertically downward.

(i) If the bodies are rigid and moving together then their accelerations, velocities and displacements will be same. As in the figure acceleration of blocks *A*, *B* and *C* will be same



(ii) If the **surface is smooth** the contact force will only be the normal force.

(iii) If the **string is inextensible** accelerations, velocities and displacements of two blocks moving together will be same as in figure



(iv) If **string is massless,** tension throughout the string will be same.

(v) If the **pulley is massless and frictionless** then tension on the two sides of pulley will be same.

In later stage we will discuss about flexible string, massive and rough pulley also.

2.7. READING OF FORCES :

(i) Weighing machine : It gives reading of the nomral reaction and not the actual weight put on the contact surface on which it is placed.

(ii) Spring balance: It gives reading of tension T and not the hanging weight in the string, at a location where it is attached.

3. STEPS TO BE FOLLOWED TO SOLVE QUESTIONS BASED ON MOTION

In such questions you will be given a system of bodies under the action of forces and you will need to find out accelerations of different bodies and unknown forces on bodies. The following steps are needed by you to apply while solving such questions.

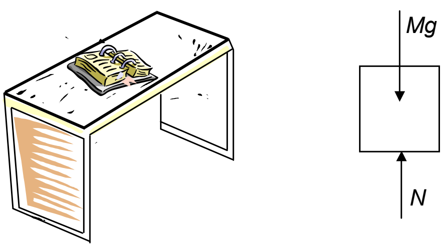
Step 1: Identify the unknown accelerations and unknown forces involved in the question.

Step 2: Draw free body diagram of different bodies in the given system.

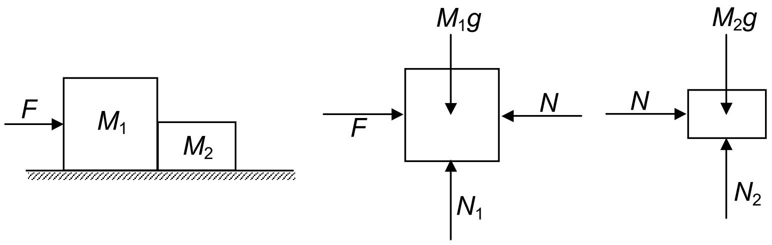
Free body diagram (FBD). It is a diagram that shows forces acting on the body making it free from other bodies applying forces on the body under consideration. Hence free body diagram will include the forces like weight of the body, normal force, tension in string and the applied force. The important thing while drawing **FBD** is the shape of the body should be taken under consideration and force should be shown in a particular way. For example weight should be applied from center of gravity of body, normal force(s) should be applied on the respective surface(s), tension should be applied on the side(s) of string(s).

Examples

(i) Free body diagram of a block resting on table

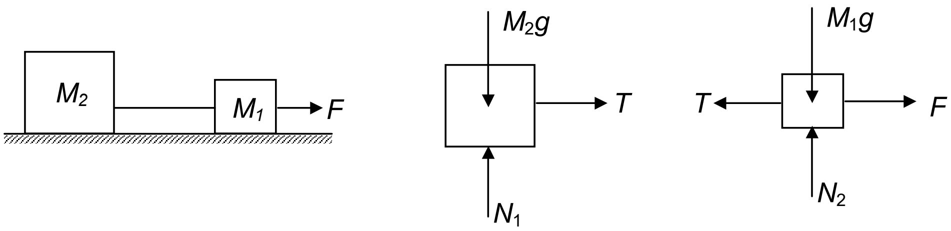


(ii) Free body diagram of bodies in contact and moving together on smooth surface.



Note that, normal force is taken normal to the surface of contact and towards the body under consideration

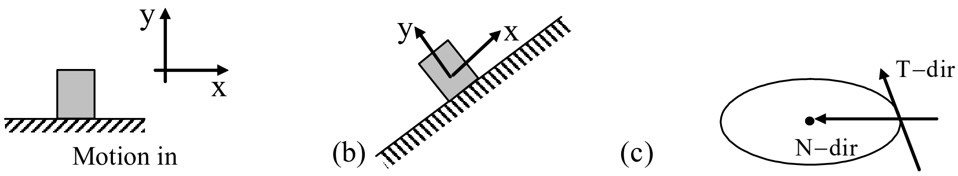
(iii) Free body diagram of bodies connected with strings and moving under the action of external force, on a smooth surface.



Note that, tension is acting along the string and away from the body under consideration.

Step 3: Identify the direction of acceleration. Draw axis along acceleration and perpendicular to it. Resolve the forces along this direction and perpendicular to it.

Axis



(a) Motion in horizontal/vertical deviation (b) Motion along an incline (c) Circular motion

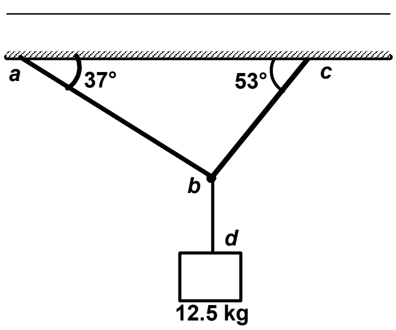
Step 4: Find net force in the direction of acceleration and apply $\vec{F} = M\vec{a}$ to write equation of motion in that direction. In the direction of equilibrium take net force zero.

Step 5: If needed write relation between accelerations of bodies given in the situation (read constraint relation).

Step 6: Solve the written equations in steps 4 and 5 to find unknown accelerations and forces.

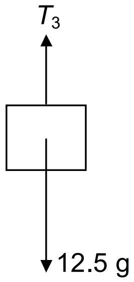
Illustration 4:

A body suspended with the help of strings. A body of mass 12.5 kg is suspended with the help of strings as shown in figure. Find tension in three strings. Strings are light [g = 10 ms^{-2}]

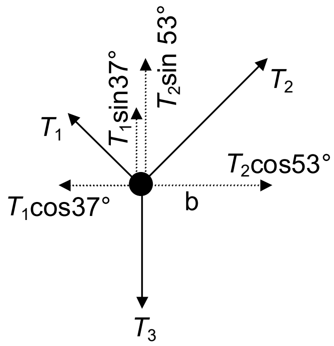


***Solution*:**

Let the tensions in strings *ab*, *bc* and *bd* are respectively T_1, T_2, and T_3. As the body is hanging in equilibrium, we can use the condition that net force on block is zero. This will give the value of T_3. To know the values of T_1 and T_2 we need to draw *FBD* of knot *b* also.



(FBD of hanging body)



(FBD of knot b)

For equilibrium of hanging body. T_3 = 12.5 g = **125 N** …(i)

For equilibrium of knot,

$T_2 \cos 53° - T_1 \sin 37° = 0$ … (ii)

and, $T_3 - T_1 \sin 37° - T_2 \sin 53° = 0$ … (iii)

From (i), (ii) & (iii)

T_2 = **99.9 N**

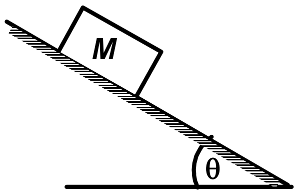
T_3 = **75.1 N**

Illustration 5:

Motion of a block on a frictionless incline

A block of mass *M* is placed on a frictionless, inclined plane of angle θ as shown in the figure.

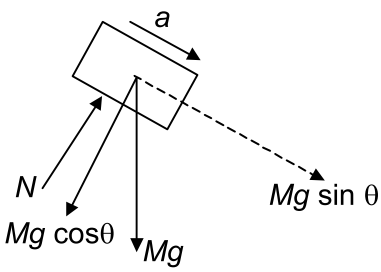
Determine the acceleration of the block after it is released. What is force exerted by the incline on the block?



***Solution*:**

When the block is released, it will move down the incline. Let its acceleration be *a*. As the surface is frictionless, so the contact force will be normal to the plane. Let it be *N*.

Here, for the block we can apply equation for motion along the plane and equation for equilibrium perpendicular to the plane.



(FBD of Block)

i.e., $Mg \sin\theta = Ma$

$\Rightarrow a = \mathbf{g \sin\theta}$

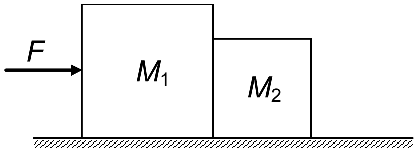
Also, $Mg \cos\theta - N = 0$

$\Rightarrow N = \mathbf{Mg \cos\theta}$

Illustration 6:

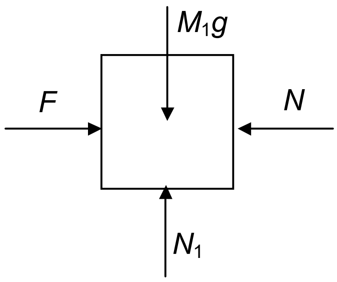
One block pushes other

Two blocks of masses M_1 and M_2 are placed in contact with each other on a frictionless horizontal surface as shown in figure. A constant force F is applied on M_1 as shown. Find magnitude of acceleration of the system. Also calculate the contact force between the blocks.

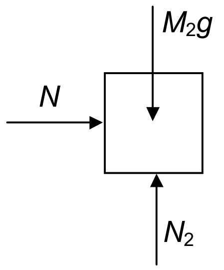


***Solution*:**

Here accelerations of both blocks will be same as they are rigid and in contact. As the surfaces are frictionless, contact force on any surface will be normal force only. Let the acceleration of each block is a and contact forces are N_1, N_2 and N as shown in free body diagrams of blocks.



(FBD of M_1)



(FBD of M_2)

Applying, Newton's Second Law for M_1

$F - N = M_1 a$ … (i)

$M_1 g - N_1 = 0$ … (ii)

Applying, Newton's second law for M_2

$N = M_2 a$ …(iii)

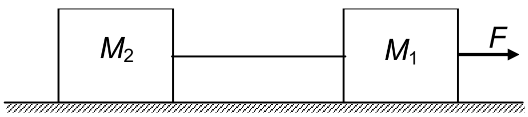
$M_2 g - N_2 = 0$ … (iv)

Solving (i) and (iii) $a = \dfrac{F}{M_1 + M_2}$ and $N = \dfrac{M_2 F}{M_1 + M_2}$

Illustration 7:

Bodies connected with strings

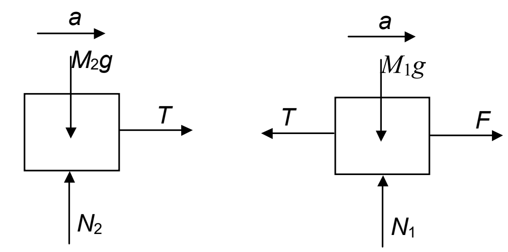
A light, inextensible string as shown in figure connects two blocks of mass M_1 and M_2. *A force F as shown acts upon M_1*. Find acceleration of the system and tension in string.



***Solution*:**

Here as the string is inextensible, acceleration of two blocks will be same. Also, string is mass less so tension throughout the string will be same. Contact force will be normal force only.

Let acceleration of each block is a, tension in string is T and contact force between M_1 and surface is N_1 and contact force between M_2 and surface is N_2.



(FBD of M_2) (FBD of M_1)

Applying Newton's second law for the blocks;

For M_1 , $F - T = M_1 a$ ... (i)

$M_1g - N_1 = 0$ ... (ii)

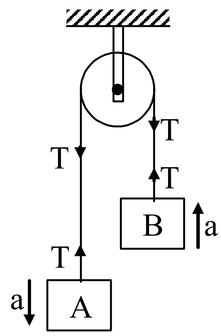
For M_2 $T = M_2a$ ... (iii)

$M_2g - N_2 = 0$ ... (iv)

Solving (i) and (iii)

$$a = \frac{F}{M_1 + M_2} \text{ and } T = \frac{M_2F}{M_1 + M_2}$$

4.1. MOTION OF CONNECTED BODIES (ATWOOD MACHINE)



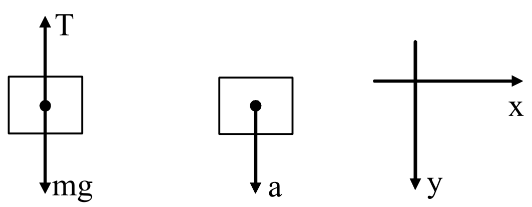
In the given figure, the two blocks are connected by a string passing over a pulley fixed to the roof. The pulley of string are ideal. This system is called Atwood Machine.

Let mass of A = m_1

Let mass of B = m_2

FBD– Block A

(A)



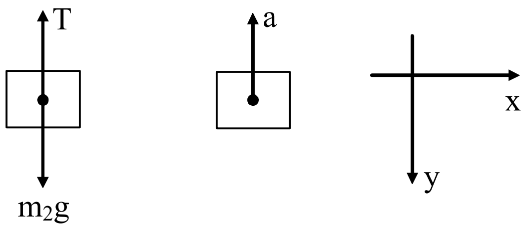
Force Acceleration

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

$$m_1g + (-T) = m_1a \qquad ...(1)$$

FBD –Block B

(B)



Force Acceleration

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

$$m_2g - T = -m_2a \quad \text{...(2)}$$

Subtracting equation (2) from (1)

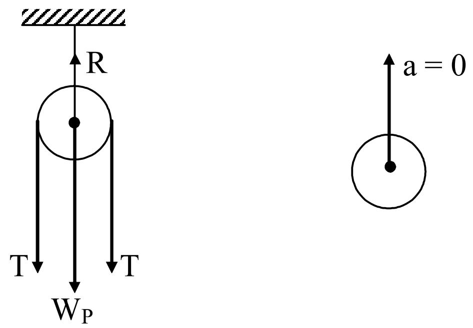
$$(m_1 - m_2)g = a(m_1 + m_2)$$

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

Using te value of acceleration, a in equation (1) and solving for T,

$$\mathbf{T = \left(\frac{2m_1m_2}{m_1 + m_2}\right)g}$$

FBD
Pulley



W_P - Weight of pulley

R - Reaction by rod on which pully is attached.

(a) Force

y – direction

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

$$2T - W_P - R = 0$$

$R = 2T$ (As ideal Pulley is massless)

Note: (1) The above results are applicable only when pulley is at rest.

(2) If the above system is placed such that pulley is also accelerated, then all results will change. Then start the problem with fresh FBD.

Special Case

(1) If $m_1 = m_2 = m$

$\therefore \quad a = 0$

$\therefore \quad T = mg \qquad \left[\therefore \quad T = \frac{2m.m}{2m}.g\right]$

(2) If $m_1 >> m_2$

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

Since $m_1 - m_2 \approx m_1$ and $m_1 + m_2 \approx m_1$

$\therefore \quad a \approx g$

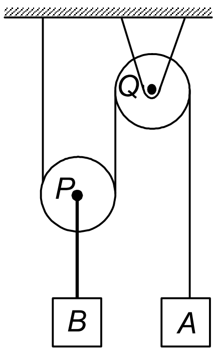
$$T = \frac{2m_2m_2}{m_1 + m_2}g$$

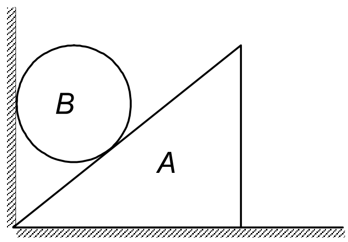
$$= \left(\frac{2m_2}{1 + \frac{m_2}{m_1}}\right)g \qquad (\because \text{ by taking m, common})$$

$\therefore \quad T = 2m_2g \qquad$ Since $\frac{m_2}{m_1}$ is nearly equal to 0. $\quad \therefore \quad 1 + \frac{m_2}{m_1} \approx 0$

4.2 RELATED MOTION (CONSTRAINT RELATION)

Till now we had seen the case when accelerations of the different parts of a system are same. There are situations in which the accelerations of different parts of the system may not be same. We get such situations in case of movable pulleys or bodies in contact where each body is free to move.





For example in the above figure, pulley *P* is movable which leads to different accelerations of block *B* and *A*.

In the other figure, triangular wedge *A* and sphere *B* will not have same acceleration.

In such cases, a relationship between accelerations can be found by considering physical properties of system. We call such relations as constrained relation.

Method to find out constraint relation

(1) Method of Visual inspection

(2) Method of virtual work

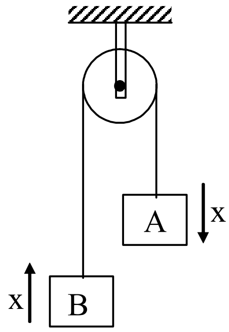
(3) Method of Differentiation

Method of visual inspection

It is used in simple problems in this method we write the relation just by visual observation. This method is explained in the following examples.

Example 1.

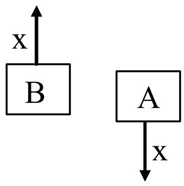
Find the C.R. of two bodies connected by a string passing over a pulley.



Solution

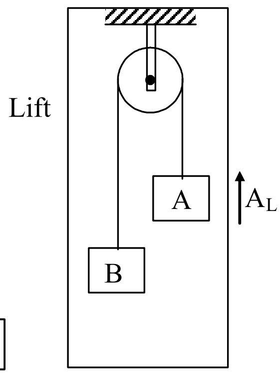
Suppose block A moves downward by a distance x, then block B moves upward by a same distance x.

- $x_A = x_B = x$
- $V_A = V_B = V \quad \left(\because \dfrac{dx}{dt} = V\right)$
- $a_A = a_B = a \quad \left(\because \dfrac{dV}{dt} = a\right)$



Example 2.

If above system is placed in a lift accelerating upward, then find the acceleration of A & B w.r.t earth. The acceleration of A & B w.r.t lift is a.



A_L = Acceleration of lift.

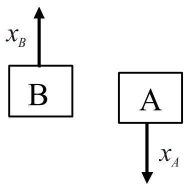
Let us solve the problem in two steps

Step-1

Suppose lift is at rest. Their disp. will be as shown

- $x_A = x_B = x$

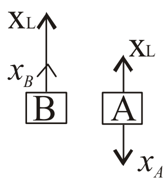
  Where x is disp. of A & B w.r.t. lift



Step-2

Now, suppose lift move upward by a disp. = x_L

Hence, their resultant disp. will be as shown



(i) $x_A = x - x_L\ (\downarrow)\quad x_B = x + x_L\ (\downarrow)$

(ii) $V_A = V - V_L\ (\downarrow)\quad V_B = V + V_L\ (\downarrow)$

(iii) $a_A = a - A_L\ (\downarrow)\quad a_B = a + A_L\ (\downarrow)$

This is C.R.

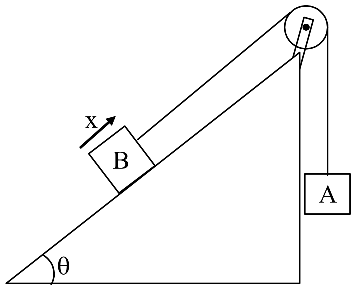
$\therefore$ Constraint relation is

$$a_A = a - A_L$$

$$a_B = a + A_L$$

Example 3.

Find C.R.



Solution:

∴ $x_A = x_B = x$

∴ $V_A = V_B = V$

∴ $a_A = a_B = a$

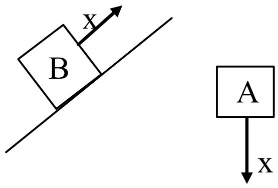
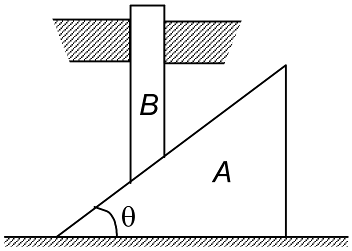


Illustration 11:

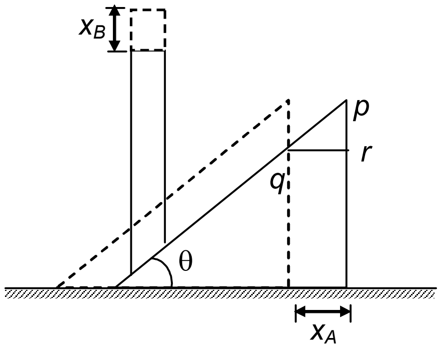
In the arrangement shown A is a wedge and B is a rod. The rod is constrained to move vertical. Find relation between accelerations of A and B.



***Solution*:**

Here the physical property that we can use is the rigidity of body. Let x_A and x_B are displacement of wedge and rod as shown in figure.

In Δpqr, $qr = x_A$ and $pr = x_B$



∴ $\tan\theta = \dfrac{x_B}{x_A}$

⇒ $x_B = x_A \tan\theta$

⇒ $V_B = V_A \tan\theta$

⇒ $\boldsymbol{a_B = a_A \tan\theta}$

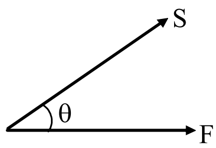
4.2.2.METHOD OF VIRTUAL WORK DONE

We use thus method when blocks are connected by string.

Some additional formulas

(i) Work done

$W = Fs\cos\theta$

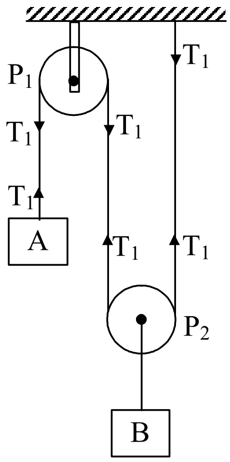


Definition - "The total work done by tension. T of the string is always zero".

It is because tension is an internal force which cause no resultant work.

Example

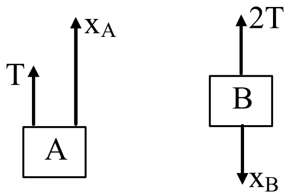
Find C.R. for the block A and B, pulley P_1 is fixed, while pulley P_2 is movable



Solution

Let block A moves upward, x_A and block B moves downward x_B.

By method of virtual work done



Total work done = 0

$$\Sigma(W.D) = 0$$

$\Rightarrow$ $W_A + W_B = 0$

$$x_A T\cos 0^\circ + x_B 2T\cos 180^\circ = 0$$

$$T\left[x_A + 2x_B(-1)\right] = 0$$

Since $T \neq 0$ $\therefore x_A - 2x_B = 0$

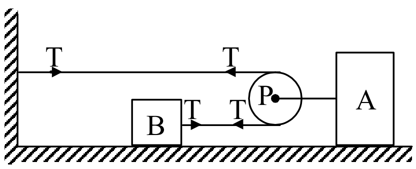
$\Rightarrow$ $x_A = 2x_B$

$V_A = 2V_B$

$a_A = 2a_B$

Example

Find C.R. for the two blocks, A and B if pulley P is movable



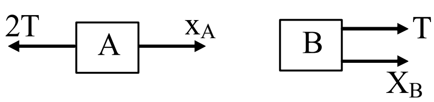
Solution

Let block A moves rightward by a distance x_A and block B moves rightward bya distane x_B.

$\Sigma(W.D.) = 0$

$W.D_A + W.D_B = 0$

$2T\cos(180^\circ)x_A + Tx_B\cos(0^\circ) = 0$



$T(2x_A(-1) + x_B) = 0$

Since $T \neq 0$

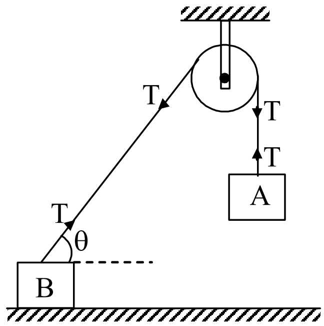
$x_B = 2x_A$

$\therefore$ $V_B = 2V_A$

$\therefore$ $a_B = 2a_A$

Example

Fidn C.R. for the block A and B. Block A falls vertically down while block B moves horizontally.

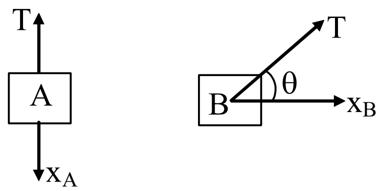


Solution

Let bjlock A moves downward by a distnace x_A and block B moves rightward by a distan ce x_B.

By method of virtual work done

Total W.D. by tension (T) is always 0.



$\Rightarrow \quad w_A + w_B = 0$

$\Rightarrow \quad Tx_A\cos(180^\circ) + Tx_B\cos\theta = 0$

$\Rightarrow \quad T\left[x_A(-1) + x_B\cos\theta\right] = 0$

Since $T \neq 0$

$\therefore x_A = x_B\cos\theta$

Differentiating

$$\frac{dx_A}{dt} = \cos\theta\frac{dx_B}{dt}$$

$$V_A = V_B\cos\theta$$

$$a_A = a_B\cos\theta$$

4.2.3. METHOD OF DIFFERENTIATION

In this method first we write relation between displacement of two bodies, then double differentiate the displacement relation to obtain acceleration relation.

