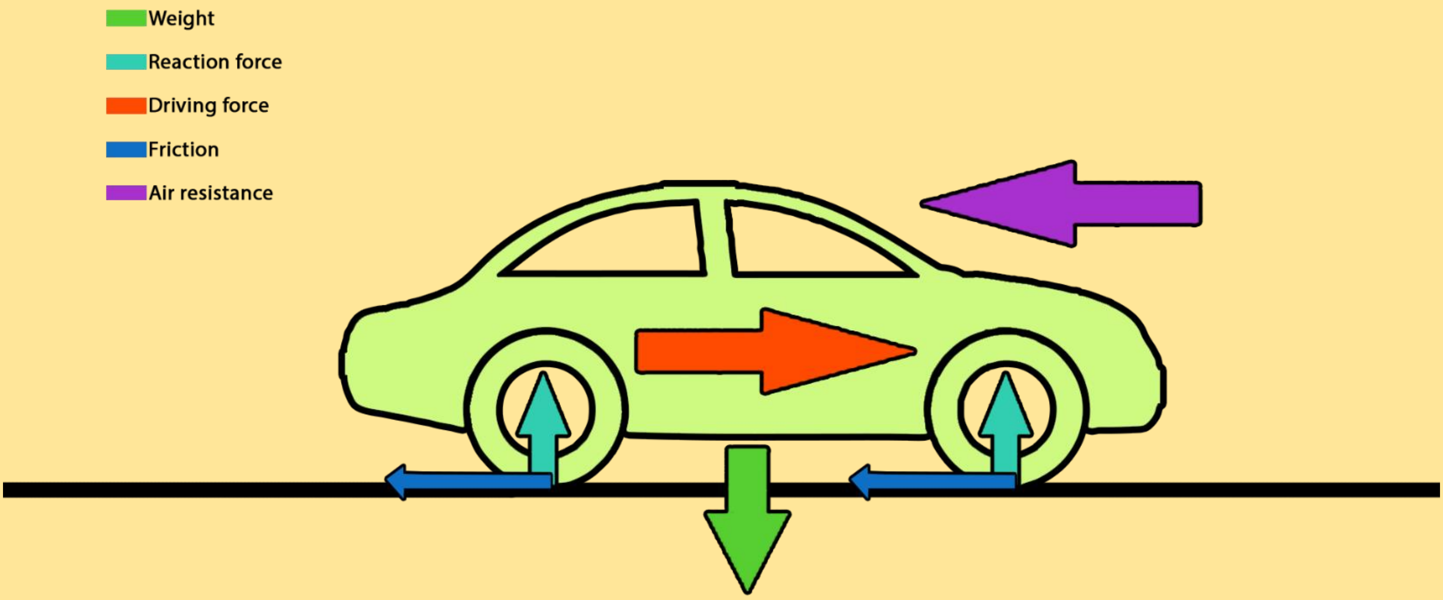
5.LAWS OF MOTION



Physics Smart Booklet

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NEWTON'S LAWS OF MOTION

INERTIA OF REST

The property of a body due to which it cannot change its state of rest by it self.

INERTIA OF DIRECTION

The property due to which a body cannot change its direction of motion by itself.

INERTIA OF MOTION

The tendency of a body to remain in a state of uniform motion in a straight line.

Newton's 1st law

A body continues its sate of rest or motion until unless an external force is acted on it.

If $\vec{F}_{ext} = 0 ;\ \vec{a} = 0$

Newton's 3rd law

To every action there is always on equal and opposite reaction.

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

Action & Reaction act on different bodies and not on the same body. - action – reaction forces are of same type.

We cannot produce a single isolated force in nature force are always produce in action – reaction pair.

Due to no time gap, any one force can be action, and other reaction.

Applicable for all the interactive forces eg. gravitational, electrostatic, electromagnetic, tension, friction, viscous forces, etc.