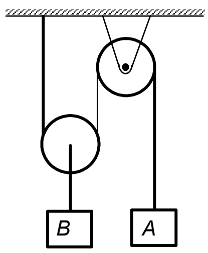


Illustration 10:

Find the relation between accelerations of blocks *A* and *B*

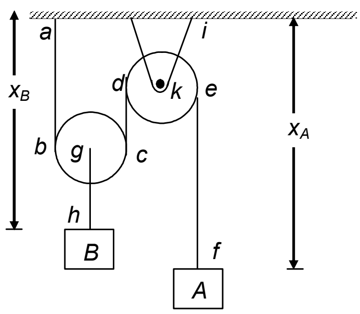
Solution:

The physical property that we can use is the inextensibility of string.

i.e., $ab + \overset{\frown}{bc} + cd + \overset{\frown}{de} + ef =$ constant … (i)

Let at any moment *A* and *B* are at distances x_A and x_B from the support as shown in figure.

Let us take $gh = l_1$ and $ik = l_2$ and express the length in equation (i) in terms of x_A, x_B, l_1 and l_2



we get,

$$x_B - l_1 + \widehat{bc} + (x_B - l_1 - l_2) + \widehat{de} + (x_A - l_2) = \text{constant}$$

Here l_1, l_2, and are constant

$\therefore$ $2x_B + x_A = \text{constant}$ … (ii)

let in time Dt, x_B charge to x_B + Dx_B and x_A changes to x_A - Dx_A

[B is assumed to move downward]

then, $2(x_B + Dx_B) + (x_A - Dx_A) = \text{constant}$ … (iii)

From (ii) and (iii)

$$2Dx_B - Dx_A = 0$$

$\Rightarrow$ $2V_B - V_A = 0$

$\Rightarrow$ $\mathbf{2a_B = a_A}$

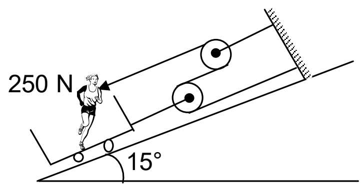
Hence magnitude of acceleration of A is two times magnitude of acceleration of B.

Here we get the relation between the acceleration by using the inextensibility of string but after some practice such relation can easily be written by observation.

Let us think B moves by a distance x during an interval of time, this will cause movement of pulley g by x. an extra length of $2x$ of string will come to the left of pulley k. This must be coming from right side of pulleys. Hence displacement of A will be $2x$. On the basis of this discussion we can say if the acceleration of block B is a, then the acceleration of A will be $2a$.

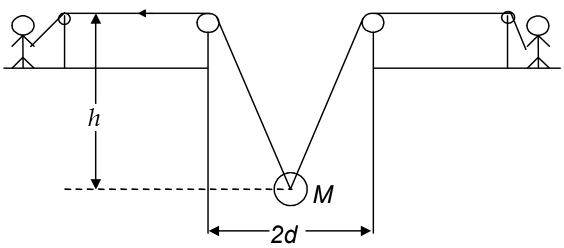
PRACTICE PROBLEMS

4. A trolley is being pulled up an incline plane by a man sitting on it (as shown in figure). He applies a force of 250 N. If the combined mass of the man and trolley is 100 kg, the acceleration of the trolley will be [sin 15° = 0.26]



(a) 2.4 m/s^2 (b) 9.4 m/s^2
(c) 6.9 m/s^2 (d) 4.9 m/s^2

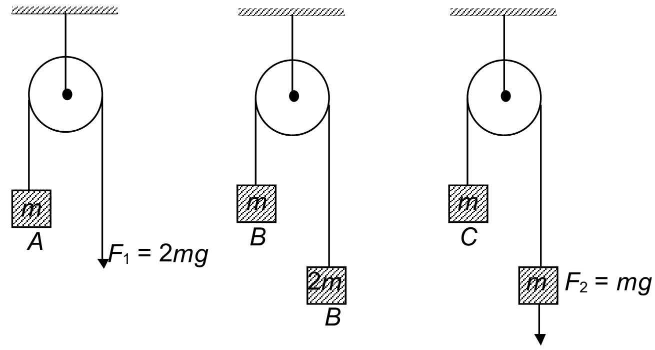
5. A big boulder of mass M has fallen into a ditch of width 2d. Two persons are slowly pulling it out using a light rope and two fixed pulleys as shown in Figure. Assuming the force exerted by two persons are equal calculate the force when the boulder is at a depth h.



(a) $\frac{Mg}{4h}\sqrt{d^2 + 4h^2}$ (b) $\frac{Mg}{4}\sqrt{d^2+4h^2}$

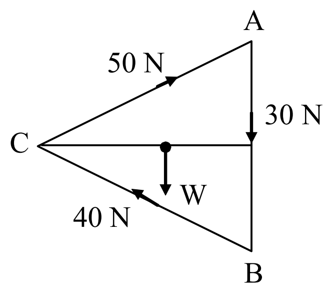
(c) $\frac{Mg}{2h}\sqrt{d^2+h^2}$ (d) $\frac{Mg}{2}\sqrt{d^2+h^2}$

6. In the figure, the block 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. Then



(a) $a_1 = a_2 = a_3$
(b) $a_1 > a_3 > a_2$
(c) $a_1 = a_2, a_2 > a_3$
(d) $a_1 > a_2, a_2 = a_3$

7. Forces of 30 N, 40 N and 50 N act along the sides $\vec{AB}$, $\vec{BC}$ and $\vec{CA}$ of an equilateral triangle ABC. The triangle is of mass 0.5 kg and kept in a vertical plane as shown in figure, with the side AB vertical. The net vertical force acting on the triangle will be (g = 10 m/s^2)



(a) 125 N
(b) 5 N downwards
(c) 10 N upwards
(d) 10 N downwards

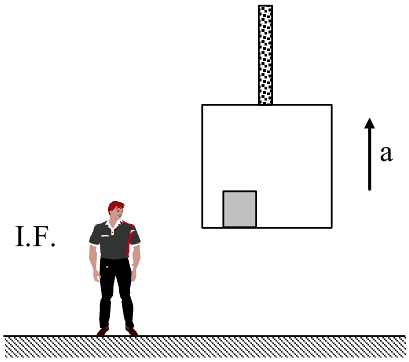
8. If the tension in the cable supporting an elevator is equal to the weight of the elevator, the elevator may
(a) going up with increasing speed
(b) going down with increasing speed
(c) going up with uniform speed
(d) going down with non-uniform speed

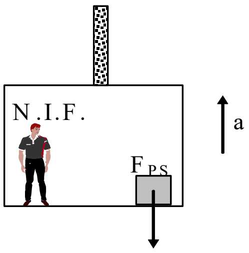
4.3. ACCELERATED FRAME OF REFERENCE

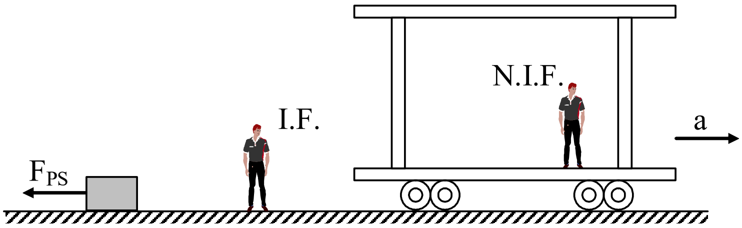
When Newton's laws of motion were introduced in lesson 1, we emphasized that the laws are valid only when observations are made in an inertial frame of reference (frame at rest or moving with uniform velocity). Now we analyze how an observer in accelerated frame of reference (Non-inertial frame) would attempt to apply Newton's second law.

Once a frame of reference begins to accelerate the frame becomes non-inertial and Newton's laws do not hold good any more. To understand this in a better way, let us consider the rail-car. Suppose a body is placed on the floor of the car which we consider as smooth. The train is moving with uniform velocity and hence the position of the body with respect to the frame of reference attached to the car remains constant. Suppose brakes are applied and the train begins to decelerate. The body which was at rest on the floor, suddenly begins to slide along the floor in the forward direction even though no force of any kind acts on it. Newton's laws seem to have been violated. Conventionally we would explain this motion as due to Newton's first law and the body due to the absence of friction continues to maintain its state of uniform motion along a straight line with respect to the railway track. The train has now become a non-inertial frame.

Non-inertial frames of reference are the system which are accelerated (or decelerated) with respect to earth. Newton's laws especially first and second cannot hold good for accelerating frames of reference. Anyhow the Newton's laws of motion can be made applicable to them by applying an imaginary force on the body considered. This imaginary force is called inertial force or pseudo-force or fictitious force. The magnitude of the force is the product of mass of the body and the acceleration of the reference system. Its direction is opposite to the acceleration of the reference.

(a) 

(b) 

(c) 

If a body of mass M is observer from a frame having acceleration $\vec{a}_{frame}$ then

$\vec{F}_{pseudo} = -M\vec{a}_{frame}$ ...(1)

It should be emphasised again that no such force actually exists. But once it is introduced Newton's laws of motion will hold true in a non-inertial frame of reference.

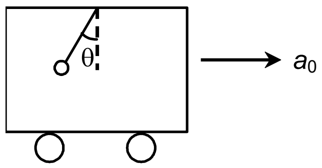
Therefore for non-inertial frame, we can write

$\vec{F}_{ext} + \vec{F}_{pseudo} = M\vec{a}$, ...(2)

where $\vec{a}$ is acceleration of body with respect to frame.

Illustration 1:

A pendulum is hanging from the ceiling of a car having an acceleration a_0 with respect to the road. Find the angle made by the string with vertical at equilibrium.



Solution:

The situation is shown in figure. Suppose the mass of bob is m and the string makes an angle θ with vertical, the forces on the bob in the car frame (non-inertial frame) are indicated. The forces are

(i) tension in the string

(ii) mg vertically downwards

(iii) ma_0 in the direction opposite to the motion of car (pseudo force).

Writing the equation of equilibrium

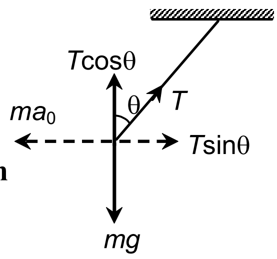
$T \sin\theta = ma_0$

$T\cos\theta = mg$

$\therefore \quad \tan\theta = \dfrac{a_0}{g}$

$\therefore$ the string is making an angle

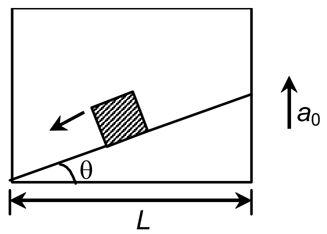
$\tan^{-1}\left(\dfrac{a_0}{g}\right)$ **with vertical at equilibrium**



FBD of bob w.r.t car

Illustration 2:

A block slides down from top of a smooth inclined plane of elevation θ fixed in an elevator going up with an acceleration a_0. The base of incline has length L. Find the time taken by the block to reach the bottom.



Solution:

Let us solve the problem in the elevator frame. The free body force diagram is shown. The forces are

(i) N normal to the plane

(ii) mg acting vertically down

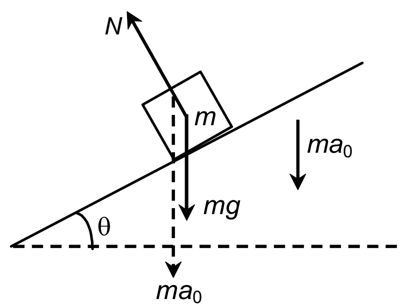
(iii) ma_0 (pseudo force).

If a is the acceleration of the body with respect to incline, taking components of forces parallel to the incline

$$mg\sin\theta + ma_0\sin\theta = ma$$

$$\therefore \quad a = (g + a_0)\sin\theta$$

This is the acceleration with respect to elevator.



The distance traveled is $\dfrac{L}{\cos\theta}$. If t is the time for reaching the bottom of incline

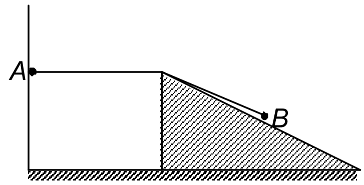
$$\frac{L}{\cos\theta} = 0 + \frac{1}{2}(g + a_0)\sin\theta . t^2$$

$$t = \left[\frac{2L}{(g + a_0)\sin\theta\cos\theta}\right]^{1/2}$$

PRACTICE PROBLEMS

9. A person standing on the floor of an elevator drops a coin. The coin reaches the floor of the elevator in a time t_1 if the elevator is stationary and in time t_2 if it is moving uniformly. Then
(a) $t_1 = t_2$
(b) $t_1 < t_2$
(c) $t_1 > t_2$
(d) $t_1 < t_2$ or $t_1 > t_2$ depending on whether the lift is going up or down.

10. A weightless inextensible rope rests on a stationary wedge forming an angle a with the horizontal. One end of the rope is fixed to the wall at the point A. When a small load is attached to the rope at the point B, the wedge starts moving to the right with constant acceleration 'a'. What is the acceleration of the load when it is still on the wedge?



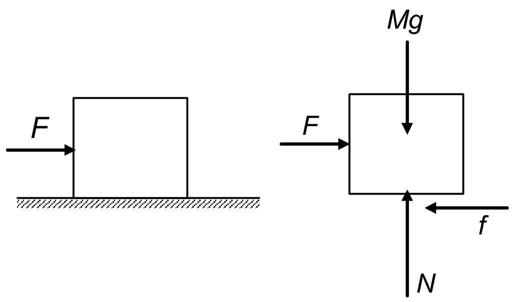
(a) 2a sin a (b) 2a cos a
(c) $2a \sin \frac{\alpha}{2}$ (d) $2a \cos \frac{\alpha}{2}$

11. A 77 kg person is parachuting and experiencing a downward acceleration of 2.5 ms^{-2} shortly after opening the parachute. The mass of parachute is 5.2 kg.
(a) Find the upward force exerted on the parachute by the air
(b) Calculate the downward force exerted by the person on the parachute.
$[g = 10\ ms^{-2}]$

5. FRICTION

Friction plays dual role in our life. It impedes the motion of object, causes abrasion and wear, and converts other forms of energy into heat. On the other hand, without it we could not walk, drive cars, climb roper, or use nails. *Friction is a contact force that opposes the relative motion or tendency of relative motion of two bodies.*

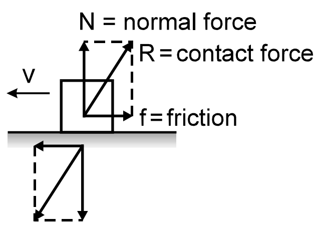
Consider a block on a horizontal table as shown in the figure. If we apply a force, acting to the right, the block remains stationary if *F* is not too large. The force that counteracts *F* and keeps the block from moving is called *frictional force*. If we keep on increasing the force, the block will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



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

5.1. FRICTION

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



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

Therefore if R is contact force then

$$R = \sqrt{f^2 + N^2}$$

5.2. REASONS FOR FRICTION

(i) Inter-locking of extended parts of one object into the extended parts of the other object.

(ii) Bonding between the molecules of the two surfaces or objects in contact.

5.3. FRICTION FORCE IS OF TWO TYPES.

a. Static   b. Kinetic

(a) STATIC FRICTION

It exists between the two surfaces when there is tendency of relative motion but no relative motion along the two contact surface.

For example consider a bed inside a room ; when we gently push the bed with a finger, the bed does not move. This means that the bed has a tendency to move in the direction of applied force but does not move as there exists static friction force acting in the opposite direction of the applied force.

Direction of static friction force :

The static friction force on an object is opposite to its impending motion relative to the surface.

Following steps should be followed in determining the direction of static friction force on an object.

(i) Draw the free body diagram with respect to the other object on which it is kept.

(ii) Include pseudo force also if contact surface is accelerating.

(iii) Decide the resultant force and the component parallel to the surface of this resultant force.

(iv) The direction of static friction is opposite to the above component of resultant force.

Note : Here once again the static friction is involved when there is no relative motion between two surfaces.

(b) Kinetic Friction Force

Kinetic friction exists between two contact surfaces only when there is **relative motion** between the two contact surfaces. It stops acting when relative motion between two surfaces ceases.

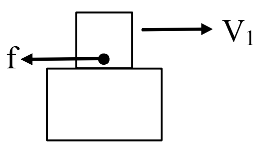
Direction of kinetic friction on an object

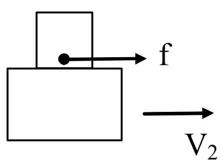
It is opposite to the relative velocity of the object with respect to the other object in contact considered.

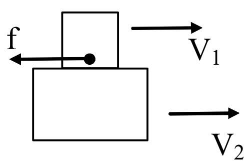
Note that its direction is not opposite to the force applied it is opposite to the relative motion of the body considered which is in contact with the other surface.

This friction forces has following characteristics

(1) It always opposes the relative motion between the two bodies.

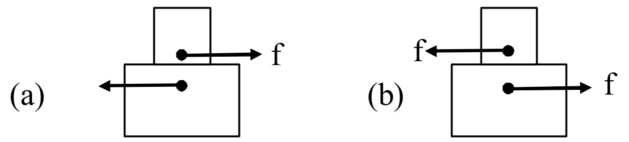
(1)


(2)


(3)


If $V_1 > V_2$

(2) The friction force also act on second object, by newtons's III Law, it is equal and opposite.



(3) Friction can adjust both its magnitude and direction. So it is also called self adjusting force.

(4) The maximum value of friction force also depends upon nature of contanct surface. The rough surface, higher is the maximum value of friction force.

5.4. MAGNITUDE OF STATIC AND KINETIC FRICTION

Static friction :

The magnitude of static friction is equal and opposite to the external force exerted, till the object at which force is exerted is at rest. **This means it is a variable and self adjusting force. However it has a maximum value called limiting friction.**

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

The actual force of static friction may be smaller than $\mu_s N$ and its value depends on other forces acting on the body. The magnitude of frictional force is equal to that required to keep the body at relative rest.

$$0 \le f_s \le f_{smax}$$

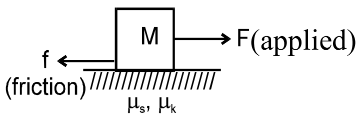
Kinetic friction :

The magnitude of the kinetic friction is proportional to the normal force acting between the two bodies. We can write

$$f_k = \mu_k N$$

where N is the normal force. **The proportionality constant μ_k is called the coefficient of kinetic friction and its value depends on the nature of the two surfaces in contact.** If the surfaces are smooth μ_k will be small, if the surfaces are rough μ_k will be large. It also depends on the materials of the two bodies in contact.

Here μ_s and μ_k are proportionality constants. μ_s is called coefficient of static friction and μ_k is called coefficient of kinetic friction. They are dimensionless quantities independent of shape and area of contact . It is a property of the two contact
surfaces. $\mu_s > \mu_k$ for a given pair of surfaces. If not mentioned then $\mu_s = \mu_k$ can be taken. Value of μ can be from 0 to 1.



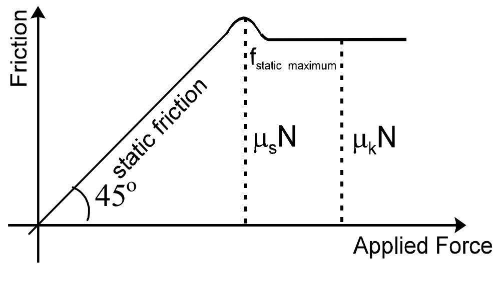
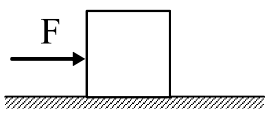


Illustration 3:

A block of mass 5 kg is resting on a rough surface as shown in the figure. It is acted upon by a force of F towards right. Find frictional force acting on block when (a) F = 5N (b) 25 N (c) 50 N

($\mu_s = 0.6$, $\mu_k = 0.5$) [$g = 10\ ms^{-2}$]



Solution:

Maximum value of frictional force that the surface can offer is

$$f_{max} = f_{lim} = \mu_s N$$
$$= 0.6 \times 5 \times 10$$
$$= 30 \text{ newton}$$

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

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

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

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

$f_s = F = 5N$

(b) F = 25N < f_{max}

$f_s = 25$ N

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

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

$f_k = \mu_k N$

$= 0.5 \times 5 \times 10 = 25$ newton

Illustration 4:

A block B slides with a constant speed on a rough horizontal floor acted upon by a force which is 1.5 times the weight of the block. The line of action F makes 30° with the ground. Find the coefficient of friction between the block and the ground.

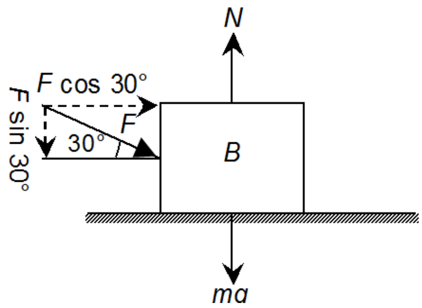
Solution:

Let m be the mass of the block. The weight of the block, then is mg. It is given that F = 1.5 mg. F can be resolved into two components F cos 30° parallel to the horizontal floor and F sin 30° perpendicular to it.

Normal reaction $N = mg + F \sin 30°$

$$= mg + \left(1.5mg \times \frac{1}{2}\right)$$

$= mg + 0.75\ mg = 1.75\ mg$



Hence the friction force

$f = \mu N = \mu \times 1.75, mg = 1.75\ \mu\ mg$

The body moves with constant speed. This means the force F cos 30° is just able to overcome the frictional force f

i.e., $f = \mu N = F \cos 30°$

or, $1.75\ \mu\ mg = (1.5\ mg)\ \dfrac{\sqrt{3}}{2}$

or, $\mu = \dfrac{(1.5)\sqrt{3}}{2 \times 1.75} = \mathbf{0.742}$

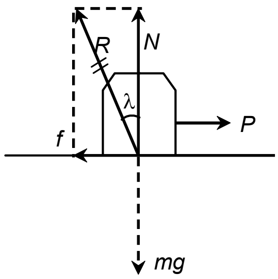
5.5 ANGLE OF FRICTION

The resultant of normal reaction N and the limiting frictional for $\vec{f}$ is R which makes an angle λ with N.

Now, $\tan\lambda = \frac{f}{R} = \frac{\mu R}{R} = \mu$ ...(**5**)

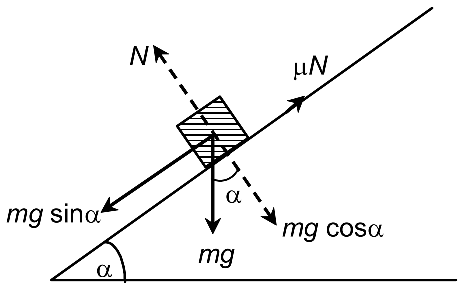
$$\lambda = \tan^{-1}(\mu)$$

The angle λ is called the angle of friction.



5.6 ANGLE OF REPOSE

This is concerned with an inclined plane on which a body rests exerting its weight on the plane. The angle of repose of an inclined plane with respect to a body in contact with it is the angle of inclination of the plane with horizontal when the block just starts sliding down the plane under its own weight.



The limiting equilibrium of a body resting on the inclined plane is shown in figure.

The forces acting are (i) Its weight mg downward, (ii) Normal reaction, (iii) The force of limiting friction. Taking α as the angle of repose and resolving the forces along the plane and perpendicular to the plane, we get for equilibrium

$mg\cos\alpha = N$ ...(i)

$mg\sin\alpha = f = \mu N$ ...(ii)

Dividing equation (ii) by (i),

$$\mu = \tan\alpha$$

$\therefore$ angle of repose $= \alpha = \tan^{-1}(\mu)$ ...(**6**)

5.7 MOTION ON A ROUGH INCLINED PLANE

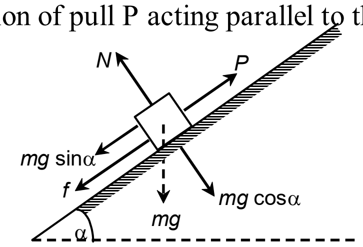
Suppose a motion up the plane takes place under the action of pull P acting parallel to the plane.

$N = mg\cos\alpha$

Frictional force acting down the plane,

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

Applying Newton's second law for motion up the plane.



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

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

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

$mg\ \sin\alpha - F = ma$

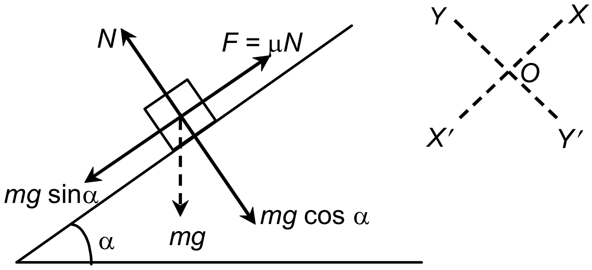
or, $mg\ \sin\alpha - \mu\ mg\ \cos\alpha = ma$

Illustration 5:

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

Solution:

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



(i) $mg\ \sin\alpha$ acting down the plane and

(ii) $mg\ \cos\alpha$ acting perpendicular to the plane.

$R = mg\ \cos\alpha$

$mg \sin - N = ma$

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

$a = g\ \sin\alpha - \mu g\ \cos\alpha$

$= g\,(\sin\alpha - \mu\ \cos\alpha) = 9.8\left(\frac{1}{2} - 0.4 \times \frac{\sqrt{3}}{2}\right)$

$= 4.9 \times 0.3072 = \mathbf{1.505\ m/s^2}$

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

Illustration 6:

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

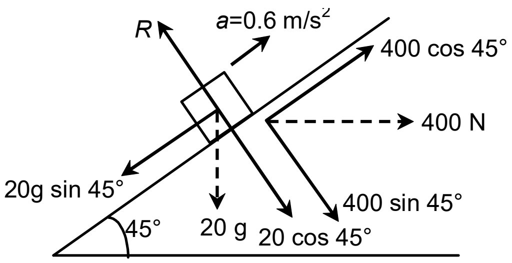
Solution:

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

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

The frictional force experienced by the block F = mN = m × 421.4 = 421.4 mN.