For Non – inertial frame

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

$$\vec{F}_{pseudo} = -M\vec{a}_{frame}$$

SOLVING PROBLEMS IN MECHANICS

- Draw FBD of bodies in the system.
- Choose a convenient part of the assembly as one system.
- Identify the unknown force and accelerations.
- Resolve forces into their components.

- Apply $\sum\vec{F} = m\vec{a}$ in the direction of motion.
- Apply $\sum\vec{F} = 0$ in the direction of equilibrium
- Write constraint relation if exists.
- Solve the equation $\sum\vec{F} = m\vec{a}$ & $\sum\vec{F} = 0$.

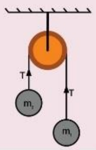
FORCES

(i) Normal Contact force

(1) always acts along the common normal of two surface in contact.
(2) Always directed towards the system.
(3) It is an electromagnetic type of force. Normal force on block is N. N = mg

(ii) Tension force

(1) Acts along the string and away from the system on which it acts.
(2) Tension in a massless string remains constant throughout the string if no tangential force acts along the string.
(3) This is force applied by a string on an object or force applied by one part of string on the remaining part of string.
(4) It is an electromagnetic type of force.



Newton's 2nd Law

The rate of change of linear momentum of a body is directly proportional to the external force applied on the body in the direction of force.

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

S.I. Unit of force = Newton (N)

if m = const $\vec{F} = \frac{md\vec{v}}{dt} = m\vec{a} \Rightarrow$ dimensional formula = $[M^1L^1T^{-2}]$

if $\vec{V} = Cost = \vec{F} = \vec{V}\frac{dm}{dt}$

convey or belt & rocket propulsion

Conservation of linear momentum:- if there is no external force acting on it, total momentum of an isolated system of interacting particles is conserved

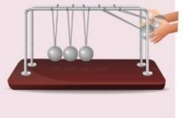
$\vec{F}_{ext} = 0 = \frac{d\vec{p}}{dt}$ or $P_{initial} = P_{final}$

Impulse

$$\vec{I} = \vec{F}_{avg}\ \Delta t = \Delta\vec{P}$$

$\Rightarrow I = \Delta P = \int F.dt$ = area under f – t curve

Horizontal Circular motion (Conical Pendulum):-

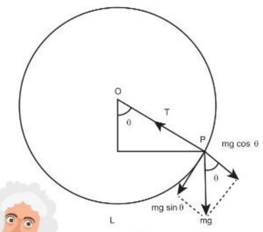


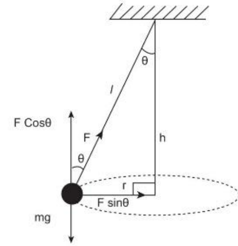
$T_{Sin\theta} = \frac{mv^2}{r}$ & $T_{cos\theta} = mg$

$V = \sqrt{rg\tan\theta}$

Angular Speed. w = $W = \frac{v}{r} = \sqrt{\frac{g\tan\theta}{r}}$

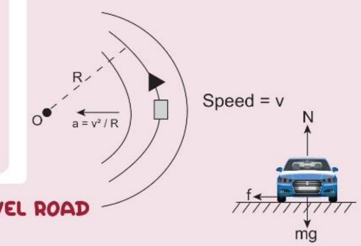
Time Period $T = \frac{2\pi}{w}\ \ 2\pi\sqrt{\frac{r}{g\tan\theta}} = 2\pi\sqrt{\frac{L\cos\theta}{g}}$





Vertical Circular motion

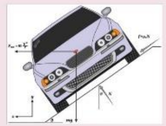
1. Particle ossillates in lower half circle.
   Condition of ossillation $(0 < u \le \sqrt{2gR})$
2. Particles moves to upper half circle but not able to complete the loop. Condition of leaving the circle: $(\sqrt{2gR} < u < \sqrt{5gR})$
3. Particle completes loop. Condition of looping the loop $(u \ge \sqrt{5gR})$