As the accelerated motion is taking place up the plane.



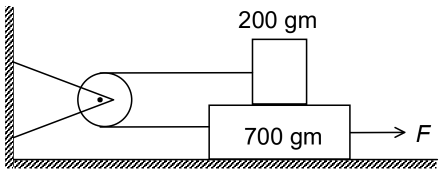
$400\cos 45° - 20g\sin 45° - f = 20a$ $\quad \frac{400}{\sqrt{2}} - \frac{20\times 9.8}{\sqrt{2}} - 421.4\mu = 20a = 20\times 0.6 = 12$

$\mu = \left(\frac{400}{\sqrt{2}} = -\frac{196}{\sqrt{2}} - 12\right)\times\frac{1}{421.4}$ $\quad = \frac{282.8 - 138.6 - 12}{421.4} = \mathbf{0.3137}$

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

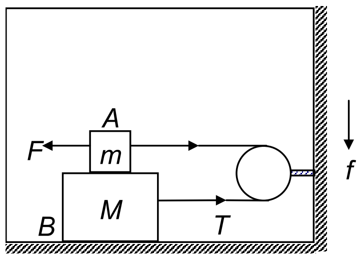
PRACTICE PROBLEMS

12. How large must F be in the Figure shown to give the 700 gm block an acceleration of 30 cm/s^2? The coefficient of friction between all surfaces is 0.15.



(a) 4 N
(b) 2.18 N
(c) 3.18 N
(d) 6 N

13. Two blocks A and B of masses m and M are placed in a platform as shown in the Figure. The friction coefficient between A and B is m but there is no friction between B and the platform. The whole arrangement is placed inside an elevator which is coming down with an acceleration f (f < g). What maximum horizontal force F can be applied to A without disturbing the equilibrium of the system?



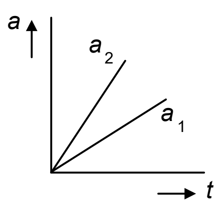
(a) 2μmg (b) 2μm(g – f)
(c) 2μm(g + f) (d) 2μmf

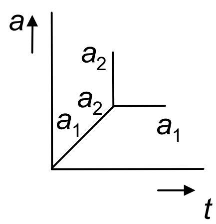
14. A body of mass m_1 is placed on a horizontal plank of mass m_2 which rests on a smooth horizontal table. The coefficient of friction between the mass m_1 and plank is m. A gradually increasing force F depending on time t as F = at where a is constant is applied to the plank. Find the time t_0 at which the plank starts sliding under the mass.

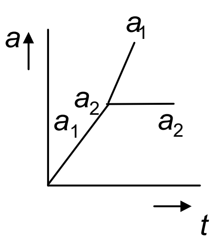
(a) $\frac{m_1\mu g}{a}$ (b) $\frac{(m_1+m_2)\mu g}{a}$

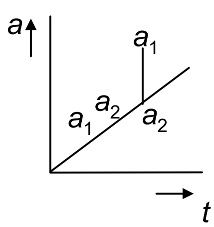
(c) $\frac{m_2\mu g}{a}$ (d) $\frac{m_1 m_2\mu g}{a}$

15. Block A is placed on block B whose mass is greater than that of A. There is friction between blocks while the ground is smooth. A horizontal force P increasing linearly with time begins to act on A. The accelerations a_1 and a_2 of A and B respectively are plotted in a graph against time. Which of the following graphs represent the real situation?

(a)


(b)


(c)


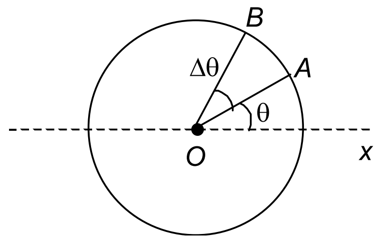
(d)


6. CIRCULAR MOTION

If a particle moves in such a way that its distance from a fixed point remains constant its path will be circular and its motion is called as circular motion. If we whirl a stone tied with a string at one end, its motion is circular motion. Motion of electron around the nucleus is treated as a circular motion. Motion of earth around the sun is treated as circular for some gravitational study.

6.1 ANGULAR KINEMATIC VARIABLES FOR CIRCULAR MOTION

Consider a particle moving on a circular path of center *O* and radius *R* as shown in figure. Let *OX* is a reference line (taken arbitrary) through *O*. At any moment *t* if particle is at *A*, then angle q between *OA* and *OX* is called as its angular position. If during a time interval of D*t* particle moves from position *A* to *B*, The angle subtended by the arc *AB* on the centre Dq is called as angular displacement. The rate at which particle subtend angle at the center is called as angular velocity represented by w



$\therefore$ Average angular velocity, $\bar{\omega} = \dfrac{\Delta\theta}{\Delta t}$ and ...(**7**)

Instantaneous angular velocity $\omega = \underset{\Delta t \to 0}{Lt} \dfrac{\Delta\theta}{\Delta t} = \dfrac{d\theta}{dt}$ ...(**8**)

The rate of change of angular speed is called as angular acceleration represented by α

$\therefore$ Average angular acceleration, $\bar{\alpha} = \dfrac{\Delta\omega}{\Delta t}$ and ...(**9**)

Instantaneous angular acceleration $\alpha = \underset{\Delta t \to 0}{Lt} \dfrac{\Delta\omega}{\Delta t} = \dfrac{d\omega}{dt}$

$$\alpha = \frac{d^2\theta}{dt^2} = \frac{\omega d\omega}{d\theta} \qquad \text{...(10)}$$

We have different kinds of motion in case of motion in one dimension such as motion with uniform velocity and motion with uniform acceleration. Also in those cases we have kinematic relation between the different linear variables. Similar derivation can be done in case of circular motion and such kinematic relations can be obtained for angular variables also.

For uniform circular motion;

Angular displacement, $\Delta\theta = \omega t$

For circular motion with uniform angular acceleration;

$$\omega = \omega_0 + \alpha t \qquad \text{...(11)}$$

$$\Delta\theta = \omega_0 t + \frac{1}{2}\alpha t^2$$

$$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$$

Illustration 7:

The moon orbits the earth with a period of 27.3 days at a distance of 3.84 ´ 10^8 m from the centre of earth. Find its linear speed and centripetal acceleration.

Solution:

The period of revolution of moon, $T = 27.3$ days $= 2.36 \times 10^6$ s

$$\text{Linear speed, } v = \omega R = \frac{2\pi}{T}R = \frac{2 \times 3.14 \times 3.84 \times 10^8}{2.36 \times 10^6} = \mathbf{1021.83\ ms^{-1}}$$

$$\text{Centripetal acceleration} = \frac{V^2}{R} = \frac{(1021.83)^2}{3.84 \times 10^8} = \mathbf{2.72 \times 10^{-3}\ ms^{-2}}$$

Illustration 8:

A particle moves in a circle of radius 20 cm. Its linear speed at any time is given by $v = 2t$ where v is in m/s and t is in seconds. Find the radial and tangential accelerations at $t = 3$ seconds and hence calculate the total acceleration at this time.

Solution:

The linear speed at 3 seconds is

$v = 2 \times 3 = 6$ m/s

The radial acceleration at 3 seconds

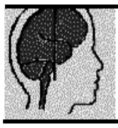
$$= \frac{v^2}{r} = \frac{6 \times 6}{0.2} = \mathbf{180\ m/s^2}$$

The tangential acceleration is given by

$\frac{dv}{dt} = 2$, because $v = 2t$.

∴ tangential acceleration is **2 m/s²**.

$$\text{Total acceleration} = \sqrt{a_r^2 + a_t^2} = \sqrt{180^2 + 2^2} = \sqrt{32400 + 4} = \sqrt{\mathbf{32404}}\ \mathbf{m/s^2}$$



Is it possible for a car to move in a circular path in such a way that it has a tangential acceleration but no centripetal acceleration?

6.2 UNIFORM CIRCULAR MOTION AND CENTRIPETAL FORCE

If a particle moves on a circular path with a constant speed, its motion is called as a uniform circular motion. In this motion angular speed of the particle is also constant. Acceleration in such motion will not have any tangential component, only radial or centripetal acceleration the particle possesses. Therefore in case of uniform circular motion the particle will have acceleration towards the center only and is called as centripetal acceleration having magnitude $\frac{v^2}{R}$ or $\omega^2 R$. The magnitude of acceleration remains constant but its direction changes with time.

If a particle moving on circular path is observed from an inertial frame it has an acceleration w^2R or acting towards center. Therefore from Newton's second law of motion, there must be a force acting on the particle towards the center of magnitude $m\omega^2 R$ or $\frac{mv^2}{R}$. This required force for a particle to move on circular path is called as **centripetal force.**

$$\therefore \quad \text{centripetal force} = \frac{mv^2}{R} \qquad \ldots\mathbf{(14)}$$

The term 'centripetal force' merely a force towards center, it tells nothing about its nature or origin. The centripetal force may be a single force due to a rope, a string, the force of gravity, friction and so forth or it may be resultant of several forces. Centripetal force is not a new kind of force, just as 'upward force' or a 'downward force' is not a new force. Therefore while analyzing motion of particle undergoing circular motion we need not consider centripetal force as a force, we need to consider only external forces.

Illustration 9:

A ball of mass 0.5 kg is attached to the end of a cord whose length is 1.50 m. The ball is whirled in a horizontal circle. If the cord can withstand a maximum tension of 50.0 N, what is the maximum speed the ball can have before the cord breaks?

Solution:

Because the centripetal force in this case is the force *T* exerted by the cord on the ball, we have

$$T = m\frac{v^2}{r}$$

Solving for *v*, we have

$$v = \sqrt{\frac{Tr}{m}}$$

The maximum speed that the ball can have corresponds to the maximum tension. Hence, we find

$$v_{max} = \sqrt{\frac{T_{max} r}{m}} = \sqrt{\frac{(50.0\,N)\,(1.50\,m)}{0.500\,kg}} = \mathbf{12.2\ m/s}$$

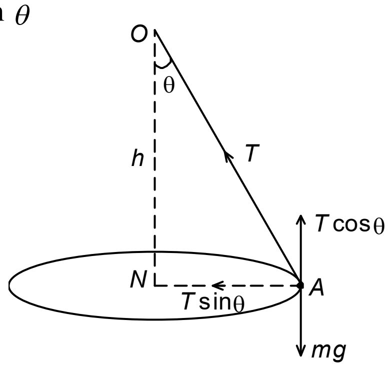
A 0.4 kg object is swung in a vertical circular path with the help of 0.50 m long string. If a constant speed of 4.0 m/s is maintained, what are the tensions in the string when the object is at the top of the circle and when object is at its lowest position?

6.3 SOME IMPORTANT UNIFORM CIRCULAR MOTIONS

(i) Conical Pendulum: It consists of a string *OA* whose upper end *O* is fixed and a bob is tied at the free end. When the bob is drawn aside and given a horizontal push let it describe a horizontal circle with uniform angular velocity w in such a way that the string makes an angle q with vertical. As the string traces the surface of a cone of semi-vertical angle q it is called conical pendulum. Let *T* be the tension in string, l be the length and *r* be the radius of the horizontal circle described. The vertical component of tension balances the weight and the horizontal component supplies the centripetal force.

$$T\cos\theta = mg \qquad T\sin\theta = mr\omega^2$$

$$\therefore \quad \tan\theta = \frac{r\omega^2}{g} \qquad \omega = \sqrt{\frac{g\tan\theta}{r}} \qquad r = l\sin\theta$$



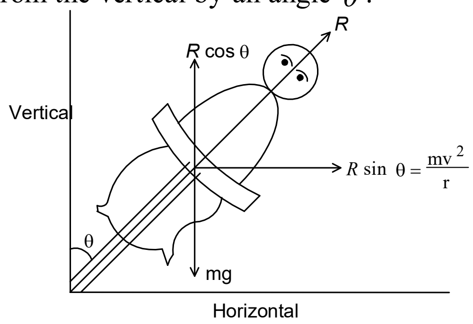
T being the period i.e., time for one revolution.

$$\therefore \quad \frac{2\pi}{T} = \sqrt{\frac{g\tan\theta}{\ell\sin\theta}}$$

$$T = 2\pi\sqrt{\frac{\ell\cos\theta}{g}}$$

$$= 2\pi\sqrt{h/g}\text{, where } h = \ell\cos\theta.$$

(ii) Motion of a cyclist on a circular path: Let a cyclist moving on a circular path of radius *r* bend away from the vertical by an angle θ.

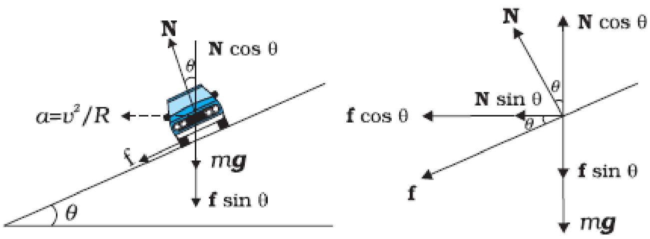


R is the normal reaction from the ground. It can be resolved in the horizontal and vertical directions. The components are respectively equal to $R\sin\theta$ and $R\cos\theta$. The vertical component balances his weight mg. The horizontal component $R\sin\theta$ supplies the necessary force for making the circular path. $\therefore$ $R\sin\theta = \frac{mv^2}{r}$ $R\cos\theta = mg$ $\therefore$ $\tan\theta = v^2/rg$

For less bending of the cyclist, v should be small and r should be great.

(iii) Motion of a car on a banked road: We can reduce the contribution of friction to the circular motion of the car if the road is banked (Figure (b)). Since there is no acceleration along the vertical direction, the net force along this direction must be zero.

Hence, $N\cos\theta = mg + f\sin\theta$ .....(1)



(b)

The centripetal force is provided by the horizontal

$$N\sin\theta + f\cos\theta = \frac{mv^2}{R} \qquad (2)$$

But $f \le \mu_s N$

Thus to obtain v_{max} we put

$f = \mu_s N$

Then equation (1) & (2) become

$$N\cos\theta = mg + \mu_s N\sin\mu$$

$$N\sin\theta + \mu_s N\cos\theta = \frac{mv^2}{R}$$

We obtain

$$N = \frac{mg}{\cos\theta - \mu_s\sin\theta}$$

Substituting value of N in Eq. (2), we get

$$\frac{mg(\sin\theta - \mu_s\cos\theta)}{\cos\theta - \mu_s\sin\theta} = \frac{mv_{max}^2}{R} \quad \text{or} \quad v_{max} = \left(Rg\frac{\mu_s + \tan\theta}{1 - \mu_s\tan\theta}\right)^{1/2}$$

Comparing this with previous results we see that maximum possible speed of a car on a banked road is greater than that on a flat road.

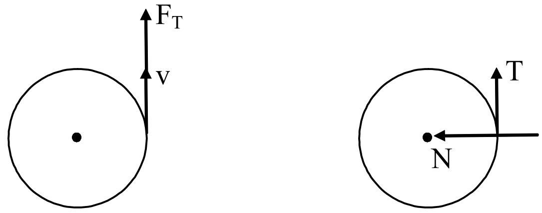
For $\mu_s = 0$ in Eq.

$v_o = (R\,g\tan\theta)^{1/2}$

At this speed, frictional force is not needed at all to provide the necessary centripetal force. Driving at this speed on a banked road will cause little wear and tear of the tyres. The same equation also tells you that for $v < v_o$, frictional force will be up the slope and that a car can be parked only if $\tan\mu \le \mu_s$.

6.4 NON-UNIFORM CIRCULAR MOTION

If the speed of the particle moving in a circular is not constant, then the motion is called non-uniform circular motion. Consider the shown figure



A force act in the dirction of velocity of particle. Due to this force the speed of the particle increases. If this force reverses its direction and act opposite to velocity, shown in fig(b) the particle slows down. This force acting along tangent causes the change in magnitude of velocity (i.e., speed) and is called tangential force and the acceleration produced is called the tangential acceleration. The tangential force is either parallel or antiparallel to velocity. If no such force act then speed of the particle will remain constant. (Uniform Circular Motion)

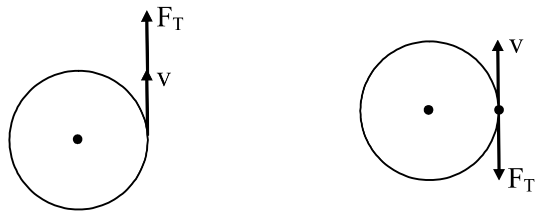
$$F_T = m\frac{dv}{dt} \qquad \left(\text{Note } \vec{F}_T \neq \frac{d\vec{v}}{dt}\right)$$

$$\Rightarrow \quad a_T = \frac{dV_t}{dt}$$

$$= r\frac{d\omega}{dt} \qquad (\because\ v_T = \omega r)$$

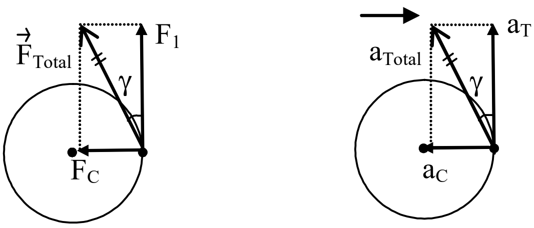
$$\Rightarrow \quad a_T = \alpha r$$

(a) Speed up (b) Speed down



Total Force

Now, we will look at complete picture. There are total two forces which act in C.M.



1. Centripetal force (F_C) : It acts along radius towards centre. It causes change in direction of velocity. For any C.M. centripetal force must be present.

$$F_C = ma_C = m\frac{v^2}{r} = m\omega^2 r$$

2. Tangentil force (F_T) : It acts along tangent. It causes change in magnitude of velocity.

for any C.M., tangential present force may or may not be present.

$$F_T = ma_T = m(\alpha r)$$

From above figure

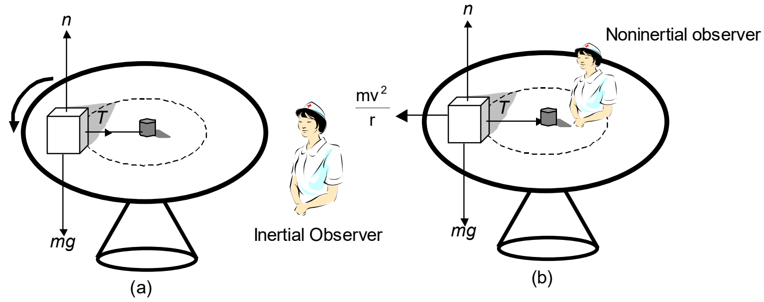
(i) Total force = $\vec{F}_{total} = \vec{F}_C + \vec{F}_T \quad \Rightarrow \quad |\vec{F}_{total}| = \sqrt{F_C^2 + F_T^2} \qquad \tan\gamma = \frac{F_c}{F_T}$

(ii) Total acceleration = $\vec{a}_{total} = \vec{a}_C + \vec{a}_T \quad \Rightarrow \quad |\vec{a}_{total}| = \sqrt{a_C^2 + a_r^2}$

$$= \left(\left(\frac{v^2}{r}\right)^2 + (\alpha r)^2\right)^{1/2}, \tan\gamma = \frac{a_c}{a_T}$$

6.5 CENTRIFUGAL FORCE

An observer in a rotating system is another example of a non-inertial observer. Suppose a block of mass m lying on a horizontal, frictionless turntable is connected to a string as in figure. According to an inertial observer, if the block rotates uniformly, it undergoes an acceleration of magnitude v^2/r, where v is its tangential speed. The inertial observer concludes that this centripetal acceleration is provided by the force exerted by the string T, and writes Newton's second law $T = mv^2/r$.



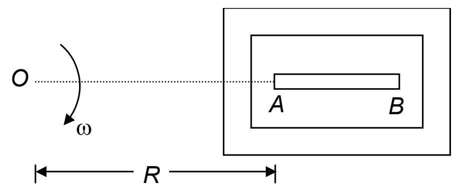
According to a non-inertial observer attached to the turntable, the block is at rest. Therefore, in applying Newton's second law, this observer introduces a fictitious outward force of magnitude mv^2/r. According to the non-inertial observer, this outward force balances the force exerted by the string and therefore $T - mv^2/r = 0$.

Therefore when we are working from a frame of reference that is rotating at a constant angular velocity ω with respect to an inertial frame. The dynamics of a particle of mass m kept at a distance r from the axis of rotation we have to assume that a force $m\omega^2 r$ acts radially outward on the particle. Only then we can apply Newton's laws of motion in the rotating frame. This radially outward pseudo force is called the centrifugal force.

You should be careful when using fictitious forces to describe physical phenomena. Remember that fictitious forces are used only in non-inertial frames of references. When solving problems, it is often best to use an inertial frame.

Illustration 10:

A table with smooth horizontal surface is fixed in a cabin that rotates with angular speed win a circular path of radius R. A smooth groove AB of length L ($<< R$) is made on the surface of table as shown in figure.



A small particle is kept at the point A in the groove and is released to move, find the time taken by the particle to reach the point B.

Solution:

Let us analyse the motion of particle with respect to table which is moving with cabin with an angular speed of w. Along AB centrifugal force of magnitude mw^2R will act at A on the particle which can be treated as constant from A to B as $L << R$.

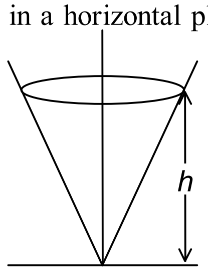
$\therefore$ acceleration of particle along AB with respect to cabin $a = \omega^2 R$ (constant)

Required time 't' is given by

$$S = ut + \frac{1}{2}at^2 \Rightarrow \quad L = 0 + \times w^2Rt^2 \Rightarrow \quad t = \sqrt{\frac{2L}{\omega^2 R}}$$

PRACTICE PROBLEMS

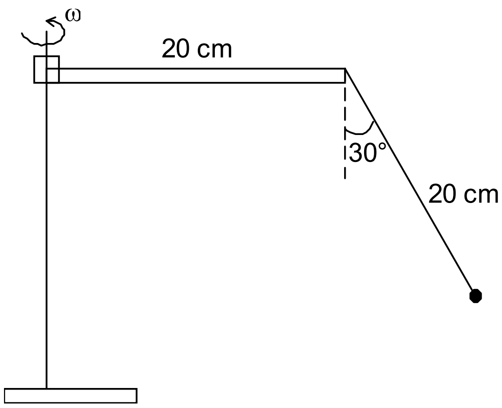
16. A right circular cone is fixed with its axis vertical and vertex down. A particle in contact with its smooth inside surface describes circular motion in a horizontal plane at a height of 20 cm above the vertex. Its velocity in m/s is



(a) 1 (b) 1.2
(c) 1.4 (d) 1.6

17. A particle is attached by means of two equal strings to points A and B in the same vertical line and describes a horizontal circle with a uniform angular speed. If the angular speed of the particle is $2\sqrt{\frac{2g}{h}}$ with AB = h, find the ratio of tensions of strings.