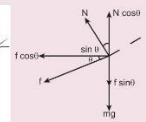


MOTION OF A CAR M LEVEL ROAD (by friction only):-

$$Vmax \le \sqrt{\mu_s Rg}$$

MOTION OF A CAR ON BANKED ROAD





(i) Optimum speed of a vehicle on a banked road. $V = \sqrt{rg\tan\theta}$

maximum safe speed on a banked frictional road. $V_{max} = \sqrt{\frac{rg(\mu + \tan\theta)}{1 - \mu\tan\theta}}$

minimum safe speed on a banked frictional road $V_{min} = \sqrt{\frac{Rg(\tan\theta - \mu)}{(1 + \mu\tan\theta)}}$

(iii) Friction force

(1) Rolling friction:- The force of friction which comes into play when one body rolls or tends to roll on the surface of a norther body.

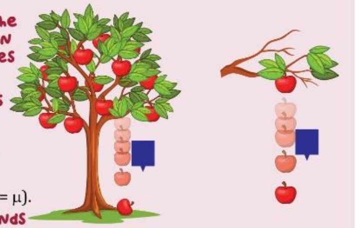
(IV) Sliding friction

Resistance offered to the relative motion between the surface of two bodies in contact.

The frictional force f is directly proportional to the normal force N exerted by the surface on the body.

($F \propto N$ or f/N = Constant = μ).

The friction force depends upon the nature of surfaces in contact and independent of the area of contact.



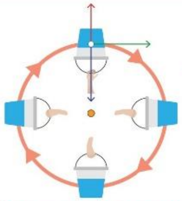
Types of friction

Static friction – acts when a body is at rest on application of a force $f_s = \mu_s N$.

Limiting friction – acts when a body is just at the verge of movement $F_l = \mu_s N$.

Kinetic friction – acts when a body is actually sliding $f_k = \mu_k N$

Circular motion



Kinematics of Uniform Circular motion

1. A particle moves in a circle at a constant speed
2. Angular displacement (θ) SI Unit: rad or degree.
3. Angular velocity (w):

$W_{avg} = \frac{\Delta\theta}{\Delta t}$ [Unit. rad / sec] $\quad W_{ins} = \frac{d\theta}{dt}$

Centripetal force

$F_c = ma_c = \frac{mv^2}{r} = mrw^2$

$\Delta S = r\Delta O \quad v = wr$

$\vec{V} = \vec{w} \times \vec{r}$

$\vec{V}$ is linear velocity (tangential vector)
$\vec{w}$ (axial vector)
$\vec{r}$ = radius vector

Kinematics of Non – Uniform circular motion

Speed of the particle in a horizontal circular motion changes with respect to time.

Tangential acceleration:

$\vec{a}_t = \vec{\alpha} \times \vec{r}$

Centripetal force

$F_c = ma_c = \frac{mv^2}{r} = mrw^2$

Tangential force $F_t = ma_t$

Net force $F_{net} = m\sqrt{a_c^2 + a_t^2}$

$\vec{a}_c$ responsible for change in direction of movement of particle

Laws of Motion

The study of the relationship between the motion of a body and the causes of this motion is called ‘dynamics’. The motion of a body is a direct result of its interactions with the other bodies around it.

Types of forces

The forces in case of dynamics of a particle can be classified in two ways (with respect to source), as

1. Contact forces and
2. Non-contact or field forces

1. Contact forces

If two surfaces are in physical contact (touching each other), contact forces come into picture. The component of the contact force normal to the surface of contact (or the line of contact) is usually known as the “normal reaction”. Also, a component of the force (called friction) may act along the surface of contact.

2. Non-contact forces

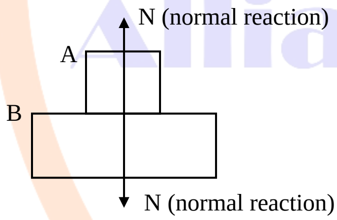
Without actual physical contact, bodies can exert forces on one another. Examples are gravitational force, electrostatic force, magnetic force etc

Weight

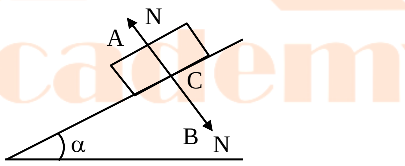
Weight of a body is the force with which, it is attracted by the earth. Its direction is always downwards (i.e., towards the centre of the earth).