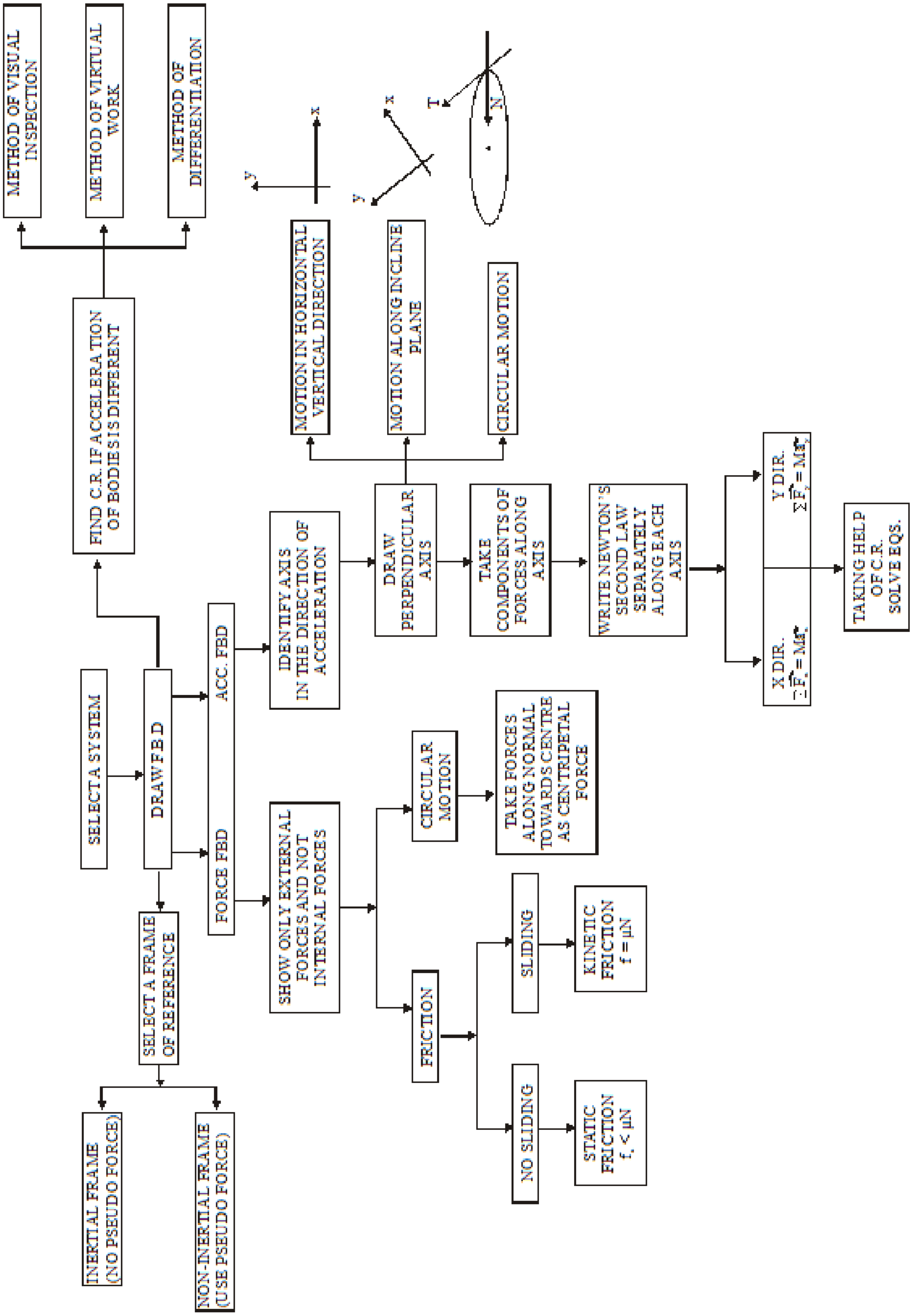
18. Figure shows a rod of length 20 cm pivoted near an end which is made to rotate in a horizontal plane with a constant angular speed. A ball of mass m is suspended by a string also of length 20 cm from the end of the rod. If the angle θ made by the string with the vertical is 30°, find the angular speed of rotation. Take $g = 10\ m/s^2$.



ANSWERS TO PRACTICE PROBLEMS

1. (d)	2. (c)	3. (b)	4. (d)	5. (c)
6. (b)	7. (c)x	8. (c)	9. (a)	10. (c)
11. (a) 618.75 N	(b) 577.5 kg	12. (b)	13. (b)	14. (b)
15. (c)	16. (c)	17. $T_1/T_2 = 5/3$		18. 4.4 rad/s

Concept Map

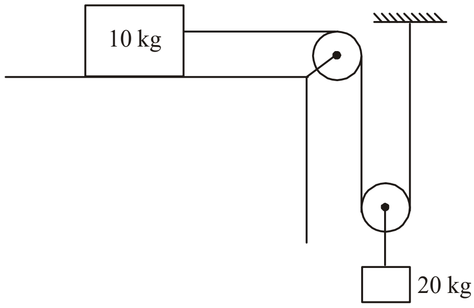

SELECT A SYSTEM
DRAW FBD
SELECT A FRAME OF REFERENCE
INERTIAL FRAME (NO PSEUDO FORCE)
NON-INERTIAL FRAME (USE PSEUDO FORCE)
FORCE FBD
ACC. FBD
FIND C.R. IF ACCELERATION OF BODIES IS DIFFERENT
METHOD OF VISUAL INSPECTION
METHOD OF VIRTUAL WORK
METHOD OF DIFFERENTIATION
SHOW ONLY EXTERNAL FORCES AND NOT INTERNAL FORCES
IDENTIFY AXIS IN THE DIRECTION OF ACCELERATION
DRAW PERPENDICULAR AXIS
MOTION IN HORIZONTAL VERTICAL DIRECTION
MOTION ALONG INCLINE PLANE
CIRCULAR MOTION
x
y
T
N
TAKE COMPONENTS OF FORCES ALONG AXIS
WRITE NEWTON'S SECOND LAW SEPARATELY ALONG EACH AXIS
X DIR. $\Sigma \vec{F}_x = M\vec{a}_x$
Y DIR. $\Sigma \vec{F}_y = M\vec{a}_y$
TAKING HELP OF C.R. SOLVE EQS.
CIRCULAR MOTION
TAKE FORCES ALONG NORMAL TOWARDS CENTRE AS CENTRIPETAL FORCE
FRICTION
SLIDING
KINETIC FRICTION $f = \mu N$
NO SLIDING
STATIC FRICTION $f_s < \mu N$

EXERCISE

LEVEL-01

CONSTRAIN MOTION

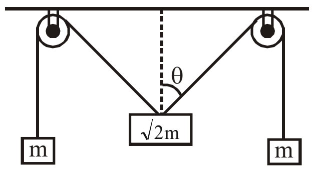
1. Two masses of 10 kg and 20 kg are connected with an inextensible string passing over two smooth pulleys as shown in the figure. The acceleration of 20 kg mass will be



(1) 10/3 m/s^2 (2) 20/3 m/s^2

(3) 40/9 m/s^2 (4) 10 m/s^2

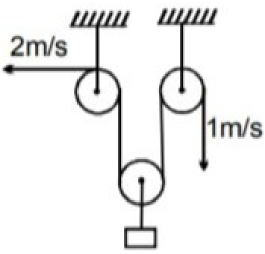
2. The pulleys and strings shown in the figure are smooth and of negligible mass. For the system that remains in equilibrium, the angle θ should be



(1) 0º (2) 30º

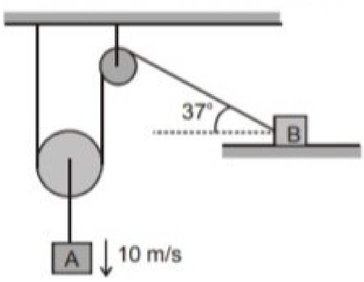
(3) 45º (4) 60º.

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



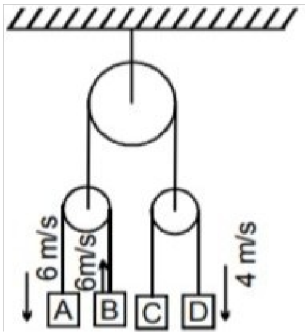
(1) $3/2\,\text{m/s}\uparrow$ (2) $3/2\,\text{m/s}\downarrow$ (3) $1/2\,\text{m/s}\uparrow$ (4) $1/2\,\text{m/s}\downarrow$

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



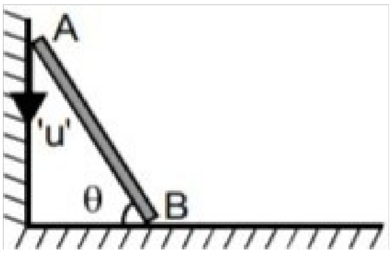
(1) 25 m/s (2) 20 m/s (3) 22 m/s (4) 30 m/s

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



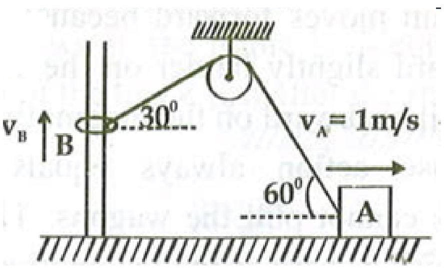
(1) 6 m/s (2) 4 m/s (3) 0 m/s (4) none of these

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



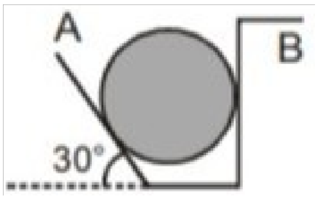
(1) $u\tan 2\theta$ (2) $u\cot\theta$ (3) $u\tan\theta$ (4) $2u\tan\theta$

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



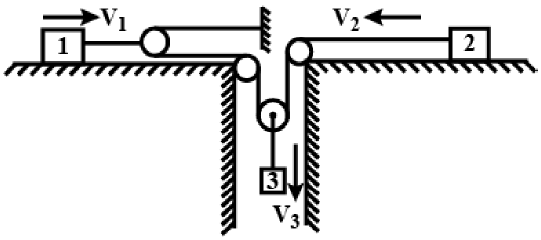
(1) $\frac{1}{2}m/s$ (2) $\frac{\sqrt{3}}{4}m/s$ (3) $\frac{1}{4}m/s$ (4) 1 m/s

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



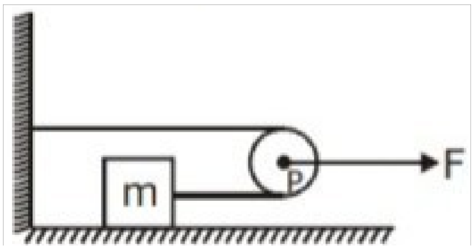
(1) $N_B = \frac{1000}{\sqrt{3}} N, N_A = \frac{500}{\sqrt{3}} N$
(2) $N_A = \frac{1000}{\sqrt{3}} N, N_B = \frac{500}{\sqrt{3}} N$
(3) $N_A = \frac{100}{\sqrt{3}} N, N_B = \frac{500}{\sqrt{3}} N$
(4) $N_A = \frac{1000}{\sqrt{3}} N, N_B = \frac{50}{\sqrt{3}} N$

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



(1) $2v_1 + v_2 = v_3$
(2) $v_1 + v_2 = v_3$
(3) $v_1 + 2v_2 = v_3$
(4) None of these

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



(1) 0.5
(2) 2
(3) 1
(4) None of these

BASIC QUESTION RELATED TO CONCEPT OF FORCE AND NEWTON'S LAWS OF MOTION

11. Rocket works on the principle of:
(1) Conservation of mass
(2) Conservation of linear momentum
(3) Conservation of energy
(4) Conservation of angular momentum

12. A ball of mass 500 gm moving with a speed of 2m/s hits a wall at right angle. It bounces back with the same speed. If the ball had been in contact for one milli-second, the average force exerted by the ball on the wall is
(1) 500 N
(2) 1000 N
(3) 2000 N
(4) 3000 N

13. A force of $3t^2$ Newton acts on a body of mass 10 kg in the forward direction where t is time and a constant frictional force of 32 Newton is present. If the initial speed of the body is 10 m/s, the velocity of the body after 5 second is

(1) 2.5 m/s (2) 3.5 m/s (3) 5.0 m/s (4) 6.5 m/s

14. A 1000 kg lift is supported by a cable that can support 2000 kg. The shortest distance in which the lift can be stopped when it is descending with a speed of 2.5 m/s is (g = 10 m/s^2)

(1) $\frac{5}{16}$ m (2) $\frac{5}{32}$ m (3) 1m (4) 2m

15. A force 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 F_2 which declerates it to rest.

(1) F_1 must be equal to F_2 (2) F_1 may be equal to F_2

(3) F_1 must be unequal to F_2 (4) none of these.

16. A jet plane flies in the air because :

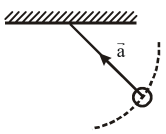
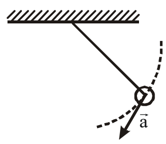
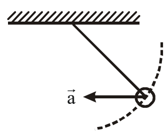
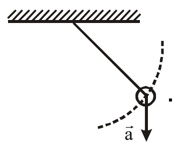
(1) The gravity does not act on bodies moving with high speeds

(2) The thrust of the jet compensates for the force of gravity

(3) The flow of air around the wings causes an upward force, which compensates for the force of gravity

(4) The weight of air whose volume is equal to the volume of the plane is more than the weight of the plane

17. A simple pendulum is oscillating without damping. When the displacement of the bob is less than maximum, its acceleration vector $\vec{a}$ is correct in

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

18. A body is moving with a velocity 5 m/s along a straight line. A force of 10 N is applied to the body perpendicular to the line of motion. If the body is of mass 2kg, then the acceleration of the body along the initial straight line of motion is :

(1) 5 m/s^2 (2) 0 (3) 10 m/s^2 (4) none of these.

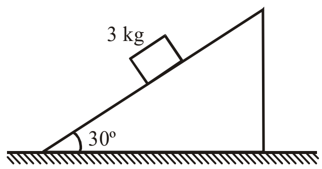
19. Which of following respresents 2^{nd} law of motion most correctly.

(1) $\vec{F} = m\vec{a}$ (2) $\vec{F} = m\frac{d\vec{v}}{dt}$ (3) $\vec{F} = \frac{d\vec{p}}{dt}$ (4) $\vec{F} = m\vec{v}$.

20. Two objects A and B are thrown upward simultaneously with the same speed. The mass of A is greater than the mass of B. Suppose the air exerts a constant and equal force of resistance on the two bodies.
(1) the two bodies will reach the same height
(2) A will go higher than B
(3) B will go higher than A
(4) any of the above three may happen depending on the speed with which the objects are thrown.

21. A block A kept on an inclined surface just begins to slide if the inclination is 30^0. The block is replaced by another block B and it is found that it just begins to slide if the inclination is 40^0.
(1) mass of A > mass of B (2) mass of A < mass of B
(3) mass of A = mass of B (4) all the three are possible.

22. A block of mass 3kg is at rest on a rough inclined plane as shown in the figure. The magnitude of net force exerted by the surface on the block will be



(1) 26N (2) 19.5N
(3) 10N (4) 30 N.

23. A toy weighing 0.5kg is kept on a spring balance fixed on a horizontal surface. The toy suddenly jumps of the balance upward. A body standing near the toy reads the seak of the balance 0.7 kg. The acceleration of the toy when it just jumps off the balance is:
(1) 0 m/s^2 (2) 3.92 m/s^2 (3) 9.8 m/s^2 (4) None of these.

24. Inertia is that property of a body by virtue of which the body is
(1) unable to change by itself the state of rest
(2) unable to change by itself the state of uniform motion
(3) unable to change by itself the direction of motion
(4) unable to change by itself the state of rest and of uniform linear motion

25. A man getting down a running bus falls forward because:
(1) Due to inertia of rest, road is left behind and man reaches forward
(2) Due to inertia of motion upper part of body continues to be in motion in forward direction while feet come to rest as soon as they touch the road.
(3) He leans forward as a matter of habit
(4) Of the combined effect of all the three factors stated in (1), (2) and (3).

26. A man is at rest in the middle of a pond on perfectly smooth ice. He can get himself to the shore by making use of Newton's :
(1) First law (2) Second law (3) Third law (4) All the laws

27. A cannon after firing recoils due to :
(1) Conservation of energy (2) Backward thrust of gases Produced
(3) Newton's third law of motion (4) Newton's first law of motion

28. We can derive Newton's :
(1) Second and third laws from the first law
(2) first and second laws from the third law
(3) third and first laws from the second law
(4) All the three laws are independent of each other

29. The force exerted by the floor of an elevator on the foot of a person standing there, is more than his weight, if the elevator is
(1) going down and slowing down (2) going up and speeding up
(3) going up and slowing down (4) either (1) and (2)

30. Pulling is easier than pushing because :
(1) When we pull a roller, the vertical component of the pulling force acts in the direction of weight
(2) The vertical component of the pulling force acts in the opposite direction of weight
(3) Force of friction is in opposite direction
(4) It is possible in the case of roller only

MOMENTUM, IMPULSE, RATE OF CHANGE OF MOMENTUM AND AVERAGE FORCE RELATED PROBLEMS

31. A machine gun of mass M fires n bullets per second, the mass and speed of each bullet is m and v respectively. The force exerted on the machine gun is
(1) zero (2) mvn (3) Mvn (4) Mvn/m

32. A spring of force constant k is cut into two pieces such that one piece is double the length of the other. Then the long piece will have a force constant of
(1) (2/3)k (2) (3/2)k (3) 3k (4) 6k

33. A balloon of mass M is descending with a constant acceleration g/3. When a mass m is released from the balloon it starts rising with the same acceleration g/3. The value of m is (Assuming that its volume does not change) :-
(1) $\frac{M}{2}$ (2) $\frac{M}{4}$ (3) 4M (4) 2M

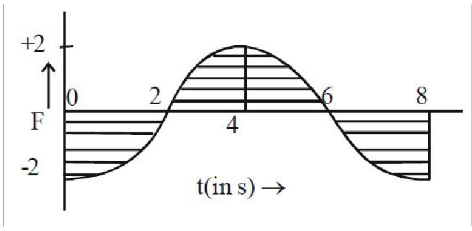
34. Gravel is droped onto a conveyer belt at a rate of 0.5 kg/s. The extra force required in newton to keep the belt moving at 2m/s is :-
(1) 1N (2) 2N (3) 4N (4) 0.5 N

35. A block of metal weighing 2kg is resting on a frictionless plane. It is struck by a jet releasing water at a rate of 1 kg/s with a speed of 5 m/s. the initial acceleration of the block will be :-
(1) 2.5 m/s^2 (2) 5 m/s^2 (3) 10 m/s^2 (4) 15 m/s^2

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

(1) 100 N (2) 10 N (3) 1 N (4) 0.1 N

37. Force-time graph for the motion of a body is shown in fig. Change in linear momentum between 0 to 8s is :-

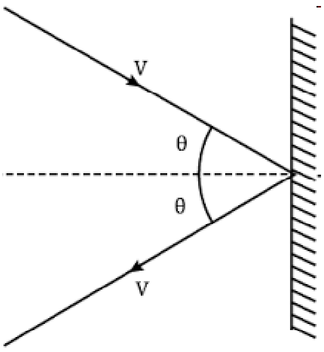


(1) Zero (2) 4 N-s (3) 8 N-s (4) None

38. Newton's II law of motion connects:

(1) Momentum and acceleration
(2) Change of momentum and velocity
(3) Rate of change of momentum and external force
(4) Rate of change of force and momentum

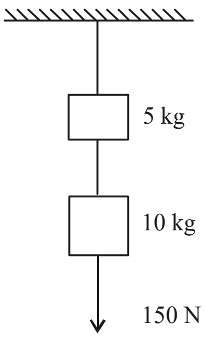
39. A water jet, whose cross sectional are is 'a' strikes a wall making an angle 'θ' with the normal and rebounds elastically. The velocity of water of density 'd' is v. Force exerted on wall is :-



(1) $2av^2d\cos\theta$ (2) $2av^2d\sin\theta$ (3) $2avd\cos\theta$ (4) $avd\cos\theta$

FREE BODY DIAGRAM, EQUILIBRIUM OF CONCURRENT FORCES-LAMI'S THEOREM

40. Two masses of 5 kg and 10 kg are suspended from a fixed support as shown in the figure. The system is pulled downwards with a force of 150 N applied to the lower mass. The string attached to the support breaks and the system accelerates downwards. If the downward force continues to act, the acceleration of the system is



(1) 5 m/s^2 (2) 10 m/s^2
(3) 20 m/s^2 (4) 30 m/s^2

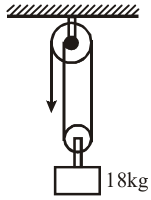
41. Tension in the cable supporting an elevator, is equal to the weight of the elevator. From this, we can conclude that the elevator is going up or down with a

(1) uniform velocity (2) uniform acceleration
(3) variable acceleration (4) either (2) and (3)

42. When a bird of weight W sits on a stretched wire, the tension T in the wire may be:

(1) > W/2 (2) = W (3) < W (4) None of these

43. The the given figure, a force F is applied at the free end to keep the suspended mass of 18 kg at rest. The value of F is [g = 10 m/s^2]



(1) 180 N
(2) 90 N
(3) 60 N
(4) 30 N.

44. A cork of mass 10g is floating on water. Net force on the cork is :-

(1) 10 N (2) 10^{-3}N (3) 10^{-2}N (4) Zero

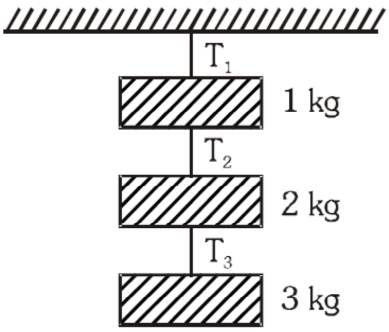
45. A person holds a rope of negligible weight tightly at its ends so that it is horizontal. A 15 kg weight is attached to the rope at the mid point which is now no longer remains horizontal. The minimum tension required to completely straighten the top is

(1) 15 kg (2) 15/2 kg (3) 5 kg (4) Infinitely large

46. A boy of mass 40 kg is hanging from a horizontal branch of a tree. The tension in his arms is minimum when the angle between the arms is :

(1) 0° (2) 90° (3) 120° (4) 180°

47. Find the tension T_2 for the system shown in fig.

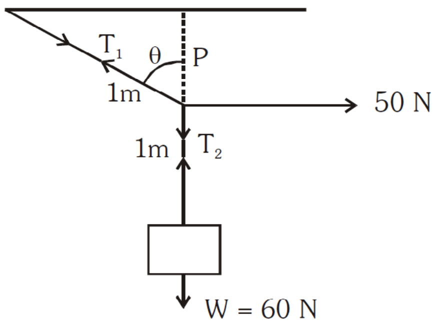


(1) 1g N (2) 2g N (3) 5g N (4) 6g N

48. Ten one rupees coins are put on top of each other on a table. Each coin has a mass 'm' kg., then the force on the 7th coin (counted from the bottom) due to all the coins on its top :-

(1) 3 mg (2) 7 mg (3) 2 mg (4) 5 mg

49. A mass of 6 kg is suspended by a rope of length 2 m from a ceiling. A force of 50 N is applied in horizontal direction at the mid point of the rope. What is the angle between the rope and the vertical in equilibrium :-



(1) $\tan^{-1}\left(\frac{4}{5}\right)$ (2) $\tan^{-1}\left(\frac{5}{4}\right)$ (3) $\tan^{-1}\left(\frac{5}{6}\right)$ (4) None

FRAME OF REFERENCE - INTERTIAL OR NON INERTIAL FRAME, PSEUDO FORCE, ACCEL ERATING LIFT

50. A pendulum with a bob of 0.1 kg is suspended from the roof of a car which is moving with an acceleration of 5 m/s^2 relative to the ground towards right. An observer travelling in the car experiences a pseudo force acting on the bob equal to

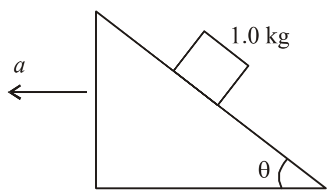
(1) 1.0 Newton downwards (2) 1.0 Newton upwards

(3) 0.5 Newton towards right (4) 0.5 Newton towards left

51. The mass of an elevator is 4000 kg. Starting from rest how much distance will it rise in 2 s, if the tension in the cable is 56 kN?

(1) 3 m (2) 4 m (3) 8 m (4) 16 m

52. A block of mass 1.0 kg rests on a wedge of angle θ. The acceleration which should be given to the wedge so that the block falls freely is



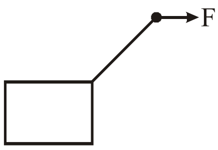
(1) 10 m/s^2 (2) 10 cos θ m/s^2

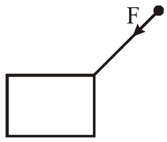
(3) 10 cot θ m/s^2 (4) 10 tan θ m/s^2

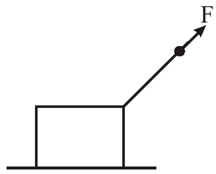
53. A pendulum is hanging from the ceiling of a railway carriage subtending an angle of 30° with the vertical direction. The acceleration of the carriage is

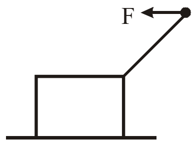
(1) $\frac{g}{\sqrt{3}}$ (2) $\frac{2g}{\sqrt{3}}$ (3) $g\sqrt{3}$ (4) $\frac{\sqrt{3}g}{2}$

54. Which of the following case correctly represents the applied force on a string under tession. End of string is represented with dot.

(1) 

(2) 

(3) 

(4) 

55. A balloon is descending at a constant acceleration a. The mass of the balloon is M. When a mass m is released from the balloon it starts rising with acceleration a. Assuming that volume does not change when the mass is released, what is the value of m? [Assume same upward buoyant force]

(1) $\frac{2a}{(a+g)}M$ (2) $\left(\frac{a+g}{2a}\right)M$ (3) $\frac{2a}{(a+g)M}$ (4) $\frac{Ma}{a+g}$.