Normal force or normal reaction

As said earlier, it always acts normal to the surface of contact (or line of contact). Observe the following figures.



Normal reaction of block B on A is upward
Normal reaction block A on B is downwards

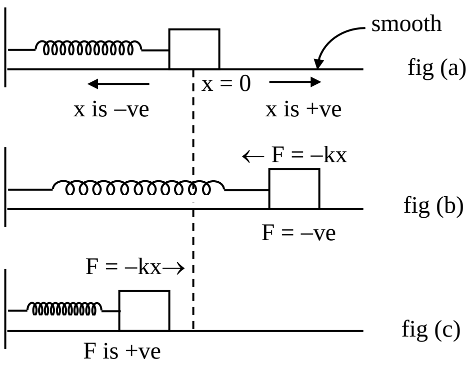


Normal reaction (N) of inclined plane on block is along CA
Normal reaction (N) of block on inclined plane is along CB

Spring force

Whenever a spring is compressed or extended, the elastic force developed in the spring, which helps the spring to restore to its original length is known as “Spring force”. Spring force is proportional to the extension (or compression), but opposite to the extension (or compression).

$|F| \propto x$ and $F = -kx$, where F = spring force, x = compression or extension and k is spring constant.



Consider a spring attached to a body as shown in figure (a). The block is at rest at position x = 0 and the spring is in its natural (unstreched) length.

If the block is pulled aside and released, it oscillates. When the block is on the right to x = 0 (the block may be moving leftwards or right wards), x is positive. As F = –kx, spring force ON the block is negative i.e., acting leftwards on the block.

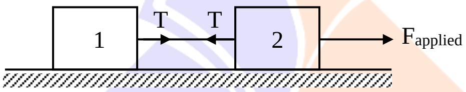
When the block is on the left to x = 0 (the block may be moving leftwards or right wards), x is negative. As F = –kx, spring force ON the block is positive i.e., acting rightwards ON the block.

Note: $k = \frac{|F|}{x}$ i.e., spring constant is the force required to have unit extension (or compression) of the spring. It is constant for a given spring. (Its unit is Nm^{-1}).

Tension

When a rope or a string is stretched, the stiffness in that rope is an electromagnetic force known as "tension". Tension (usually denoted by T) is always a pulling force. It can never push a body.

If two bodies are connected by a string and are pulled as shown in the following figure, then tension ON body 1, is rightwards and tension ON body 2 is leftwards.



If the string is massless, then tension throughout the string is same. If the string has (considerable) mass, tension at different points in it will be different.

Newton's first law of motion (or law of inertia)

If states that "if a body is at rest, it continues to be in its state of rest unless acted upon by an external force and if a body is in uniform motion, it continues to be in its state of uniform motion unless acted upon by an external force". In other words, the net force on a body which is at rest or in uniform motion is zero. A body moving with some initial velocity on a horizontal floor comes to rest, due to the external force (which is frictional force) acting on it. If the horizontal floor were perfectly smooth (so that there is no friction between the body and the floor), the body would continue to move with the same velocity (in the same direction) and would never come to a halt.

Inertia of rest

The inability of a body which is at rest, to change its state of rest on its own i.e., without the external force, is known as inertia of rest".

A man standing in a stationary bus, falls backward when the bus suddenly starts moving, due to inertia of rest. When a foot-mat is hit by a stick, the dust particles get separated due to inertia of rest. The foot-mat moves backwards, but the dust particles remain in their original positions. If the wind is blowing, they are carried away and if there is no wind, they fall down.

Inertia of motion

"The inability of a body which is in uniform motion, to change its state of motion on its own i.e., without the external force is known as inertia of motion". A man standing in a moving bus, falls forward, when the bus suddenly stops, due to inertia of motion.