56. A man is standing on a spring platform. Reading of spring balace is 60 kg-wt. If the man jumps off from the plateform, then reading of spring balace:-
(1) First increases then decreases to zero
(2) Decreases
(3) Increases
(4) Remains same

57. A small sphere is suspended by a string from the ceiling of a car. If the car begins to move with a constant acceleration $\frac{g}{2}$, the inclination of the string with the vertical is :-

(1) $\tan^{-1}\left(\frac{1}{2}\right)$ in the direction of motion

(2) $\tan^{-1}\left(\frac{1}{2}\right)$ opposite to the direction of motion

(3) $\tan^{-1}(2)$ in the direction of motion

(4) $\tan^{-1}(2)$ opposite to the direction of motion

58. A boy sitting on the upper berth in the compartment of a train, which is about to stop at a railway station, drops an apple aiming at the open hand of his brother vertically below his hands at a distnace of about 2 m.
The apple will fall :-
(1) In the hand of his brother
(2) Slightly amay from the hands of his brother in the direction of motion of the train
(3) Slightly away from the hands of his brother in the direction opposite to the direction of motion of the train
(4) None of the above

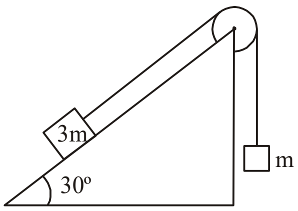
59. The force exerted by a person on the floor of an elevator is more than the weight of the person if the elevator is :-
(a) Going up and showing down
(b) Going up and speeding up
(c) Going down and slowing down
(d) Going down and speeding up
(1) a, c (2) b,c (3) a, d (4) b,d

MOTION OF BODIES IN CONTACT OR CONNECTED BY STRINGS, PULLEY SYSTEM

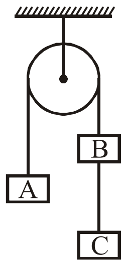
60. A boy of mass 60 kg is holding a vertical rope. The rope can break when a mass of 75 kg is suspended from it. The maximum acceleration with which the boy can climb the rope without breaking it is
(1) 2.5 m/s^2 (2) 5.0 m/s^2 (3) 7.5 m/s^2 (4) 22.5 m/s^2

61. The weights W and 2W are suspended from the ends of a light string passing over a smooth fixed pulley. If the pulley is pulled with an acceleration of 10 m/s^2, the tension in the string will be
(1) $\frac{W}{3}$ (2) $\frac{2W}{3}$ (3) $\frac{4W}{3}$ (4) $\frac{8W}{3}$

62. Two masses *m* and 3*m* are connected as shown in the figure. The tension in the string is
(1) $\frac{3mg}{4}$ (2) $\frac{9mg}{8}$
(3) *mg* (4) 2*mg*

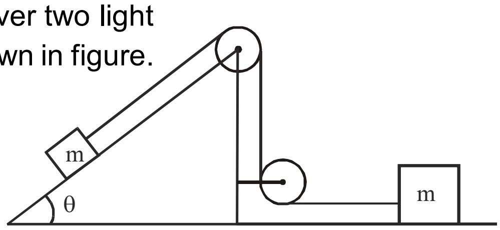


63. Three equals weights A, B, C of mass 2 kg each are hanging on a string passing over a fixed frictionless pulley as shown in the figure. The tension in the string connecting weights B and C is
(1) 6.6 N (2) 13.3 N
(3) 19.6 N (4) 26.6 N



64. The weights w_1 and w_2 are suspended from the ends of a light strig passing over a smooth fixed pulley. If the pulley is pulled up with an acceleration g, the tension in the string will be
(1) $\frac{w_1 w_2}{w_1 + w_2}$ (2) $\frac{2w_1 w_2}{w_1 + w_2}$
(3) $\frac{4w_1 w_2}{w_1 + w_2}$ (4) $\frac{w_1 w_2}{2(w_1 + w_2)}$

65. Two blocks each of mass m are connected over two light and frictionless pulleys by a light string as shown in figure. The tension in the string is



(1) 2 mg sin θ (2) $\frac{3}{2}$ mg sin θ

(3) $\frac{2mg\sin\theta}{3}$ (4) $\frac{mg\sin\theta}{2}$

66. A fireman is sliding down with the help of a rope. If the breaking strength of the rope is $\frac{2mg}{3}$ where *m* is the mass of the man, the acceleration with which the fireman should slide, so that the rope does not break, is

(1) $\frac{g}{2}$ (2) $\frac{g}{3}$ (3) $\frac{g}{4}$ (4) $\frac{2g}{3}$

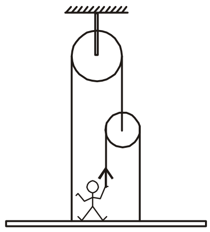
67. A uniform rope of length L resting on a frictionless horizontal surface is pulled at one end by a force F. The tension of the rope at a distance l from the end where the force is applied is

(1) $\frac{FL}{L-l}$ (2) $\frac{FL}{L+l}$ (3) $\frac{F(L-l)}{L}$ (4) $\frac{F(L+l)}{L}$

68. Two masses m_1 and m_2 are connected by a light string passing over a smooth pulley. When the masses start moving, m_1 moves downwards by 1.4 m in 2 seconds, the ratio m_1/m_2 is (g = 9.8 m/s^2)

(1) $\frac{9}{7}$ (2) $\frac{11}{9}$ (3) $\frac{13}{11}$ (4) $\frac{15}{13}$

69. In the given diagram, with what force must the man pull the rope to hold the plank in position? Weight of the man is 60 kgf. Neglect the weights of plank, rope and pulley.



(1) 15 kgf (2) 30 kgf
(3) 60 kgf (4) 120 kgf

70. A small cart with a sphere suspended from ceiling by a string is moving up an inclined plane at a speed V. The direction of string supporting the sphere is

(1) vertical (2) horizontal
(3) perpendicular to the inclined plane (4) none of these.

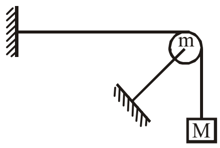
71. Two masses m and m' are tied with a thread passing over a pulley, m' is on a frictionless horizontal surface and m is hanging freely. If acceleration due to gravity is g, the acceleration of m' in this arrangment will be

(1) g (2) mg/(m + m') (3) mg/m' (4) mg/(m - m').

72 A massless string passes over a frictionless pulley whose axis is horizontal. Two monkeys hang from the ends of the string at the same distance $\frac{l}{2}$ from the pulley. The monkeys start climbing upwards simultaneously. First monkey climbs with a speed V relative to string and the second with speed 2V. Both monkeys have equal masses. Then, the time taken by the first and second monkey in reaching the pulley are respectively.

(1) $\frac{l}{3V}$ and $\frac{l}{3V}$ (2) $\frac{l}{2V}$ and $\frac{l}{4V}$ (3) $\frac{l}{4V}$ and $\frac{l}{2V}$ (4) $\frac{l}{V}$ and $\frac{l}{2V}$.

73. A string of negligible mass going over a clamped pulley of mass m supports a block of mass M as shown in the figure. The force on the pulley by the clamp is given by



(1) $\sqrt{2}Mg$ (2) $\sqrt{2}\ mg$

(3) $\left(\sqrt{[(M+m)^2+m^2]}\right)g$ (4) $\left(\sqrt{[(M+m)^2+M^2]}\right)g$.

FRICTION

74. The time taken by a block to slide down a rough inclined plane at 45º to the horizontal is twice as compared the time required by the block to slide down smooth frictionless plane inclined at 45º to the horizontal. The coefficient of kinetic friction between the block and rough plane is

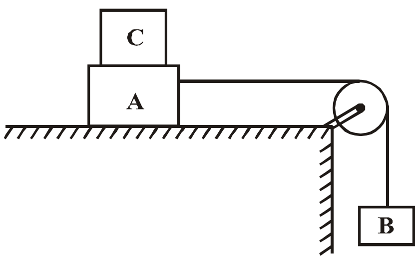
(1) $\frac{1}{3}$ (2) $\sqrt{\frac{3}{4}}$ (3) $\frac{3}{4}$ (4) $\sqrt{\frac{3}{2}}$

75. The force required to just move a body up the inclined plane is twice the force required to just prevent the body from sliding down the plane. If μ is the coefficient of friction, the inclination of the plane to the horizontal is

(1) $\tan^{-1}\left(\frac{\mu}{2}\right)$ (2) $\tan^{-1}(\mu)$ (3) $\tan^{-1}(2\mu)$ (4) $\tan^{-1}(3\mu)$

76. Two blocks *A* and *B* of respective masses 6 kg and 4 kg are connected with a spring passing over a light frictionless pulley

as shown in the figure. The coefficient of friction between the block *A* and horizontal surface is 0.4. Then the minimum mass of block C which should be placed over A to prevent it from moving is

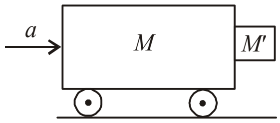


(1) 2 kg (2) 4 kg (3) 5 kg (4) 10 kg

77. A trolley of mass M is moving on smooth horizontal rails as shown in the figure. It has a rectangular block of mass M' placed in contact with its vertical face as shown. If the coefficient of friction between the block and trolley is μ, then the minimum acceleration a of the trolley, so that the block does not fall, is

(1) μ/g (2) μg

(3) $\frac{\mu Mg}{M'}$ (4) $\frac{g}{\mu}$



78. A box of mass M is gently placed over a conveyer belt moving linearly with speed v. The coefficient of friction between the box and conveyer belt is μ. The box will start sliding on the belt after travelling a distance of

(1) $\frac{v^2}{\mu g}$ (2) $\frac{v^2}{2\mu g}$ (3) $\frac{v}{\mu g}$ (4) $\frac{v}{2\mu g}$

79. A particle is projected up a 45° rough incline with a velocity v'. The coefficient of friction is 0.5. The speed with which it returns back to the starting point is v. Then v' /v is

(1) 1.3 (2) $\sqrt{3}$ (3) 1/2 (4) $1/\sqrt{2}$

80. A uniform chain of length L lies on a table. If the coefficient of friction is μ, then the maximum length of the chain which can hang from the edge of the table wihout the chain sliding down is

(1) $\frac{L}{\mu}$ (2) $\frac{L}{\mu-1}$ (3) $\frac{\mu L}{\mu+1}$ (4) $\frac{\mu L}{\mu-1}$

81. A block of mass 50 kg can slide on a rough horizontal surface. The coefficient of friction between the block and the surface is 0.6. The least force of pull, acting 30° to the upward drawn vertical, which causes the block to just slide is (g = 9.8 m/s^2)

(1) 288.3 N (2) 215.2N (3) 219.6N (4) 294.2 N

82. It is difficult to move a cycle with brakes on because
(1) Rolling friction opposes motion on road.
(2) Sliding friction opposes motion on road.
(3) Rolling friction is more than sliding friction.
(4) Sliding friction is more than rolling friction.

83. A boy of mass M is applying a horizontal force to slide a box of mass M' on a rough horizontal surface. The coefficient of friction between the shoes of the boy and the floor is μ and that between the box and the floor is μ'. In which of the following cases it is certainly not possible to slide the box ?

(1) $\mu < \mu'$, $M < M'$ (2) $\mu > \mu'$, $M < M'$ (3) $\mu > \mu'$, $M > M'$ (4) none of these

84. A body of mass M is kept on a rough horizontal surface (friction coefficient = μ). A person is trying to pull the body by applying a horizontal force but the body is not moving. The force by the surface on body is F where

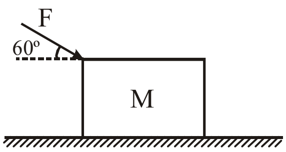
(1) F = Mg (2) F = μ Mg

(3) $Mg \le F \le Mg\sqrt{1+\mu^2}$ (4) $Mg \ge F \ge Mg\sqrt{1-\mu^2}$

85. A body of mass 60 kg is dragged with just enough force to start moving on a rough surface with coefficients of static and kinetic frictions 0.5 and 0.4 respectively. On continuing ($g = 9.8\ m/s^2$) the same force what is the accelertion :

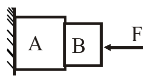
(1) $0.98\ m/s^2$ (2) $9.8\ m/s^2$ (3) $0.54\ m/s^2$ (4) $5.292\ m/s^2$

86. A block of mass $\sqrt{3}$ kg is placed on a rough horizontal surface whose coefficient of fiction is $\frac{1}{2\sqrt{3}}$. Then the maximum value of force F (shown in figure) such that block doesn't move ($g = 10\ m/s^2$).



(1) 10 N (2) 20 N (3) 12 N (4) none of these

87. Consider the situation shown in figure. The wall and the surface of A and B in contact are rough. The friction on A due to.



(1) B is upward (2) wall is downward

(3) wall is zero (4) B is downward.

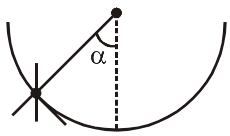
88. Let F, F_N and f denote the magnitudes of the contact force, normal force and the friction exerted by one surface on the other kept in contact. If none of these is zero.

(1) $F > F_N > f$ (2) $F_N > F > f$ (3) $F_N > f$ (4) $F_N - f < F < F_N + f$.

89. A heavy uniform chain partly lies on a horizontal table. If the coefficient of friction between the chain and the table surface is 0.25, then the maximum fraction of the length of the chain that can hang over edge of the table is

(1) 20% (2) 25% (3) 33% (4) 15%.

90. An insect crawls up hemispherical surface very slowly as shown in figure. The coefficient of friction between the insect and the surface is 1/3. If the line joining the centre of the hemispherical surface to the insect makes an angle α with the vertical, the max. possible value of α is given by



(1) $\cot\alpha = 3$ (2) $\sec\alpha = 3.$
(3) $\operatorname{cosec}\alpha = 3.$ (4) None.

LEVEL-02

BASIC QUESTION RELATED TO CONCEPT OF FORCE AND NEWTON'S LAWS OF MOTION

1. A particle is found to be at rest when seen from frame S_1, and moving with a constant velocity when seen from another frame S_2. Mark out the possible options
(1) S_1 is inertial and S_2 is non-inertial frame (2) both the frames are non-inertial
(3) both the frames are inertial (4) either (2) or (3).

2. An empty plastic box of mass 5 kg is observed to accelerate up at the rate of g/6 when placed deep inside water. What mass of sand should be put inside the box so that it may accelerate down at the rate of g/6 ?
(1) 1 kg (2) 1.5 kg (3) 2 kg (4) 2.5 kg

3. An object of mass 10 kg. moves at a constant speed of 10 ms^{-1}. A constant force, that acts for 4 sec on the object, gives it a speed of 2 ms^{-1} in opposite direction. The force acting on the object is
(1) –3N (2) –30N (3) 3 N (4) 30 N

4. A machine gun has a mass 5 kg. It fires 50 gram bullets at the rate of 30 bullets per minute at a speed of 400 ms^{-1}. What force is required to keep the gun in position?
(1) 10N (2) 5N (3) 15N (4) 3N

5. 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 (g is acceleration due to gravity) will be
(1) $mg\cos\theta$ (2) $mg\sin\theta$ (3) mg (4) $mg/\cos\theta$

6. A force of 6N acts on a body at rest and of mass 1 kg. During this time, the body attains a velocity of 30 m/s. The time for which the force acts on body is
(1) 7 seconds (2) 5 seconds (3) 10 seconds (4) 8 seconds

7. Rocket engines lift a rocket from the earth surface, because hot gases with high velocity
(1) react against the rocket and push it up (2) push against the air
(3) push against the earth (4) heat up the air which lifts the rocket

8. The forces, which meet at one point but their lines of action do not lie in one plane, are called
(1) non-coplanar concurrent forces (2) coplanar concurrent forces
(3) non-coplanar non-concurrent forces (4) coplanar non-concurrent forces

9. Which of the following is a non-conservative
(1) electrostatic force (2) viscous force (3) interatomic force (4) gravitational force.

10. A block of mass m is placed on a smooth inclined plane of inclination θ with the horizontal. The force exerted by the plane on the block has a magnitude
(1) mg (2) $\frac{mg}{\cos\theta}$ (3) mg $\cos\theta$ (4) mg $\tan\theta$

11. A machine gun fires n bullets per second, each of mass m. If the speed of each bullet is u, then the force of recoil is
(1) mng (2) mnυ (3) mnυ g (4) $\frac{mn\upsilon}{g}$

12. A force of 5 N acts on a body of wt. 9.80 N. What is the acceleration produced in m/s^2?
(1) 0.51 (2) 1.96 (3) 5.00 (4) 49.00

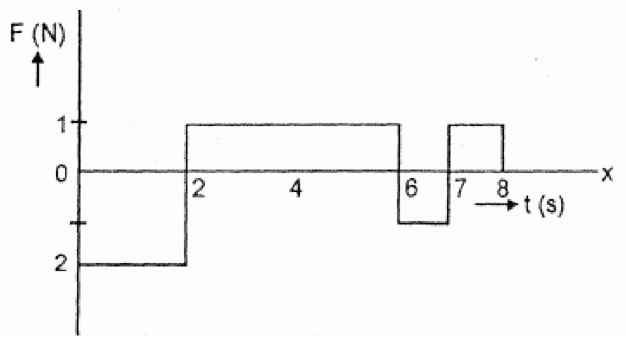
13. A toy cart of mass $\sqrt{3}$ kg is pulled by a force of 20 N at an angle of 30° with the frictionless horizontal surface on which the cart is placed. The cart shall move on the surface with an acceleration
(1) 0 m/s^2 (2) 1 m/s^2 (3) 10 m/s^2 (4) $10\sqrt{3}$ m/s^2

MOMENTUM, IMPULSE, RATE OF CHANGE OF MOMENTUM AND AVERAGE FORCE RELATED PROBLEMS

14. A toy gun consists of a spring and a rubber dart of mass 16 g. When compressed by 4 cm and released, it projects the dart to a height of 2 m. If compressed by 6 cm, the height achieved is
(1) 3 m (2) 4 m (3) 4.5 m (4) 6 m

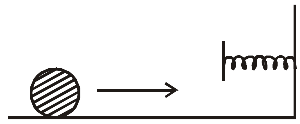
15. A player stops a football weighting 0.5 kg which comes flying towards him with a velocity of 10m/s. If the impact lasts for 1/50th sec. and the ball bounces back with a velocity of 15 m/s, then the average force involved is
(1) 250 N (2) 1250 N (3) 500 N (4) 625 N

16. A force time graph for the motion of a body is shown in Fig. Change in linear momentum between 0 and 8s is



(1) zero (2) 4 N-s (3) 8 Ns (4) None

17. A mass of 0.5 kg moving with a speed of 1.5 m/s on a horizontal smooth surface, collides with a nearly weightless spring of force constant k = 50 N/m. The maximum compression of the spring would be



(1) 0.15 m (2) 0.12 m
(3) 1.5 m (4) 0.5 m

18. A cricketer catches a ball of mass 150 gm in 0.1 sec moving with speed 20 m/s, then he experiences force of
(1) 300 N (2) 30 N (3) 3 N (4) 0.3 N.

19. A body of mass 3 kg moving with speed 5 ms^{-1},hits a wall at an angle of 60° and returns at the same angle. The impact time was 0.2 sec. Calculate the force exerted on the wall
(1) $150\sqrt{3}N$ (2) $50\sqrt{3}N$ (3) 100 N (4) $75\sqrt{3}N$

20. If the force on a rocket, ejecting gases with a velocity of 300 m/s is 210 N, then the rate of combustion of the fuel is
(1) 0.07 kg/s (2) 1.4kg/s (3) 0.7 kg/s (4) 10.7 kg/s

21. A 5000 kg rocket is set for vertical firing. The exhaust speed is 800ms^{-1}. To give an initial upward acceleration of 20ms^{-2}, amount of gas ejected per second to supply the needed thrust will be (g = 10ms^{-2})
(1) 185.5 kgs^{-1} (2) 187.5 kgs^{-1} (3) 127.5 kgs^{-1} (4) 137.5 kgs^{-1}

22. The dimension of impulse are equal to that of
(1) pressure (2) linear momentum
(3) force (4) angular momentum

23. Conservation of linear momentum is equivalent to
(1) Newton's law of gravity (2) Newton's first law of motion
(3) Newton's second law of motion (4) Newton's third law of motion

24. A shell of mass m moving with velocity υ suddenly explodes into two pieces. One part of mass $\frac{m}{4}$ remains stationary. The velocity of the other part will be
(1) υ (2) 2υ (3) $\frac{3\upsilon}{4}$ (4) $\frac{4\upsilon}{3}$

25 The linear momentum of a particle varies with time t as p = a + bt + ct^2
Which of the following statements is correct?
(1) Force varies with time in a quadratic manner.
(2) Force is time-dependent
(3) The velocity of the particle is proportional to time
(4) The displacement of the particle is proportional to t

26. A disc of mass 10 g is kept floating horizontally in air by firing bullets, each of mass 5 g, with the same velocity at the same rate of 10 bullets per second. The bullets rebound with the same speed in opposite direction. The velocity of each bullet at the time of impact is

(1) 196 cm/s (2) 98 cm/s (3) 49 cm/s (4) 392 cm/s

27. A U^{238} nucleus decays by emitting an alpha particle of speed ν m/s. The recoil speed of the residual nucleus is

(1) $\frac{\nu}{4}$ m/s (2) $-\frac{4}{238}\nu$ m/s (3) $-\frac{4}{234}\nu$ m/s (4) $\frac{4}{238}\nu$ m/s

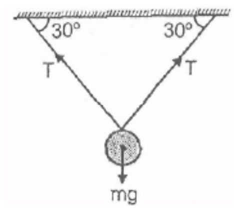
28. An object at rest in space suddenly explodes into three parts of same mass. The momentum of the two parts are $2p\hat{i}$ and $p\hat{j}$. The momentum of the third part

(1) will have a magnitude $p\sqrt{3}$ (2) will have a magnitude $p\sqrt{5}$

(3) will have a magnitude p (4) will have a magnitude 2p

FREE BODY DIAGRAM, EQUILIBRIUM OF CONCURRENT FORCES-LAMI'S THEOREM

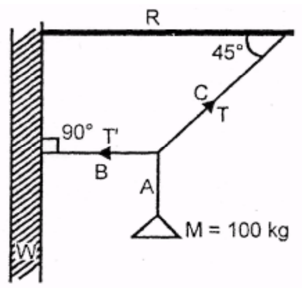
29. A solid sphere of 2 kg is suspended from a horizontal beam by two supporting wires as shown in Fig. Tension in each wire is approximately ($g = 10\ ms^{-2}$)



(1) 30N (2) 20 N

(3) 10N (4) 5 N

30. A mass M of 100 kg is suspended with use of strings A, B and C as shown in figure, where W is vertical wall and R is a rigid horizontal rod. The tension in string B is



(1) 100g N (2) 0

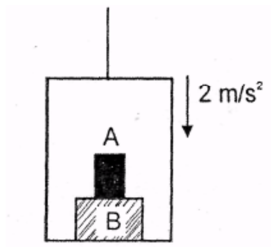
(3) $100\sqrt{2}$ g N (4) $\frac{100}{\sqrt{2}}$ g N

FRAME OF REFERENCE - INTERTIAL OR NON INERTIAL FRAME, PSEUDO FORCE, ACCELERATING LIFT

31. Consider an elevator moving down-wards with an acceleration a, the force exerted by a passenger of mass m on the floor of the elevator is

(1) ma (2) ma – mg (3) mg – ma (4) mg + ma

32. The elevator shown in fig. is descending with an acceleration of 2 m/s^2. The mass of the block A = 0.5 kg. The force exerted by the block A on block B is



(1) 2 N (2) 4 N

(3) 6 N (4) 8 N

33. A man weights 80kg. He stands on a weighing scale in a lift which is moving upwards with a uniform acceleration of 5 m/s^2. What would be the reading on the scale ? (g = 10m/s^2)
(1) zero (2) 400 N (3) 800 N (4) 1200 N

34. A lift of mass 1000 kg which is moving with acceleration of 1 m/s^2 in upward direction, then the tension developed in string which is connected to lift is
(1) 9800 N (2) 10,800 N (3) 11,000 N (4) 10,000 N

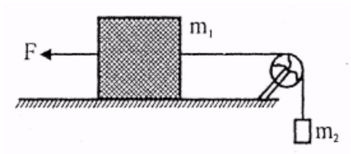
35. A mass of 1 kg is suspended by a thread. It is (i) lifted up with an acceleration 4.9 m/s^2, (ii) lowered with an acceleration 4.9 m/s^2. The ratio of the tensions is
(1) 1:3 (2) 1:2 (3) 3:1 (4) 2:1

36. An elevator is moving up with an acceleration $\frac{g}{5}$. The apparent weight of a 60 kg man standing in the lift is [Take g = 10 m/s^2]
(1) 480 N (2) 720 N (3) 600 N (4) 1000 N

MOTION OF BODIES IN CONTACT OR CONNECTED BY STRINGS, PULLEY SYSTEM

37 A uniform rope of length L resting on a frictionless horizontal surface is pulled at one end by a force F. What is the tension in the rope at a distance ℓ from the end where the force is applied.
(1) F (2) F (1 + ℓ / L) (3) F/2 (4) F (1 – ℓ / L)

38. A constant force F = $m_2g/2$ is applied on the block of mass m_1 as shown in fig. The string and the pulley are light and the surface of
the table is smooth. The acceleration of m_1 is

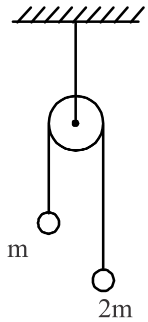


(1) $\frac{m_2g}{2(m_1+m_2)}$ towards right (2) $\frac{m_2g}{2(m_1-m_2)}$ towards left

(3) $\frac{m_2g}{2(m_2-m_1)}$ towards right (4) $\frac{m_2g}{2(m_2-m_1)}$ towards left

39. A monkey of mass 20kg is holding a vertical rope. The rope will not break when a mass of 25kg is suspended from it but will break if the mass exceeds 25kg. What is the maximum acceleration with which the monkey can climb up along the rope ?
(1) 5 m/s^2 (2) 10 m/s^2 (3) 25 m/s^2 (4) 2.5 m/s^2

40. Two masses as shown are suspended from a massless pulley. Calculate the acceleration of the system when masses are left free.



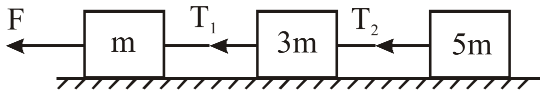
(1) $\frac{2g}{3}$

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

(3) $\frac{g}{9}$

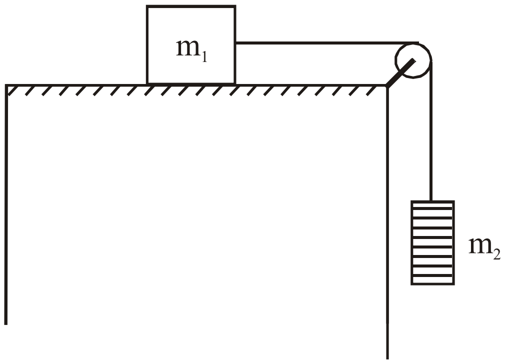
(4) $\frac{g}{7}$

41. Fig. below shows a system of three masses being pulled with a force F. The masses are connected to each other by strings. The horizontal surface is frictionless. The tension T_1 in the first string is 16 N. The acceleration of the system is



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

42. Fig. shows a block of mass m_1 resting on a smooth surface. It is connected to a mass m_2 by a string passing over a massless and frictionless pulleys $m_2 > m_1$. The acceleration of the hanging mass m_2 is.



(1) $\frac{m_1 - m_2}{m_1 + m_2} g$ (2) $\frac{m_2 - m_1}{m_2 + m_1} g$ (3) $\frac{m_1 g}{m_1 + m_2}$ (4) $\frac{m_2 g}{m_1 + m_2}$

FRICTION

43. The force required to just move a body up the inclined plane is double the force required to just prevent the body from sliding down the plane. The coefficient of friction is μ. The inclination θ of the plane is

(1) $\tan^{-1} \mu$ (2) $\tan^{-1} (\mu/2)$ (3) $\tan^{-1} 2\mu$ (4) $\tan^{-1} 3\mu$

44. If μ_s, μ_k and μ_r are coefficients of static friction, sliding friction and rolling friction, then

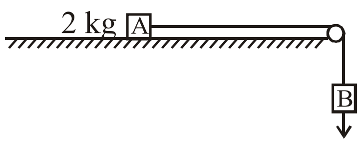
(1) $\mu_s < \mu_k < \mu_r$ (2) $\mu_k < \mu_r < \mu_s$ (3) $\mu_r < \mu_k < \mu_s$ (4) $\mu_r = \mu_k = \mu_s$

45. A 30 kg block rests on a rough horizontal surface. A force of 200 N is applied on the body. The block acquires a speed of 4 m/sec,starting from rest, in 2 seconds. What is the value of coefficient of friction?

(1) $10/\sqrt{3}$ (2) $\sqrt{3}/10$ (3) 0.47 (4) 0.185

46. The coefficient of static friction, μ_s, between block A of mass 2kg and the table as shown in figure is 0.2. What would be the maximum mass value of block B so that the two blocks do not move ? The string and the pulley are assumed to be smooth and massless.

(g = 10m/s^2)



(1) 2.0 kg (4) 4.0 kg (3) 0.2 kg (4) 0.4 kg

47. A block of mass 10kg placed on rough horizontal surface having coefficient of friction $\mu = 0.5$, if a horizontal force of 100 N acting on it the acceleration of the block will be

(1) 10 m/s^2 (2) 5 m/s^2 (3) 15 m/s^2 (4) 0.5 m/s^2

48. On the horizontal surface of a truck a block of mass 1 kg is placed ($\mu = 0.6$) and truck is moving with acceleration 5m /sec^2 then the frictional force on the block will be

(1) 5 N (2) 6 N (3) 5.88 N (4) 8 N

49. A body of mass m is placed on a rough surface with coefficient of friction (μ) inclined at θ. If the mass is in equilibrium, then

(1) $\theta = \tan^{-1}\left(\frac{m}{\mu}\right)$ (2) $\theta = \tan^{-1}(\mu)$ (3) $\theta = \tan^{-1}\left(\frac{\mu}{m}\right)$ (4) $\theta = \tan^{-1}(1/\mu)$

50. A block of mass 4 kg rests on an inclined plane. The inclination of the plane is gradually increased. It is found that when the inclination is 3 in 5, the block just begins to slide down the plane. The coefficient of friction between the block and the plane is

(1) 0.4 (2) 0.6 (3) 0.8 (4) 0.75

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

(1) 9.8 N (2) $0.7 \times 9.8 \times \sqrt{3}$ N

(3) 9.8 N $\times \sqrt{3}$ N (4) 0.7×9.8 N

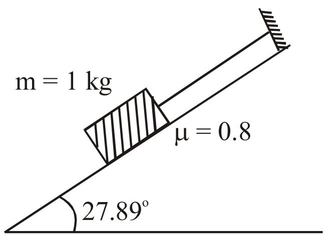
52. A heavy uniform chain lies on a horizontal table top. If the coefficient of friction between the chain and the table is 0.25, then the maximum percentage of the length of the chain that can hang over one edge of the table is

(1) 20% (2) 25% (3) 35% (4) 15%

53. A body of mass 2 kg is placed on a horizontal surface having kinetic friction 0.4 and static friction 0.5. If the force applied on the body is 2.5 N, then the frictional force acting on the body will be [g = 10 m/s^2]

(1) 8 N (2) 10 N (3) 20 N (4) 2.5 N

54. For the arrangement shown in the Fig. below the tension in the string is [Given : $\tan^{-1}(0.8) = 39°$].



(1) 6 N (2) 6.4 N (3) 0.4 N (4) zero

55. A partly hanging uniform chain of length L is resting on a rough horizontal table . l is the maximum possible length that can hang in equilibrium. The coefficient of friction between the chain and table is

(1) $\frac{l}{L-l}$ (2) $\frac{L}{l}$ (3) $\frac{l}{L}$ (4) $\frac{lL}{L+l}$

Assertion & Reason

Each of the questions given below consists of two statements, an assertion (A) and reason (R). Select the number corresponding to the appropriate alternative as follows
(1) If both A and R are true and R is the correct explanation of A.
(2) If both A and R are true but R is not the correct explanation of A.
(3) If A is true but R is false.
(4) If both A and R are false.

1. **Assertion** : If the net external force on the body is zero, then its acceleration is zero.
Reason : Acceleration does not depend on force.

2. **Assertion** : Newton's second law of motion gives the measurement of force.
Reason : According to Newton's second law of motion, force is directly proportional to the rate of change of momentum.

3. **Assertion** : Force is required to move a body uniformly along a circle.
Reason : When the motion is uniform, acceleration is zero.

4. **Assertion** : If two objects of different masses have same momentum, the lighter body possess greater velocity.
Reason : For all bodies momentum always remains same.

5. **Assertion** : Aeroplanes always fly at low altitudes.
Reason : According to Newton's third law of motion, for every action there is an equal and opposite reaction.

6. **Assertion** : Impulse and momentum have different dimensions.
Reason : From Newton's second law of motion, impulse is equal to rate of change in momentum.

7. **Assertion** : Mass is a measure of inertia of the body in linear motion.
Reason : Greater the mass, greater is the force required to change its state of rest or of uniform motion.

8. **Assertion** : The slope of momentum versus time curve give us the acceleration.
Reason : Acceleration is given by the rate of change of momentum.

9. **Assertion** : A cyclist always bends inwards while negotiating a curve.
Reason : By bending, cyclist lowers his centre of gravity.

10. **Assertion** : The work done in bringing a body down from the top to the base along a frictionless incline plane is the same as the work done in bringing it down the vertical side.
Reason : The gravitational force on the body along the inclined plane is the same as that along the vertical side.

11. **Assertion** : Linear momentum of a body changes even when it is moving uniformly in a circle.
Reason : Force required to move a body uniformly along a straight line is zero.

12. **Assertion** : A bullet is fired from a rifle. If the rifle recoils freely, the kinetic energy of rifle is more than that of the bullet.
Reason : In the case of rifle bullet system the law of conservation of momentum violates.

13. **Assertion** : A rocket works on the principle of conservation of linear momentum.
Reason : Whenever there is a change in momentum of one body, the same change occurs in the momentum of the second body of the same system but in the opposite direction.

14. **Assertion** : The apparent weight of a body in an elevator moving with some downward acceleration is less than the actual weight of body.
Reason : The part of the weight is spent in producing downward acceleration, when body is in elevator.

15. **Assertion** : When the lift moves with uniform velocity the man in the lift will feel weightlessness.
Reason : In downward accelerated motion of lift, apparent weight of a body increases.

16. **Assertion** : In the case of free fall of the lift, the man will feel weightlessness.
Reason : In free fall, acceleration of lift is equal to acceleration due to gravity.

17. **Assertion** : A player lowers his hands while catching a cricket ball and suffers less reaction force.
Reason : The time of catch increases when cricketer lowers its hand while catching a ball.

18. **Assertion** : The acceleration produced by a force in the motion of a body depends only upon its mass.
Reason : Larger is the mass of the body, lesser will be the acceleration produced.

19. **Assertion** : Linear momentum of a body changes even when it is moving uniformly in a circle.
Reason : In uniform circular motion velocity remain constant.

20. **Assertion** : Newton's third law of motion is applicable only when bodies are in motion.
Reason : Newton's third law does not apply to gravitational forces.

21. **Assertion** : A reference frame attached to earth is an inertial frame of reference.
Reason : The reference frame which has zero acceleration is called a non inertial frame of reference.

22. **Assertion** : A table cloth can be pulled from a table without dislodging the dishes.
Reason : To every action there is an equal and opposite reaction.

23. **Assertion** : A body subjected to three concurrent forces cannot be in equilibrium.
Reason : If large number of concurrent forces act on the same point, then the point will not be in equilibrium.

Previous Year's Questions

LAWS OF MOTION

1. A block of mass 10 kg is in contact against the inner wall of a hollow cylindrical drum of radius 1 m. The coefficient of friction between the block and the inner wall of the cylinder is 0.1. The minimum angular velocity needed for the cylinder to keep the block stationary when the cylinder is vertical and rotating about its axis, will be : (g = 10 m/s^2)

(1) $\sqrt{10}\text{rad / s}$ (2) $\frac{10}{2\pi}\text{rad / s}$ (3) 10 rad/s (4) $10\pi\,\text{rad / s}$

2. Choose the incorrect statement. **[Kerala CEE 2011]**

(1) No work is done if the displacement is perpendicular to the direction of the applied force.

(2) If the angle between the force and displacement vectors is obtuse, then the work done is negative.

(3) Frictional force is non-conservative.

(4) All the central forces are non-conservative.

(5) Kinetic energy is conserved in elastic collision.

3. A car moving with a speed of 50 km/h can be stopped by brakes, over a distance of 6 m. If the same car is moving at a speed of 100 km/h, the stopping distance is **[J&K CET 2011]**

(1) 12 m (2) 18 m (3) 6 m (4) 24 m

4. In non-inertial frame, the second law of motion is written a **[DUMET 2011]**

where $\mathbf{F_p}$ is pseudo-force while **a** is the acceleration of the body relative to non-inertial frame.

(1) F = ma (2) $F = ma + F_p$ (3) $F = ma - F_p$ (4) F = 2ma

5. A man of mass 60 kg is riding in a lift. The weight of the man, when the lift is accelerating upwards and downwards at 2 ms^{-2}, are respectively (Taking g = 10 ms^{-2}) **[AMU 2010]**

(1) 720 N and 480 N (2) 480 N and 720 N (2) 600 N and 600 N (4) None of the above

6. The x and y-coordinates of a particle at any time t are given by $x = 7t + 4t^2$ and y = 5t, where x and y are in metre and t is in second. The acceleration of the particle at t = 5 s is **[BVP 2010]**

(1) zero (2) 8 ms^4 (3) 20 ms^{-2} (4) 40 ms^{-2}

7. A ball of mass 0.5 kg is moving with a velocity v of 2 ms^{-1}. It is subjected to a force of x Newton in 2 s. Because of this force, the ball moves with a velocity of 3 ms^{-1}. The value of x is **[Manipal 2010]**

(1) 5 N (2) 8.25 N (3) 0.25 N (4) 1 N

8. A force F_1 of 500 N is required to push a car of mass 1000 kg slowly at constant speed on a leveled road. If a force F_2 of 1000 N is applied, the acceleration of the car will be **[Manipal 2010]**

(1) zero (2) 1.5 ms^{-2} (3) 1 ms^{-2} (4) 0.5 ms^{-2}

9. A monkey of mass m kg slides down a light rope attached to a fixed spring balance, with an acceleration *a*. The reading of this balance is w kg (*g* = acceleration due to gravity) **[AIIMS 2009]**

(1) $m = \frac{wg}{g-a}$

(2) $m = w\left(1+\frac{a}{g}\right)$

(3) the force of friction exerted by the rope on the monkey is m(g – a) Newton

(4) the tension in the rope is wg Newton

10. A ball hits a vertical wall horizontally at 10 m/s and bounces back at 10 m/s, then **[UP CPMT 2009]**

(1) there is no acceleration because 10 m/s - 10 m/s = 0

(2) there may be an acceleration because its initial direction is horizontal

(3) there is an acceleration because there is a momentum change

(4) even though there is no change in momentum there is a change in direction. Hence, it has an acceleration

11. The apparent weight of a person inside a lift is w, when lift moves up with a certain acceleration and is w_2 when lift moves down with same acceleration. The weight of the person when lift moves up with constant speed is **[Punjab PMET 2008]**

(1) $\frac{w_1+w_2}{2}$ (2) $\frac{w_1-w_2}{2}$ (3) $2w_1$ (4) $2w_2$

12. A man slides down on a telegraphic pole with an acceleration equal to one-fourth of acceleration due to gravity. The frictional force between man and pole is equal to in terms of man's weight *w*

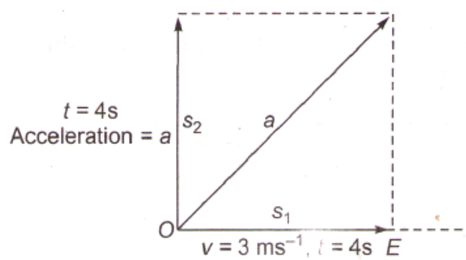
[Punjab PMET 2008]

(1) $\frac{w}{4}$ (2) $\frac{w}{2}$ (3) $\frac{3w}{4}$ (4) w

13. A body of mass 2 kg has an initial velocity of 3 ms^{-1} along *OE* and it is subjected to a force of 4 N in a direction perpendicular to *OE*. The distance of body from *O* after 4 s will be **[Manipal 2008]**

(1) 12 m (2) 20 m

(3) 8 m (4) 48 m



14. An object of mass 10 kg moves at a constant speed of 10 ms^{-1}. A constant force, that acts for 4 s on the object, gives it a speed 2 ms~' in opposite direction. The force acting on the object is

[Manipal 2008]

(1) –3 N (2) –30 N (3) 3 N (4) 30 N

15. A block of mass M is pulled along a horizontal frictionless surface by a rope of mass m. If a force P is applied at the free end of the rope, the force exerted by the rope on the block is **[RPMT 2008]**

(1) $\frac{Pm}{M+m}$ (2) $\frac{Pm}{M-m}$ (3) P (4) $\frac{PM}{M+m}$

16. A light spring balance hangs from the hook of the other light spring balance and a block of mass M kg hangs from the former one. Then the true statement about the scale reading is **[RPMT 2008]**

(1) both the scales read M kg each

(2) the scale of the lower one reads M kg and of the upper one zero

(3) the reading of the two scales can be anything but the sum of the readings will be M kg

(4) both the scales read $M/2$ kg

17. A 60 kg man stands on a spring scale in the lift. At some instant he finds, scale reading has changed from 60 kg to 50 kg for a while and then comes back to the original mark. What should we conclude?

(1) The lift was in constant motion upwards

(2) The lift was in constant motion downwards

(3) The lift while in constant motion upwards, is suddenly stopped

(4) The lift while in constant motion downwards, is suddenly stopped

18. The minimum force required to move a body of mass m vertically upward is **[UP CPMT 2007]**

(1) mg (2) $mg/2$ (3) more than $2mg$ (4) more than mg

19. A man weighs 80 kg. He stands on a weighing scale in a lift which is moving upwards with a uniform acceleration of 5 ms^{-2}. What would be the reading on the scale? ($g = 10\ ms^{-2}$) **[BHU 2007]**

(1) 800 N (2) 1200 N (3) Zero (4) 400 N

20. When a car moves on a road with uniform speed of 30 kmh^{-1}, then the net resultant force on the car is

(1) the driving force, drives the car in the direction of propagation of car **[BHU 2007]**

(2) the resistive force acts opposite to the direction of propagation of car

(3) zero

(4) None of the above

21. A spring balance and a physical balance are kept in a lift. In these balances equal masses are placed. If now the lift starts moving upwards with constant acceleration, then **[Punjab PMET 2007]**

(1) the reading of spring balance will increase and the equilibrium position of the physical balance will disturb

(2) the reading of spring balance will remain unchanged and physical balance will remain in equilibrium

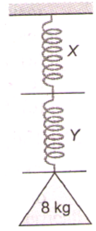
(3) the reading of spring balance will decrease and physical balance will remain in equilibrium

(4) the reading of spring balance will increase and the physical balance will remain in equilibrium

22. A coin is dropped in a lift. It takes time t_1 to reach the floor when lift is stationary. It takes time t_2 when lift is moving up with constant acceleration. Then **[Punjab PMET 2007]**

(1) $t_1 > t_2$ (2) $t_2 > t_1$ (3) $t_1 = t_2$ (4) $t_1 >> t_2$

23. A body of mass 8 kg is suspended through two light springs *X* and *Y* connected in series as shown in figure. The readings in *X* and *Y* respectively are



(1) 8 kg, zero (2) zero, 8 kg
(3) 6 kg, 2 kg (4) 2 kg, 6 kg
(5) 8 kg, 8 kg

24. Same force acts on two bodies of different masses 3 kg and 5 kg initially at rest. The ratio of times required to acquire same final velocity is **[Kerala CEE 2007]**
(1) 5 : 3 (2) 25 : 9 (3) 9 : 25 (4) $\sqrt{3}:\sqrt{5}$
(5) 3 : 5

25. A body of mass 0.1 kg attains a velocity of 10 ms^{-1} in 0.1 s. The force *acting* on the body is **[RPMT 2007]**
(1) 10N (2) 0.01 N (3) 0.1N (4) 100 N

26. Which motion does not require force to maintain it? **[Haryana PMT 2007]**
(1) Uniform circular motion (2) Elliptical motion
(3) Uniform straight line motion (4) Projectile motion

27. The mass of a lift is 500 kg. When it ascends with an acceleration of 2 ms^{-2}, the tension in the cable will be (g = 10 ms^{-2}) **[JCECE 2007]**
(1) 6000 N (2) 5000 N (3) 400 N (4) 1000 N

28. A person sitting in an open car moving at constant velocity throws a ball vertically up into air. The ball falls **[EAMCET (Med.) 1995; MH CET 2003;BCECE 2004]**
(1) Outside the car (2) In the car ahead of the person
(3) In the car to the side of the person (4) Exactly in the hand which threw it up

29. If a bullet of mass 5 gm moving with velocity 100 m /sec, penetrates the wooden block upto 6 cm. Then the average force imposed by the bullet on the block is **[MP PMT 2003]**
(1) 8300 N (2) 417 N (3) 830 N (4) Zero

30. A diwali rocket is ejecting 0.05 kg of gases per second at a velocity of 400 m/sec. The accelerating force on the rocket is **[NCERT 1979; DPMT 2001; MP PMT 2004]**
(1) 20 dynes (2) 20 N (3) 22 dynes (4) 1000 N

31. A person is standing in an elevator. In which situation he finds his weight less than actual when
(1) The elevator moves upward with constant acceleration **[AIIMS 2005]**
(2) The elevator moves downward with constant acceleration.
(3) The elevator moves upward with uniform velocity
(4) The elevator moves downward with uniform velocity

32. A particle of mass 0.3 kg is subjected to a force F = –kx with k = 15 N/m. What will be its initial acceleration if it is released from a point 20 cm away from the origin **[AIEEE 2005]**

(1) 5 m/s^2 (2) 10 m/s^2 (3) 3 m/s^2 (4) 15 m/s^2

33. A boy having a mass equal to 40 kilograms is standing in an elevator. The force felt by the feet of the boy will be greatest when the elevator ($g = 9.8\ m/s^2$) **[MP PMT 1995; BVP 2003]**

(1) Stands still (2) Moves downward at a constant velocity of 4 metres/sec

(3) Accelerates downward with an acceleration equal to $4\,\text{metres}/\sec^2$

(4) Accelerates upward with an acceleration equal to $4\,\text{metres}/\sec^2$

34. If force on a rocket having exhaust velocity of 300 m/sec is 210 N, then rate of combustion of the fuel is **[CBSE PMT 1999; MH CET 2003; Pb. PMT 2004]**

(1) 0.7 kg/s (2) 1.4 kg/s (3) 0.07 kg/s (4) 10.7 kg/s

35. The average force necessary to stop a bullet of mass 20 g moving with a speed of 250 m/s, as it penetrates into the wood for a distance of 12 cm is **[CBSE PMT 2000; DPMT 2003]**

(1) 2.2×10^3 N (2) 3.2×10^3 N (3) 4.2×10^3 N (4) 5.2×10^3 N

36. A player caught a cricket ball of mass 150 gm moving at the rate of 20 m/sec. if the catching process be completed in 0.1 sec the force of the blow exerted by the ball on the hands of player is

(1) 0.3 N (2) 30 N (3) 300 N (4) 3000 N

37. A man weighs 80kg. He stands on a weighing scale in a lift which is moving upwards with a uniform acceleration of $5 m/s^2$. What would be the reading on the scale. $(g = 10 m/s^2)$ **[CBSE PMT 2003]**

(1) 400 N (2) 800 N (3) 1200 N (4) Zero

38. A monkey of mass 20kg is holding a vertical rope. The rope will not break when a mass of 25 kg is suspended from it but will break if the mass exceeds 25 kg. What is the maximum acceleration with which the monkey can climb up along the rope ($g = 9.8\ m/s^2$) **[CBSE PMT 2003]**

(1) 10 m/s^2 (2) 25 m/s^2 (3) 2.5 m/s^2 (4) 5 m/s^2

39. If in a stationary lift, a man is standing with a bucket full of water, having a hole at its bottom. The rate of flow of water through this hole is R_0 If the lift starts to move up and down with same acceleration and then that rates of flow of water are R_u and R_d then **[UPSEAT 2003]**

(1) $R_0 > R_u > R_d$ (2) $R_u > R_0 > R_d$ (3) $R_d > R_0 > R_u$ (4) $R_u > R_d > R_0$

40. A rocket with a lift- off mass 3.5×10^4 kg is blasted upwards with an initial acceleration of 10 m/s^2 Then the initial thrust of the blast is **[AIEEE 2003]**

(1) 1.75×10^5 N (2) 3.5×10^5 N (3) 7.0×10^5 N (4) 14.0×10^5 N

41. A spring balance is attached to the ceiling of a lift. A man hangs his bag on the spring and the spring reads 49 N, when the lift is stationary. If the lift moves downward with an acceleration of 5 m/s^2 the reading of the spring balance will be **[AIEEE 2003]**

(1) 49 N (2) 24 N (3) 74 N (4) 15 N

42. A plumb line is suspended from a ceiling of a car moving with horizontal acceleration of a. What will be the angle of inclination with vertical **[Orissa JEE 2003]**

(1) $\tan^{-1}(a/g)$ (2) $\tan^{-1}(g/a)$ (3) $\cos^{-1}(a/g)$ (4) $\cos^{-1}(g/a)$

43. Mass of a person sitting in a lift is 50 kg. If lift is coming down with a constant acceleration of 10 m/s^2. Then the reading of spring balance will be $(g = 10 m/s^2)$ **[RPET 2003; Kerala PMT 2005]**

(1) 0 (2) 1000N (3) 100 N (4) 10 N

44. 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 (g is acceleration due to gravity) will be **[CBSE PMT 2004]**

(1) $mg\cos\theta$ (2) $mg\sin\theta$ (3) mg (4) $mg/\cos\theta$

45. A machine gun fires a bullet of mass 40 g with a velocity $1200\ ms^{-1}$. The man holding it can exert a maximum force of 144 N on the gun. How many bullets can he fire per second at the most