You might have observed a fly in a bus moving with constant velocity. The fly in this case is as comfortable as it is in a room. It sits on you, goes to your co-passenger and sits on him etc., This happens only if the fly has acquired the velocity of the bus i.e., the fly should have sat on any part of the bus or on any of the passengers, initially. Now, if the bus suddenly accelerates forward, the flying fly would hit the back glass pane of the bus. If the bus suddenly stops, the fly would hit the front glass pane of the bus. All this happens due to inertia of motion of the fly.

Inertia of direction

"The inability of a body to change its direction of motion on its own is called inertia of direction".

Suppose, you are in a bus going to Tirumala up the hills. If the bus takes a right turn, your body falls left wards (and vice versa) due to inertia of direction. If a body is dropped from a rising balloon, the body would move upwards first (due to inertia of direction and inertia of motion) and then falls downwards.

Linear momentum ($\bar{p}$)

"The product of mass and velocity of a body is defined as its linear momentum $(\bar{p})$". Sometimes it is simply called momentum.

$\bar{p} = m\bar{v}$, where m = mass of the body, and

$\bar{v}$ = velocity of the body

Momentum is a vector physical quantity. Its direction is same as that of velocity.

Its SI unit is kg ms^{-1} (or NS)

1 kg ms^{-1} = 1 newton – second (= 1 NS)

1 NS = 1 $MLT^{-2}.T = [MLT^{-1}]$

kg $ms^{-1} = [MLT^{-1}]$

Newton's second law of motion

It states that "the rate of change of momentum of a body is directly proportional to the external force acting on it and takes place in the direction of force".

$$\therefore \frac{d\bar{p}}{dt} \propto \bar{F}$$

$$\frac{d}{dt}(m\bar{v}) \propto \bar{F} \qquad [\because \bar{p} = m\bar{v}]$$

If mass is constant, $m\frac{d\bar{v}}{dt} \propto \bar{F}$ or, $\bar{F} = Km\left(\frac{d\bar{v}}{dt}\right)$, where k is a constant.

With proper choice of units, k = 1

$$\therefore \bar{F} = m\frac{d\bar{v}}{dt}$$

$\bar{F} = m\bar{a}$ [where $\bar{a}$ is acceleration equal to $\frac{d\bar{v}}{dt}$, by definition]

So, Newton's second law in the equation form is $\bar{F} = \frac{d\bar{p}}{dt} = m\bar{a}$

The SI unit of force is Newton (N) and its CGS unit is dyne.

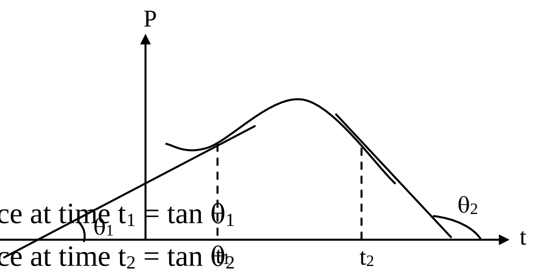
1 N = 10^5 dyne.

The gravitational unit of force is kg wt or $kg_{(f)}$ [Kilogram weight or kilogram force]

1 kg wt = 1 $kg_{(f)}$ = 9.8 N on earth.

Important points

1. If F = 0, a = 0 (as F = ma). So if net external force acting on a body is zero, its acceleration is zero. That means, the body may be moving with constant velocity or may be at rest. This is nothing but first law of motion.
2. The slope of p–t (momentum – time) graph gives the force. The p–t graph of a moving body is as shown below.



The net external force at time t_1 = tan θ_1

The net external force at time t_2 = tan θ_2

3. In the equation $\bar{F} = m\bar{a}$, $\bar{F}$ is the resultant external force acting on the body.

So $\overline{F}_{ext} = m\overline{a}$.

4. The direction of $\overline{F}$ is along $\overline{a}$ (or) along change in momentum $(\Delta\overline{p})$ of the body. Note that direction of $\overline{F}$ need not be along $\overline{p}_i$ or $\overline{p}_f$ (initial or final momentum).