(1) One (2) Four (3) Two (4) Three **[AIEEE 2004]**

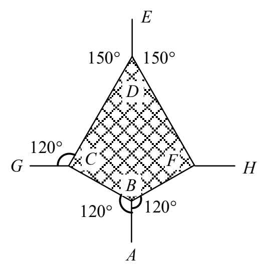
46. An automobile travelling with a speed of $60\ km/h$, can brake to stop within a distance of 20 m. If the car is going twice as fast, i.e. 120 km/h, the stopping distance will be **[AIEEE 2004]**

(1) 20 m (2) 40 m (3) 60 m (4) 80 m

47. A man of weight 75 kg is standing in an elevator which is moving with an acceleration of $5\,m/s^2$ in upward direction the apparent weight of the man will be $(g = 10\ m/s^2)$ **[Pb. PMT 2004]**

(1) 1425 N (2) 1375 N (3) 1250 N (4) 1125 N

48. The adjacent figure is the part of a horizontally stretched net. section AB is stretched with a force of 10 N. The tensions in the sections BC and BF are **[KCET 2005]**



(1) 10 N, 11 N

(2) 10 N, 6 N

(3) 10 N, 10 N

(4) Can't calculate due to insufficient data

49. The spring balance inside a lift suspends an object. As the lift begins to ascent, the reading indicated by the spring balance will **[DCE 2003]**

(1) Increase (2) Decrease

(3) Remain unchanged (4) Depend on the speed of ascend

50. There is a simple pendulum hanging from the ceiling of a lift. When the lift is stand still, the time period of the pendulum is T. If the resultant acceleration becomes $g/4$, then the new time period of the pendulum is **[DCE 2004]**

(1) 0.8 T (2) 0.25 T (3) 2 T (4) 4 T

51. A man of weight 80 kg is standing in an elevator which is moving with an acceleration of $6\ m/s^2$ in upward direction. The apparent weight of the man will be $(g = 10\, m/s^2)$ **[DPMT 2003]**

(1) 1480 N (2) 1280 N (3) 1380 N (4) None of these

52. A force of 100 dynes acts on a mass of 5 gram for 10 sec. The velocity produced is **[Pb. PET 2004]**

(1) 2000 cm/s (2) 200 cm/s (3) 20 cm/s (4) 2 cm/s

53. When the speed of a moving body is doubled **[UPSEAT 2004]**

(1) Its acceleration is doubled

(2) Its momentum is doubled

(3) Its kinetic energy is doubled

(4) Its potential energy is doubled

54. A body of mass m collides against a wall with a velocity v and rebounds with the same speed. Its change of momentum is **[Kerala PMT 2004]**

(1) 2 mv (2) mv (3) – mv (4) Zero

55. A ball of mass m moves with speed v and it strikes normally with a wall and reflected back normally, if its time of contact with wall is t then find force exerted by ball on wall **[BCECE 2005]**

(1) $\frac{2mv}{t}$ (2) $\frac{mv}{t}$ (3) mvt (4) $\frac{mv}{2t}$

56. n small balls each of mass m impinge elastically each second on a surface with velocity u. The force experienced by the surface will be **[MP PMT/PET 1998; RPET 2001; MP PMT 2003]**

(1) mnu (2) 2 mnu (3) 4 mnu (4) $\frac{1}{2}$mnu

57. Swimming is possible on account of **[AFMC 1998, 2003]**

(1) First law of motion (2) Second law of motion

(3) Third law of motion (4) Newton's law of gravitation

58. A light spring balance hangs from the hook of the other light spring balance and a block of mass M kg hangs from the former one. Then the true statement about the scale reading is **[AIEEE 2003]**

(1) Both the scales read M/2 kg each

(2) Both the scales read M kg each

(3) The scale of the lower one reads M kg and of the upper one zero

(4) The reading of the two scales can be anything but the sum of the reading will be M kg

59. A book is lying on the table. What is the angle between the action of the book on the table and the reaction of the table on the book **[Kerala PMT 2005]**

(1) 0° (2) 30° (3) 45° (4) 180°

60. When a horse pulls a wagon, the force that causes the horse to move forward is the force

[Pb. PET 2004]

(1) The ground exerts on it (2) It exerts on the ground

(3) The wagon exerts on it (4) It exerts on the wagon

61. A student attempts to pull himself up by tugging on his hair. He will not succeed **[KCET 2005]**

(1) As the force exerted is small

(2) The frictional force while gripping, is small.

(3) Newton's law of inertia is not applicable to living beings.

(4) As the force applied is internal to the system.

62. A man is standing at the centre of frictionless pond of ice. How can he get himself to the shore

(1) By throwing his shirt in vertically upward direction **[J&K CET 2005]**

(2) By spitting horizontally

(3) He will wait for the ice to melt in pond

(4) Unable to get at the shore

Conservation of Linear Momentum Impulse

1. The acceleration of an object moving in a circle of radius *R* with uniform speed v is

[J&K CET 2011]

(1) $\frac{v^2}{R}$ (2) $\frac{v^2}{2R}$ (3) $\frac{2v^2}{R}$ (4) $\frac{3v^2}{2R}$

2. A particle of mass m is projected with velocity v making an angle of 45° with the horizontal. When the particle lands on the level ground the magnitude of the change in its momentum will be

[CBSE AIPMT 2011]

(1) $2mv$ (2) $mv/\sqrt{2}$ (3) $mv\sqrt{2}$ (4) zero

3. Sand is being dropped on a conveyor belt at the rate of M kgs"[1]. The force necessary to keep the belt moving with a constant velocity of v ms^{-1} will be **[CBSE AIPMT 2011]**

(1) Mv Newton (2) 2 Mv Newton (3) $\frac{Mv}{2}$ Newton (4) zero

4. A machine gun is mounted on a 200 kg vehicle on a horizontal smooth road (friction negligible). The gun fires 10 bullets/s with a velocity of 500 ms^{-1}. If the mass of each bullet be 10 g, what is the acceleration produced in the vehicle? **[BHU 2010]**

(1) 25 cms^{-2} (2) 30 cms^{-2} (3) 50 cms^{-2} (4) 50 cms^{-2}

5. The object at rest suddenly explodes into three parts with the mass ratio $2:1:1$. The parts of equal masses move at right angles to each other with equal speeds. The speed of the third part after the explosion will be **[EAMCET 2010]**

(1) 2v (2) $v/\sqrt{2}$ (3) $v/2$ (4) $\sqrt{2}v$

6. Diwali rocket is ejecting 50 g of gases/s at a velocity of 400 ms^{-1}. The accelerating force on the rocket will be **[RPMT 2009]**

(1) 22 dyne (2) 20 N (3) 20 dyne (4) 100N

7. A gun fires N bullets per second, each of mass m with velocity v. The force exerted by the bullets on the gun is **[J&K CET 2008]**

(1) vNm (2) $\frac{mv}{N}$ (3) mvN^2 (4) $\frac{mv^2}{N}$

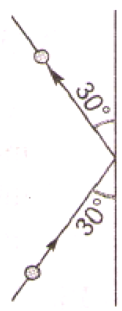
8. The rate of mass of the gas emitted from rear of a rocket is initially 0.1 kgs^{-1}. If the speed of the gas relative to the rocket is 50 ms^{-1} and mass of the rocket is 2 kg, then the acceleration of the rocket (in ms^{-2}) is **[J&K CET 2007]**

(1) 5 (2) 5.2 (3) 2.5 (4) 25

9. A disc of mass 100 g is kept floating horizontally in air by firing bullets, each of mass 5 g with the same velocity at the same rate of 10 bullets per second. The bullets rebound with the same speed in opposite direction, the velocity of each bullet at the time of impact is **[AMU 2006]**

(1) 196 cms^{-1} (2) 9.8 cms^{-1} (3) 98 cms^{-1} (4) 980 cms^{-1}

10. A 0.5 kg ball moving with a speed of 12 ms^{-1} V strikes a hard wall at an angle of 30° with the Vg, wall. It is reflected with the same speed and at the same angle. If the ball is in contact with the wall for 0.25 s, the average force acting on the wall is **[BHU 2006]**



(1) 48 N

(2) 24 N

(3) 12 N

(4) 96 N

11. Impulse is **[J&K CET 2006]**

(1) a scalar (2) equal to change in the momentum of a body

(3) equal to rate of change of momentum of a body (4) a force

12. A ball of mass 150g starts moving with an acceleration of 20 m/s^2. When hit by a force, which acts on it for 0.1 sec. The impulsive force is **[AFMC 1999; Pb. PMT 2003]**

(1) 0.5 N-s (2) 0.1 N-s (3) 0.3 N-s (4) 1.2 N-s

13. An aircraft is moving with a velocity of $300\,ms^{-1}$. If all the forces acting on it are balanced, then **[Kerala PMT 2004]**

(1) It still moves with the same velocity (2) It will be just floating at the same point in space

(3) It will fall down instantaneously (4) It will lose its velocity gradually

(5) It will explode

14. A rocket of mass 1000 kg exhausts gases at a rate of 4 kg/sec with a velocity 3000 m/s. The thrust developed on the rocket is **[Orissa JEE 2005]**

(1) 12000 N (2) 120 N (3) 800 N (4) 200 N

15. A bullet of mass 5 g is shot from a gun of mass 5 kg. The muzzle velocity of the bullet is 500 m/s. The recoil velocity of the gun is **[DCE 2004]**

(1) 0.5 m/s (2) 0.25 m/s (3) 1 m/s (4) Data is insufficient

Equilibrium of Forces

1. Two forces in the ratio 1 : 2 act simultaneously on a particle. The resultant of these forces is three times the first force. The angle between them is **[Kerala CEE 2011]**

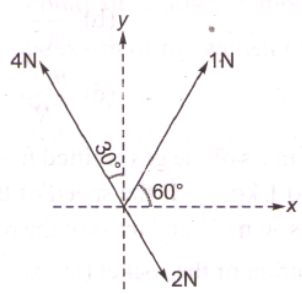
(1) 0° (2) 60° (3) 90° (4) 45°

(5) 30°

2. The resultant of two forces acting at an angle of 120° is 10 kg-wt and is perpendicular to one of the forces. That force is **[KCET 2011]**

(1) $10\sqrt{3}$ kg-wt (2) $20\sqrt{3}$ kg-wt (3) 10 kg-wt (4) $\frac{10}{\sqrt{3}}$ kg-wt

3. Three forces acting on a body are shown in the figure. To have the *resultant* force only along the y-direction, the magnitude of the minimum additional force needed is



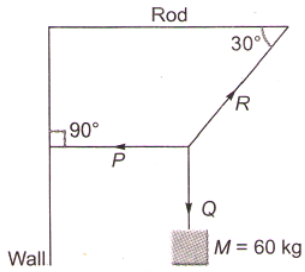
(1) 0.5 N (2) 1.5 N

(3) $\frac{\sqrt{3}}{4}$N (4) $\sqrt{3}$N

4. The square of resultant of two equal forces is three times their product. Angle between the forces is

(1) π (2) $\frac{\pi}{2}$ (3) $\frac{\pi}{4}$ (4) $\frac{\pi}{3}$ **[AMU 2008]**

5. A body of mass 60 kg suspended by means of three strings *P, Q* and *R* as shown in the figure is in equilibrium. The tension in the string *P* is **[Kerala CEE 2008]**



(1) 130.9 gN (2) 60 gN

(3) 50 gN (4) 103.9 gN

(5) 100 gN

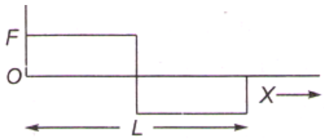
6. Two equal forces are acting at a point with an angle of 60° between them. If the resultant force is equal to 40√3 N, the magnitude of each force is **[Kerala CEE 2008]**

(1) 40 N (2) 20 N (3) 80 N (4) 30 N (5) 10 N

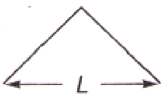
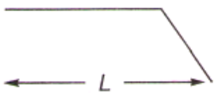
7. A body is under the action of two mutually perpendicular forces of 3 N and 4 N. The resultant force acting on the body is **[J&K CET 2008]**

(1) 7 N (2) 1 N (3) 5 N (4) zero (5) 10N

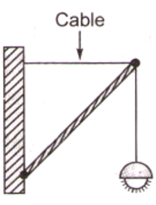
8. A person used force (F), shown in figure to move a load with constant velocity on given surface.

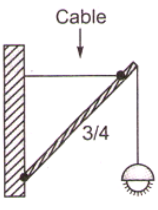


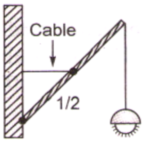
Identify the correct surface profile. **[AIIMS 2006]**

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

9. If a street light of mass *M* is suspended from the end of a uniform rod of length *L* in different possible patterns as shown in figure, then **[AIIMS 2006]**

(1) 

(2) 

(3) 

(1) pattern A is more sturdy (2) pattern B is more sturdy

(3) pattern C is more sturdy (4) all will have same sturdiness

10. A weight w is suspended from, the mid-point of a rope, whose ends are at the same level. In order to make the rope perfectly horizontal, the force applied to each of its ends must be **[AMU 2006]**

(1) less than *w* (2) equal to *w* (3) equal to 2w (4) infinitely large

11. If two forces each of 2 N are inclined at 60°, then resultant force is **[JCECE 2006]**

(1) 2 N (2) $2\sqrt{3}$N (3) $3\sqrt{2}$N (4) $4\sqrt{2}$N

12. Two particles of equal mass are connected to a rope *AB* of negligible mass, such that one is at end *A* and the other dividing the length of the rope in the ratio 1 : 2 from *B*. The rope is rotated about end *B* in a horizontal plane. Ratio of the tensions in the smaller part to the other is (ignore effect of gravity) **[J&K CET 2006]**

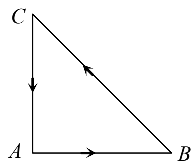
(1) 4 : 3 (2) 1 : 4 (3) 1 : 2 (4) 1 · 3

13. Which of the following sets of concurrent forces may be in equilibrium **[KCET 2003]**

(1) $F_1 = 3N, F_2 = 5N, F_3 = 9N$ (2) $F_1 = 3N, F_2 = 5N, F_3 = 1N$

(3) $F_1 = 3N, F_2 = 5N, F_3 = 15N$ (4) $F_1 = 3N, F_2 = 5N, F_3 = 6N$

14. Three forces starts acting simultaneously on a particle moving with velocity $\vec{v}$. These forces are represented in magnitude and direction by the three sides of a triangle ABC (as shown). The particle will now move with velocity **[AIEEE 2003]**



(1) $\vec{v}$ remaining unchanged

(2) Less than $\vec{v}$

(3) Greater than $\vec{v}$

(4) $\vec{v}$ in the direction of the largest force BC

15. Which of the following groups of forces could be in equibrium **[UPSEAT 2004]**

(1) 3 N, 4 N, 5 N (2) 4N, 5 N, 10 N (3) 30N, 40 N, 80 N (4) 1N, 3 N, 5 N

16. If two forces of 5 N each are acting along X and Y axes, then the magnitude and direction of resultant is **[DCE 2004]**

(1) $5\sqrt{2}, \pi/3$ (2) $5\sqrt{2}, \pi/4$ (3) $-5\sqrt{2}, \pi/3$ (4) $-5\sqrt{2}, \pi/4$

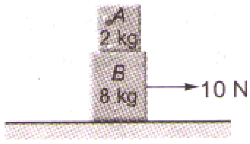
Motion of Connected Bodies and Friction

1. Two bodies of masses 4 kg and 6 kg are tied to the ends of a massless string. The string passes over a frictionless pulley. The acceleration of the system is **[Kerala CEE 2011]**

(1) $\frac{g}{2}$ (2) $\frac{g}{3}$ (3) $\frac{g}{5}$ (4) $\frac{g}{10}$

(5) $\frac{g}{4}$

2. Block *A* of mass of 2 kg is placed over block *B* of mass 8 kg. The combination is placed over a rough horizontal surface. Coefficient of friction between *B* and the floor is 0.5. Coefficient of friction between blocks *A* and *B* is 0.4. A horizontal force of 10 N is applied on block *B*. The force of friction between blocks *A* and *B* is $(g = 10\ ms^{-2})$ **[KCET 2011]**

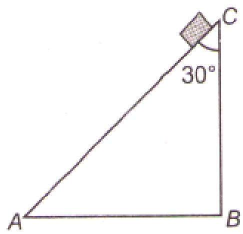


(1) 100 N (2) 40 N (3) 50 N (4) zero

3. An object is moving on a plane surface with uniform velocity 10 ms^{-1} in presence of a force 10 N. The frictional force between the object and the surface is **[DUMET 2011]**

(1) 1N (2) –10N (3) 10N (4) 100 N

4. A body of mass *M* starts sliding down on the inclined plane where the critical angle is *Z ACB* = 30° as shown in figure. The coefficient of kinetic friction will be **[DUMET 2010]**



(1) $Mg/\sqrt{3}$ (2) $\sqrt{3}Mg$

(3) $\sqrt{3}$ (4) None of these

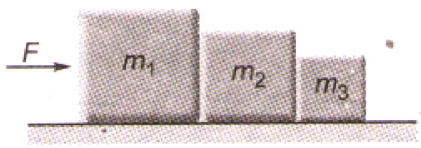
5. A smooth block is released at rest on a 45° incline and then slides a distance *d*. The time taken to slide is *n* times as much to slide on rough incline than on a smooth incline. The coefficient of friction is **[AIIMS 2010]**

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

6. **Assertion** : Angle of repose is equal to the angle of limiting friction. **[AIIMS 2009]**

Reason : When the body is just at the point of motion, the force of friction in this stage is called limiting friction.

7. Three blocks of masses m_1, m_2 and m_3 kg are placed in contact with each other on a frictionless table. A force *F* is applied on the heaviest mass m_1; the acceleration of w_3 will be **[BHU 2009]**



(1) $\frac{F}{m_1}$ (2) $\frac{F}{m_1 + m_2}$ (3) $\frac{F}{m_2 + m_3}$ (4) $\frac{F}{m_1 + m_2 + m_3}$

8. A block of mass 2 kg is placed on the surface of a trolley of mass 20 kg which is on a smooth surface. The coefficient of friction between the block and the surface of the trolley is 0.25. If a horizontal force of 2 N acts on the block, the acceleration of the system in ms^{-2} is **[Punjab PMET 2008]**

$(g = 10\ ms^{-2})$

(1) 1.8 (2) 1.0 (3) 0.9 (4) 0.09

9. Consider a vehicle going on a horizontal road towards east. Neglect any force by the air. The frictional force on the vehicle by the road **[DUMET 2008]**

(1) is zero if the vehicle is moving with a uniform velocity

(2) is towards west if the vehicle is accelerating

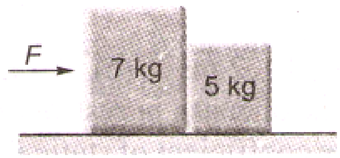
(3) must the towards east

(4) must be towards west

10. Masses *m* and *M* on pulley move 0.6 m in 4 s. What is ratio of $\frac{m}{M}$?

(1) $\frac{55}{57}$ (2) $\frac{113}{117}$ (3) $\frac{57}{55}$ (4) $\frac{397}{403}$

11. Two blocks of masses 7 kg and 5 kg are placed in contact with each other on a smooth surface. If a force of 6 N is applied on the heavier mass, the force on the lighter mass is **[Kerala CEE 2008]**

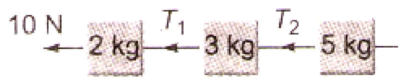


(1) 3.5 N (2) 2.5 N
(3) 7 N (4) 5 N
(5) 6 N

12. A marble block of mass 2 kg lying on ice when given a velocity of 6 ms"[1] is stopped by friction in 10 s. Then the coefficient of friction is **[RPMT 2008]**

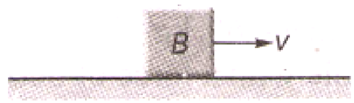
(1) 0.02 (2) 0.03 (3) 0.06 (4) 0.01

13. Three blocks of masses 2 kg, 3 kg and 5 kg are connected to each other with light string and are then placed on a frictionless surface as shown in the figure. The system is pulled by a force *F* = 10 N, then tension T_1, is equal to **[BCECE 2008]**



(1) 1 N (2) 5 N (3) 8 N (4) 10 N

14. A block *B* is pushed momentarily along a horizontal surface with an initial velocity v. If μ is the coefficient of sliding friction between *B* and the surface, block *B* will come to rest after a time **[CBSE AIPMT 2008]**



(1) $\frac{v}{g\mu}$ (2) $\frac{g\mu}{v}$ (3) $\frac{g}{v}$ (4) $\frac{v}{g}$

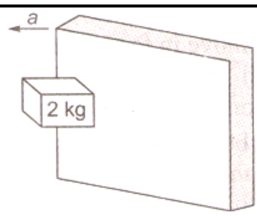
15. The limiting friction is **[AFMC 2008]**

(1) always greater than the dynamic friction
(2) always less than the dynamic friction
(3) equal to the dynamic friction
(4) sometimes greater and sometimes less than the dynamic friction

16. If coefficient of static friction is and coefficient of kinetic friction is (μ_k, which is correct? **[UP CPMT 2008]**

(1) $\mu_s = \mu_k$ (2) $\mu_s > \mu_k$ (3) $\mu_s < \mu_k$ (4) Cannot predict

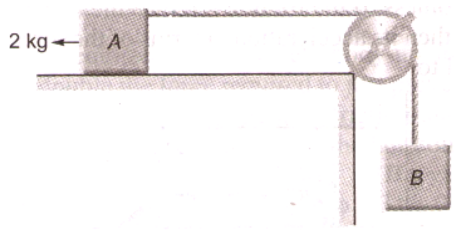
17. A rough vertical board has an acceleration a so that a 2 kg block pressing against it does not fall. The coefficient of friction between the block and the board should be **[Punjab PMET 2008]**



(1) > g / a (2) < g / a

(3) = g / a (4) > a / g

18. The coefficient of static friction, μ_s, between block A of mass 2 kg and the table as shown in the figure is 0.2. What would be the maximum mass value of block B so that the two blocks do not move? The string and the pulley are assumed to be smooth and massless ($g = 10$ ms^{-2}) **[Manipal 2007]**

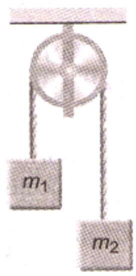


(1) 2.0 (2) 4.0 kg (3) 0.2 kg (4) 0.4 kg

19. Two masses m_1 = 5 kg and m_2 = 4.8 kg tied to a stnng are hanging over a light frictionless pulley. What is the acceleration of the masses when lift is free to move? (g = 9.8 ms $^{-2}$) **[MP PMT 2007]**

(1) 0.2 ms^{-2} (2) 9.8 ms^{-2}

(3) 5 ms^{-2} (4) 4.8 ms^{-2}



20. A force of 49 N is just able to move a block of wood weighing 10 kg on a rough horizontal surface. Its coefficient of friction is **[RPMT 2007]**

(1) 1 (2) 0.7

(3) 0.5 (4) zero

21. If the coefficient of static friction between the tyres and road is 0.5, what is the shortest distance in which an automobile can be stopped when travelling at 72 kmh^{-1}? **[BCECE 2007]**

(1) 50 m (2) 60 m

(3) 40.8 m (4) 80.16 m

22. With increase of temperature, the frictional force acting between two surface **[J&K CET 2007]**

(1) increases (2) remains the same

(3) decreases (4) becomes zero

23. A body of mass 2 kg is placed on rough horizontal plane. The coefficient of friction between body and plane is 0.2. Then **[AMU 2006]**

(1) body will move in forward direction, if F = 5 N

(2) body will move in backward direction with acceleration 0.6 ms ^{2}, if force F = 3 N

(3) body will be in rest condition, if F =3 N

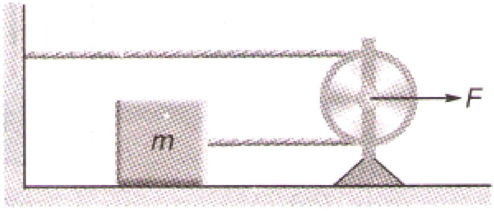
(4) Both (1) and (3) are correct

24. Which of the following statements is not true? **[BHU 2006]**

(1) The coefficient of friction between two surfaces increases as the surface in contact are made rough

(2) The force of friction acts in the direction opposite to the applied force
(3) Rolling friction is greater than sliding friction
(4) The coefficient of friction between wood and wood is less than 1

25. In the given figure the pulley is assumed massless and frictionless. If the friction force on the object of mass *m* is f, if it is moving then its acceleration in terms of the force *F* will be equal to **[BCECE 2006]**



(1) (F – f)/m
(2) $\left(\frac{F}{2}-f\right)/m$
(3) F/m
(4) None of these

26. A block of mass 10 kg is placed on a rough horizontal surface whose coefficient of friction is 0.5. If a horizontal force of 100 N is applied on it, then acceleration of block will be **[JCECE 2006]**

(1) $10\ ms^{-2}$ (2) $5\ ms^{-2}$ (3) $15ms^{-2}$ (4) $0.5ms^{-2}$

27. A block of mass 2 kg rests on a horizontal surface. If a horizontal force of 5 N is applied on the block the frictional force on, it is ($\mu_k = 0.4$, $\mu_s = 0.5$) **[J&K CET 2006]**

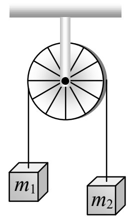
(1) 5 N (2) 10N (3) 8 N (4) zero

28. A block of mass M is pulled along a horizontal frictionless surface by a rope of mass m. If a force P is applied at the free end of the rope, the force exerted by the rope on the block will be

[CBSE PMT 1993; CPMT 1972, 75, 82; MP PMT 1996; AIEEE 2003]

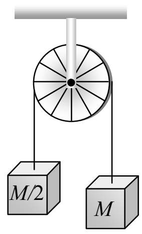
(1) P (2) $\frac{Pm}{M+m}$ (3) $\frac{PM}{M+m}$ (4) $\frac{Pm}{M-m}$

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



(1) $0.2\ m/s^2$ (2) $9.8\ m/s^2$
(3) $5\ m/s^2$ (4) $4.8\ m/s^2$

30. Two masses M and M/2 are joint together by means of a light inextensible string passes over a frictionless pulley as shown in figure. When bigger mass is released the small one will ascend with an acceleration of



(1) g/3 (2) 3g/2 **[Kerala PET 2005]**
(3) g/2 (4) g

31. Two masses m_1 and m_2 ($m_1 > m_2$) are connected by massless flexible and inextensible string passed over massless and frictionless pulley. The acceleration of centre of mass is **[J&K CET 2005]**

(1) $\left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2 g$ (2) $\frac{m_1 - m_2}{m_1 + m_2} g$ (3) $\frac{m_1 + m_2}{m_1 - m_2} g$ (4) Zero

32. The vector sum of two forces is perpendicular to their vector differences. In that case, the force

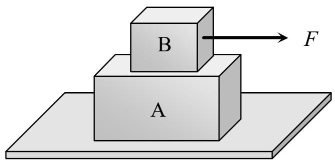
[CBSE PMT 2003]

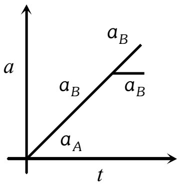
(1) Are equal to each other in magnitude (2) Are not equal to each other in magnitude

(3) Cannot be predicted (4) Are equal to each other

Graphical Questions

1. A block B is placed on block A. The mass of block B is less than the mass of block A. Friction exists between the blocks, whereas the ground on which the block A is placed is taken to be smooth. A horizontal force F, increasing linearly with time begins to act on B. The acceleration a_A and a_B of blocks A and B respectively are plotted against t. The correctly plotted graph is



(1)


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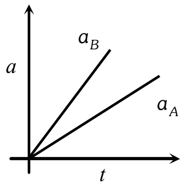
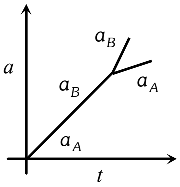
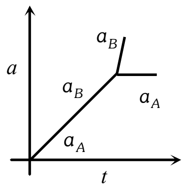
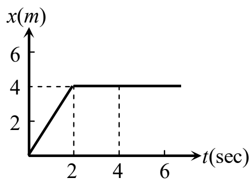


(3)


(4)


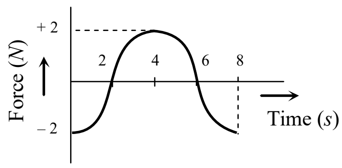
2. In the figure given below, the position-time graph of a particle of mass 0.1 Kg is shown. The impulse at $t = 2\sec$ is **[AIIMS 2005]**



(1) $0.2\,\text{kg}\,\text{m}\,\text{sec}^{-1}$ (2) $-0.2\,\text{kg}\,\text{m}\,\text{sec}^{-1}$

(3) $0.1\,\text{kg}\,\text{m}\,\text{sec}^{-1}$ (4) $-0.4\,\text{kg}\,\text{m}\,\text{sec}^{-1}$

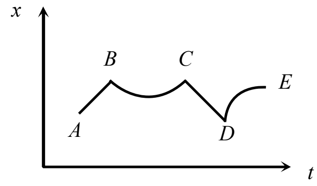
3. The force-time (F – t) curve of a particle executing linear motion is as shown in the figure. The momentum acquired by the particle in time interval from zero to 8 second will be



(1) – 2 N-s (2) + 4 N-s

(3) 6 N-s (4) Zero

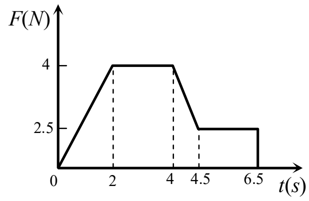
4. Figure shows the displacement of a particle going along the X-axis as a function of time. The force acting on the particle is zero in the region



(1) none of these (2) BC

(3) CD (4) DE

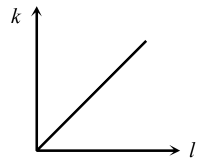
5. A body of 2 kg has an initial speed $5 ms^{-1}$. A force acts on it for some time in the direction of motion. The force time graph is shown in figure. The final speed of the body.

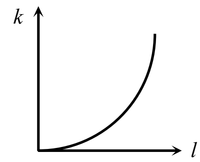


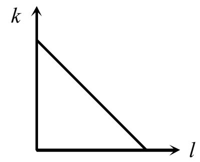
(1) $9.25 ms^{-1}$ (2) $5 ms^{-1}$

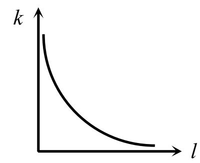
(3) $14.25 ms^{-1}$ (4) $4.25 ms^{-1}$

6. Which of the following graph depicts spring constant k versus length l of the spring correctly

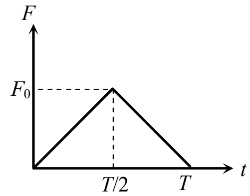
(1)


(2)


(3)


(4)


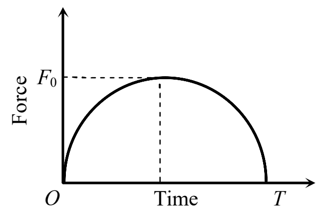
7. A particle of mass m moving with velocity u makes an elastic one dimensional collision with a stationary particle of mass m. They are in contact for a very short time T. Their force of interaction increases from zero to F_0 linearly in time T/2, and decreases linearly to zero in further time T/2. The magnitude of F_0 is



(1) mu / T (2) 2mu / T

(3) mu / 2T (4) None of these

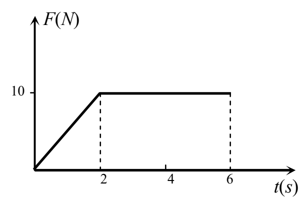
8. A particle of mass m, initially at rest, is acted upon by a variable force F for a brief interval of time T. It begins to move with a velocity u after the force stops acting. F is shown in the graph as a function of time. The curve is a semicircle.



(1) $u = \frac{\pi F_0^2}{2m}$ (2) $u = \frac{\pi T^2}{8m}$

(3) $u = \frac{\pi F_0 T}{4m}$ (4) $u = \frac{F_0 T}{2m}$

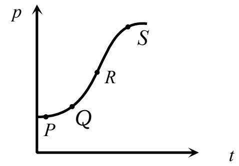
9. A body of mass 3kg is acted on by a force which varies as shown in the graph below. The momentum acquired is given by



(1) Zero (2) 5 N-s

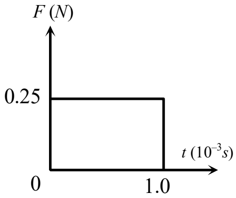
(3) 30 N-s (4) 50 N-s

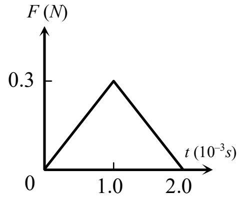
10. The variation of momentum with time of one of the body in a two body collision is shown in fig. The instantaneous force is maximum corresponding to point

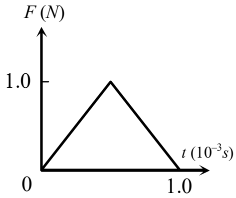


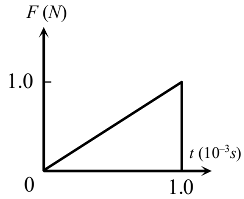
(1) P (2) Q
(3) R (4) S

11. Figures I, II, III and IV depict variation of force with time

(I)


(II)


(III)


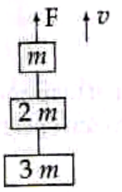
(IV)


The impulse is highest in the case of situations depicted. Figure

(1) I and II (2) III and I (3) III and IV (4) IV only.

Question Asked in 2013 to 2021

1. Three blocks with masses m, 2m and 3m are connected by strings, as shown in the figure. After an upward force F is applied on block m, the masses move upward at constant speed v. What is the net force on the block of mass 2 m? (g is the acceleration due to gravity) **[NEET-2013]**



(1) 6 mg (2) Zero (3) 2 mg (4) 3 mg

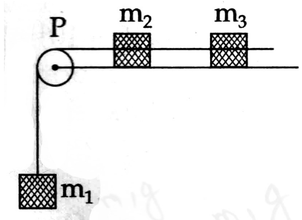
2. The upper half of an inclined plane of inclination θ is perfectly smooth while lower half is rough. A block starting from rest at the top of the plane will again come to rest at the bottom, if the coefficient of friction between the block and lower half of the plane is given by : **[NEET-2013]**

(1) $\mu = \tan\theta$ (2) $\mu = \frac{1}{\tan\theta}$ (3) $\mu = \frac{2}{\tan\theta}$ (4) $\mu = 2\tan\theta$

3. A balloon with mass 'm' is descending down with an acceleration 'a' (where a < g). How much mass should be removed from it so that it starts moving up with an acceleration 'a'? **[AIPMT-2014]**

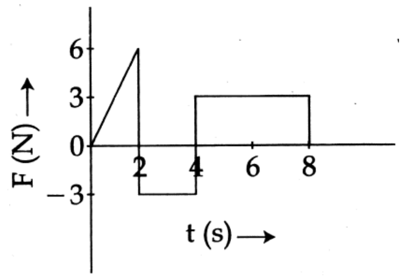
(1) $\frac{ma}{g+a}$ (2) $\frac{ma}{g-a}$ (3) $\frac{2ma}{g+a}$ (4) $\frac{2ma}{g-a}$

4. A system consists of three masses m_1, m_2 and m_3 connected by a string passing over a pulley P. The mass m_1 hangs freely and m_2 and m_3 are on rough horizontal table (the coefficient of friction = μ). The pulley is frictionless and of negligible mass. The downward acceleration of mass m_1 is : (Assume $m_1 = m_2 = m_3 = m$) **[AIPMT-2014]**



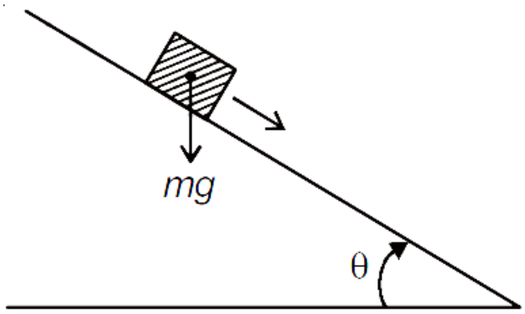
(1) $\frac{g(1-2\mu)}{3}$ (2) $\frac{g(1-2\mu)}{2}$ (3) $\frac{g(1-g\mu)}{9}$ (4) $\frac{2g\mu}{3}$

5. The force 'F' acting on a particle of mass 'm' is indicated by the force–time graph shown below. The change in momentum of the particle over the time interval from zero to 8 s is: **[AIPMT-2014]**



(1) 12 Ns (2) 6 Ns (3) 24 Ns (4) 20 Ns

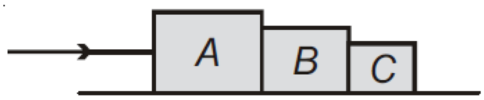
6. A plank with a box on it at one end is gradually raised about the other end. As the angle of inclination with the horizontal reaches 30o, the box starts to slip and slides 4.0 m down the plank in 4.0 s. The coefficients of static and kinetic friction between the box and the plank will be, respectively **[Re-AIPMT-2015]**



(1) 0.4 and 0.3 (2) 0.6 and 0.6 (3) 0.6 and 0.5 (4) 0.5 and 0.6

7. Two stones of masses *m* and 2 *m* are whirled in horizontal circles, the heavier one in a radius $\frac{r}{2}$ and lighter one in radius *r*. The tangential speed of lighter stone is *n* times that of the value of heavier stone when they experience same centripetal forces. The value of *n* is **[Re-AIPMT-2015]**
(1) 1 (2) 2 (3) 3 (4) 4

8. Three blocks A, B and C of masses 4 kg, 2 kg and 1 kg respectively, are in contact on a frictionless surface, as shown. If a force of 14 N is applied on the 4 kg block, then the contact force between A and B is **[AIPMT-2015]**

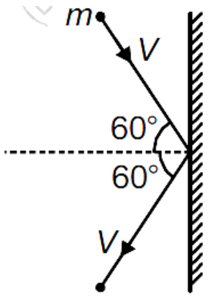


(1) 18 N (2) 2 N (3) 6 N (4) 8 N

9. A block A of mass m_1 rests on a horizontal table. A lights string connected to it passes over a frictionless pulley at the edge of table and from its other end another block B of mass m_2 is suspended. The coefficient of kinetic friction between the block and the table is μ_k. When the block A is sliding on the table, the tension in the string is : **[AIPMT 2015]**

(1) $\frac{m_1 m_2(1-\mu_k)g}{(m_1+m_2)}$ (2) $\frac{(m_2+\mu_k m_1)g}{(m_1+m_2)}$ (3) $\frac{(m_2-\mu_k m_1)g}{(m_1+m_2)}$ (4) $\frac{m_1 m_2(1+\mu_k)g}{(m_1+m_2)}$

10. A rigid ball of mass *m* strikes a rigid wall at 60° and gets reflected without loss of speed as shown in the figure below. The value of impulse imparted by the wall on the ball will be **[NEET (Phase-2) 2016]**



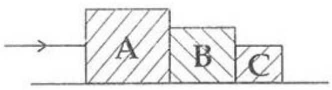
(1) mV (2) 2mV (3) $\frac{mV}{2}$ (4) $\frac{mV}{3}$

11. A car is negotiating a curved road of radius R. The road is banked at an angle θ. The coefficient of friction between the tyres of the car and the road is μ_s. The maximum safe velocity on this road is **[NEET-2016]**

(1) $\sqrt{\frac{g}{R^2}\frac{\mu_s+\tan\theta}{1-\mu_s\tan\theta}}$ (2) $\sqrt{gR^2\frac{\mu_s+\tan\theta}{1-\mu_s\tan\theta}}$

(3) $\sqrt{gR\frac{\mu_s+\tan\theta}{1-\mu_s\tan\theta}}$ (4) $\sqrt{\frac{g}{R}\frac{\mu_s+\tan\theta}{1-\mu_s\tan\theta}}$

12. Three blocks A, B and C, of masses 4 kg, 2 kg and 1 kg respectively, are in contact on a frictionless surface, as shown. If a force of 14 N is applied on the 4 kg block, then the contact force between A and B is :



(1) 18 N (2) 2 N (3) 6 N (4) 8 N

13. Suppose the charge of the proton and an electron differ slightly. One of them is –e, the other is $(e+\Delta e)$. If the net of electrostatic force and gravitational force between two hydrogen atoms placed at a distance d (much greater than atomic size) apart is zero, then Δe is of the order of [Given mass of hydrogen [$mh = 1.67\times10^{-27}$ kg] **[NEET-2017]**

(1) 10^{-20} C (2) 10^{-23} C (3) 10^{-37} C (4) 10^{-47} C

14. One end of string of length l is connected to a particle of mass 'm' and the other end is connected to a small peg on a smooth horizontal table. If the particle moves in circle with speed 'ν', the net force on the particle (directed towards center) will be (T represents the tension in the string) **[NEET 2017]**

(1) T (2) $T+\frac{mv^2}{l}$ (3) $T-\frac{mv^2}{l}$ (4) Zero

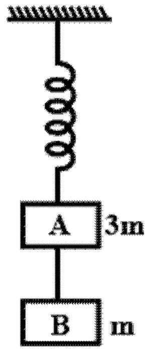
15. A spring of force constant k is cut into lengths of ratio 1:2:3. They are connected in series and the new constant is k'. Then they are connected in parallel and force constant is k''. Then $k':k''$ is:

[NEET 2017]

(1) 1:6 (2) 1:9 (3) 1:11 (4) 1:14

16. Two blocks A and B of masses 3m and m respectively are connected by a massless and inextenable string. The whole system is suspended by a massless spring as shown in figure. The magnitudes of acceleration of A and B immediately afte the string is cut, are respectively.

[NEET 2017]

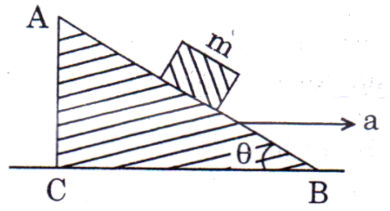


(1) $g, \frac{g}{3}$ (2) $\frac{g}{3}, g$ (3) g, g (4) $\frac{g}{3}, \frac{g}{3}$

17. Which one of the following statements is ***incorrect*** ? **[NEET 2018]**

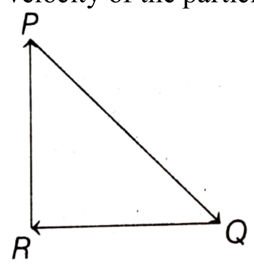
(1) Frictional force opposes the relative motion.
(2) Coefficient of sliding friction has dimensions of length.
(3) Limiting value of static friction is directly proportional to normal reaction.
(4) Rolling friction is smaller than sliding friction.

18. A block of mass m is placed on a smooth inclined wedge ABC of inclination θ as shown in the figure. The wedge is given an acceleration 'a' towards the right. the relation between a and θ for the block to remain stationary on the wedge is **[NEET 2018]**



(1) $a = g\cos\theta$ (2) $a = g\tan\theta$ (3) $a = \frac{g}{\sin\theta}$ (4) $a = \frac{g}{\operatorname{cosec}\theta}$

19. A particle moving with velocity v is acted by three forces shown by the vector triangle PQOR. The velocity of the particle will **[NEET (national) 2019]**



(1) decrease
(2) remain constant
(3) change according to the smallest force QR
(4) increase

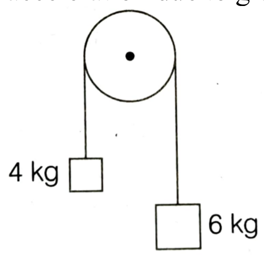
20. Two particles A and B are moving in uniform circular motion in concentric circles of radii r_A and r_B, with speed V_A and V_B respectively. Their time period of rotation is the same. The ratio of angular speed of A to that of B will be **[NEET (National) 2019]**

(1) $V_A : V_B$ (2) $r_B : r_A$ (3) $1 : 1$ (4) $r_A : r_B$

21. A block of mass 10 kg is in contact against the inner wall of a hollow cylindrical drum of radius 1 m. The coefficient of friction between the block and the inner wall of the cylinder is 0.1. The minimum angular velocity needed for thecylinder to keep the block stationary when the cylinder is vertical and rotating about its axis, will be (g =10 m/s^2) **[NEET (National) 2019]**

(1) $\frac{10}{2\pi}$ rad / s (2) 10 rad/s (3) 10π rad / s (4) $\sqrt{10}$ rad / s

22. Two bodies of mass 4 kg and 6 kg are tied to the ends of a massless string. The string passes over a pulley which is frictionless (see figure). The acceleration of the blocks of the system in terms of acceleration due to gravity g is **[NEET (Sep.)2020]**



(1) g/2 (2) g/5 (3) g/10 (4) g

23. A ball of mass 0.15 kg is dropped from a height 10 m, strikes the ground and rebounds to the same height. The magnitude of impulse imparted to the ball is nearly g=10 m/s^2) **[NEET 2021]**

(1) 0 (2) 4.2 kg-m/s (3) 2.1 kg-m/s (4) 1.4 kg- m/s

EXERCISE KEY

Level-I

1.	(1)	2.	(3)	3.	(1)	4.	(1)	5.	(2)
6.	(3)	7.	(4)	8.	(2)	9.	(4)	10.	(1)
11.	(2)	12.	(3)	13.	(4)	14.	(1)	15.	(2)
16.	(2)	17.	(3)	18.	(2)	19.	(3)	20.	(2)
21.	(4)	22.	(4)	23.	(2)	24.	(4)	25.	(2)
26.	(3)	27.	(3)	28.	(3)	29.	(4)	30.	(2)
31.	(2)	32.	(2)	33.	(1)	34.	(1)	35.	(1)
36.	(2)	37.	(1)	38.	(3)	39.	(1)	40.	(3)
41.	(1)	42.	(1)	43.	(2)	44.	(4)	45.	(4)
46.	(1)	47.	(3)	48.	(1)	49.	(3)	50.	(4)
51.	(3)	52.	(3)	53.	(1)	54.	(3)	55.	(1)
56.	(1)	57.	(2)	58.	(2)	59.	(2)	60.	(1)
61.	(4)	62.	(2)	63.	(2)	64.	(3)	65.	(4)
66.	(2)	67.	(3)	68.	(4)	69.	(1)	70.	(1)
71.	(2)	72.	(2)	73.	(4)	74.	(3)	75.	(4)
76.	(2)	77.	(4)	78.	(2)	79.	(2)	80.	(3)
81.	(1)	82.	(4)	83.	(1)	84.	(3)	85.	(1)
86.	(2)	87.	(4)	88.	(4)	89.	(1)	90.	(1)

Level-II

1.	(4)	2.	(3)	3.	(2)	4.	(1)	5.	(4)
6.	(2)	7.	(1)	8.	(1)	9.	(2)	10.	(3)
11.	(2)	12.	(3)	13.	(3)	14.	(3)	15.	(4)
16.	(1)	17.	(1)	18.	(2)	19.	(4)	20.	(3)
21.	(2)	22.	(2)	23.	(2)	24.	(4)	25.	(2)
26.	(2)	27.	(3)	28.	(2)	29.	(2)	30.	(1)
31.	(3)	32.	(2)	33.	(4)	34.	(2)	35.	(3)
36.	(2)	37.	(4)	38.	(1)	39.	(4)	40.	(2)
41.	(2)	42.	(4)	43.	(4)	44.	(3)	45.	(3)
46.	(4)	47.	(2)	48.	(1)	49.	(2)	50.	(4)
51.	(2)	52.	(1)	53.	(4)	54.	(4)	55.	(1)

Assertion & Reason

1	(3)	2	(1)	3	(2)	4	(3)	5	(2)
6	(4)	7	(1)	8	(4)	9	(3)	10	(3)
11	(2)	12	(4)	13	(1)	14	(3)	15	(4)
16	(1)	17	(1)	18	(2)	19	(3)	20	(4)
21	(4)	22	(2)	23	(4)				

Previous Year's Questions

Laws of Motion

1.	(3)	2.	(4)	3.	(4)	4.	(3)	5.	(1)
6.	(2)	7.	(3)	8.	(4)	9.	(3)	10.	(3)
11.	(1)	12.	(3)	13.	(2)	14.	(2)	15.	(4)
16.	(1)	17.	(4)	18.	(4)	19.	(2)	20.	(3)

21. (1)	22. (1)	23. (5)	24. (5)	25. (1)
26. (3)	27. (1)	28. (4)	29. (2)	30. (2)
31. (2)	32. (2)	33. (4)	34. (1)	35. (4)
36. (2)	37. (3)	38. (3)	39. (2)	40. (3)
41. (2)	42. (1)	43. (1)	44. (4)	45. (4)
46. (4)	47. (4)	48. (3)	49. (1)	50. (3)
51. (2)	52. (2)	53. (2)	54. (1)	55. (1)
56. (2)	57. (3)	58. (2)	59. (4)	60. (1)
61. (4)	62. (2)			

Conservation of Linear Momentum Impulse

1. (1)	2. (3)	3. (1)	4. (1)	5. (2)
6. (2)	7. (1)	8. (3)	9. (4)	10. (2)
11. (2)	12. (3)	13. (1)	14. (1)	15. (1)

Equilibrium of Forces

1. (1)	2. (4)	3. (1)	4. (4)	5. (4)
6. (1)	7. (3)	8. (1)	9. (1)	10. (4)
11. (2)	12. (1)	13. (4)	14. (1)	15. (1)
16. (2)				

Motion of Connected Bodies and Friction

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

Graphical Questions

1. (4)	2. (2)	3. (4)	4. (3)	5. (3)
6. (4)	7. (2)	8. (3)	9. (4)	10. (3)
11. (3)				

Question Asked in 2013-2021

1. (2)	2. (4)	3. (3)	4. (1)	5. (1)
6. (3)	7. (2)	8. (3)	9. (4)	10. (1)
11. (3)	12. (3)	13. (3)	14. (1)	15. (3)
16. (2)	17. (2)	18. (2)	19. (2)	20. (3)
21. (2)	22. (2)	23. (2)		