5. $\overline{F} = m\overline{a}$ can be used only when mass (m) of the body is constant

Illustrations

1. The linear momentum of a body moving in one dimension varies with time according to the equation $p = At + Bt^2$, where A and B are positive constants. Find out the net force acting on the body as a function of time.

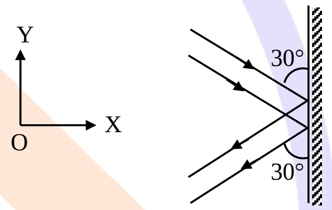
Solution

Momentum, $p = At + Bt^2$ (given)

$$\frac{dp}{dt} = A + 2Bt$$

We know that $F = \frac{dp}{dt}$ $\quad \therefore \; F = A + 2Bt$.

2. A jet of water (5 kg s^{-1}) travelling with a velocity of 5 ms^{-1} makes an angle of 30° with the vertical wall as shown in the figure. The jet rebounds with the same speed making an angle of 30° with the wall. Calculate the average force on the wall.



Solution

m = mass of water striking the wall = 5 kg in 1 second

So, time is taken as 1 second.

Velocity of jet = 5 ms^{-1}

Initial momentum along OX is $(p_i)_x$ = mv sin 30 = $5 \times 5 \times \frac{1}{2} = 12.5\,kg\;ms^{-1}$

Initial momentum along OY is $(p_i)_y$ = mv cos 30 = $-5 \times 5 \times \frac{\sqrt{3}}{2} = -\frac{25\sqrt{3}}{2}\,kg\,ms^{-1}$

Final momentum along OX is $(p_f)_x$ = –mv sin 30 = –12.5 kg ms^{-1}

Final momentum along OY is $(p_f)_y$ = –mv cos 30 = $-\frac{25\sqrt{3}}{2}\;kg\,ms^{-1}$

Change in momentum of water jet along OX is $(\Delta p)_x$ = –12.5 – (+12.5) = –25 kg ms^{-1}

Change in momentum of the water jet along OY is $(\Delta p)_y = -\frac{25\sqrt{3}}{2} - \left(-\frac{25\sqrt{3}}{2}\right) = 0.$

$\therefore$ Net change in momentum of jet is Δp = –25 kg ms^{-1} i.e., 25 kg ms^{-1} along XO

Average force on the wall $= \frac{|\Delta p|}{t} = \frac{25}{1} = 25$ N

This force on the wall is along OX and on the jet is along XO.

3. A net force of 200 N gives a body of mass m_1 an acceleration of 80 ms^{-2} and a body of mass m_2, an acceleration of 240 ms^{-2}. What acceleration will this force cause when the masses combine together?

Solution

We know that F = ma

$\therefore\; 200 = m_1 \times 80 \Rightarrow m_1 = \frac{200}{80} = 2.5$ kg and $200 = m_2 \times 240 \Rightarrow m_2 = \frac{200}{240} = 0.833$ kg

When joined together, $m = m_1 + m_2 = \frac{20}{6}$ kg

Final acceleration is $a = \frac{F}{m} = \frac{200}{20/6} = 60\;ms^{-2}$.

Newton's third law of motion

It states that "when two particles interact, the force on the first particle exerted by the second particle is equal and opposite to the force on the second particle exerted by the first particle" or "to every action there is equal and opposite reaction".

Suppose that a body A experiences a force $\overline{F}_{AB}$ due to a body B. Also body B will experience a force $\overline{F}_{BA}$ due to A, then $\overline{F}_{AB} = -\overline{F}_{BA}$ or Action = –Reaction

The very important thing to be noted down is, though action and reaction are equal and opposite, they never cancel each other because they act on two DIFFERENT bodies.

Impulse ($\overline{J}$)

If a large force acts on a body for a very short interval of time, it is called impulsive force. The product of this impulsive force and the time for which it acts is called "impulse".

Impulse, $\overline{J} = \overline{F}\,t$

We know that $\overline{F} = \dfrac{\Delta\overline{p}}{\Delta t}$ or $\overline{F}\Delta t = \Delta\overline{P}$

$\therefore\ \overline{J} = \Delta\overline{p}$

or, Impulse = change in momentum $[\overline{J} = \Delta\overline{p}]$

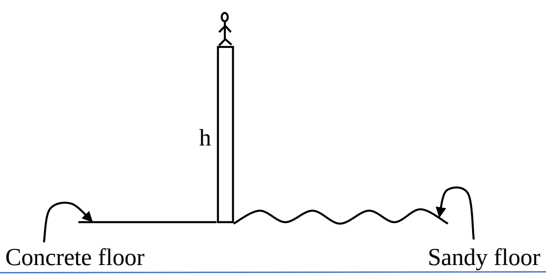
Impulse = Force × time $[\overline{J} = \overline{F}t]$

Also, $\overline{J} = \int_{t_1}^{t_2} \overline{F}\,dt$, when force is a function of time

Important points

1. Impulse is a vector. The direction of impulse is along the force or change in momentum.
2. Its SI unit is Ns (or) kg ms^{-1}
3. The area under F – t(force – time) graph gives impulse
4. Impulse is not force. It is the product of force and time
5. Impulse force is like any other force with the only difference that, it is large and acts for a short time. Even if the net force is small and acts for a long time, we can still calculate the impulse imparted by it and equate it to the total change in momentum of the body on which it has acted.
6. While taking a catch, the fielder in a cricket match moves his hands backwards. Just before the ball is caught, it has initial momentum and this is fixed for a given shot. After the catch is taken final momentum is zero and so this is also constant. So, during the catch, the change in momentum is constant, i.e., impulse (J) is constant. We know J = Ft

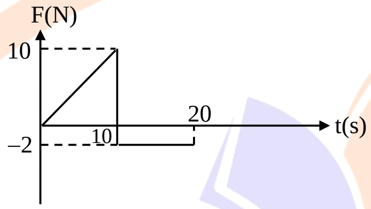
   If the time of taking the catch (i.e., time required for the change in momentum, t) is increased, F decreases (as J for a given catch is constant). That means the fielder feels less pain in his hands, as he draws his hands back while catching.
7. Consider the situation (shown in the figure) in which a man is standing on a wall of height 'h'. When he jumps, the velocity (and so initial momentum) with which he reaches the floor is same on either side. After jumping final momentum is zero. So the change in momentum (and so impulse, J) is constant.



If he jumps onto the concrete floor, the time for change in momentum (t) is small. So F is more in this case (as J has to be constant). Thus the man gets hurt. If he jumps on to the sandy floor, the time for change in momentum (t) is more. So F is less in this case (as J has to be constant). Thus the man does not get hurt more.

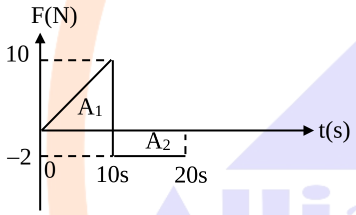
Illustrations

4. The force-time graph for the motion of a body is shown in the following figure



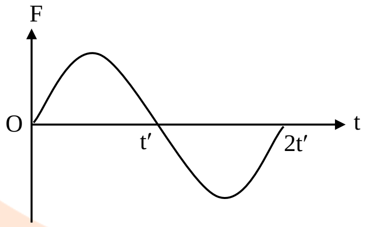
What is the change in momentum of the body between 0 and 20 s?

Solution

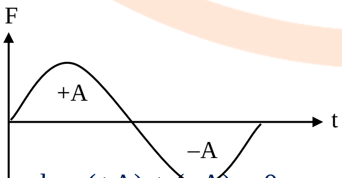


Change in momentum = impulse = Net area under F-t graph = $\left(\frac{1}{2}\times 10\times 10\right)-(10\times 2)=30\ \text{kg ms}^{-1}$

5. A time varying force F acts on a body for a short time 2t′ as shown in the figure. The body was initially at rest. What is the velocity acquired by the body?



Solution



Net area under F-t graph = (+A) + (–A) = 0

∴ Change in momentum = zero

Initially the body was at rest. So after a time 2t′ also it will be at rest.

∴ Velocity acquired = zero.

6. As shown in the figures, two identical balls strike a rigid wall with equal speeds but at different angles. They are reflected back without any loss of speed. Determine the ratio of impulses imparted by the two balls on the wall

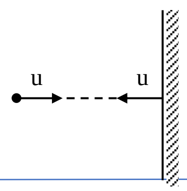


fig (a)

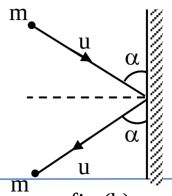


fig (b)

Solution

Case (i): Impulse = change in momentum = $|\Delta\bar{p}|$ = mu + mu = 2mu

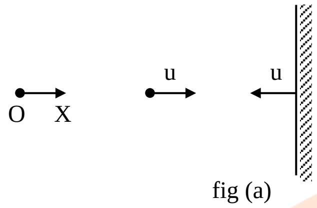


fig (a)

Case (ii):

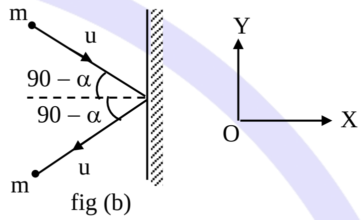


fig (b)

Angle of incidence = Angle of reflection = 90 – α

Initially:

$(p_i)_x = mu\cos(90-\alpha) = mu\sin\alpha$

$(p_i)_y = -mu\sin(90-\alpha) = -mu\cos\alpha$

Finally

$(p_f)_x = -mu\cos(90-\alpha) = -mu\sin\alpha$

$(p_f)_y = -mu\sin(90-\alpha) = -mu\cos\alpha$

$(\Delta p)_x = (p_f)_x - (p_i)_x = (-mu\sin\alpha) - (mu\sin\alpha) = -2mu\sin\alpha$

$(\Delta p)_y = (p_f)_y - (p_i)_y = (-mu\cos\alpha) - (-mu\cos\alpha) = 0$

∴ Total change in momentum, $\Delta p = -2mu\sin\alpha$

i.e., change in momentum of the ball is 2mu sin α along XO direction

∴ Impulse (imparted to wall) = 2mu sin α

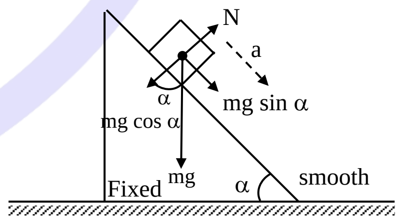
Ratio of impulse in cases (i) and (ii) is $\frac{2mu}{2mu\sin\alpha} = \operatorname{cosec}\alpha$

7. In the above example, what is the direction of force exerted by the ball on the wall in both the cases?

Solution

In both the cases the direction of change in momentum of the ball is along XO. So in both the cases force on the ball is along XO and force on the wall is along OX.

Motion of a body on a smooth inclined plane



Consider a body of mass ‘m’ sliding down a smooth inclined plane of inclination α. The forces on it are its weight (mg) acting vertically downward and normal reaction(N) perpendicular to the inclined plane. If ‘mg’ is resolved perpendicular and parallel to the inclined plane,

$mg\sin\alpha = ma \rightarrow$ (i)

(where ‘a’ is acceleration of body down the plane)

and $N = mg\cos\alpha \rightarrow$ (ii)

From equation (i), $a = g\sin\alpha$

So, the acceleration of a body on a smooth inclined plane is g sin α and normal reaction on the body is mg cos α

Free body diagrams (FBDs):

Free body diagram of a body (or a system) gives all the forces acting ON the body (or the system), with magnitudes and directions. FBD’s are very useful while solving the problems using Newton’s Laws of motion. While drawing the FBD of a body only those forces acting ‘ON’ the body are drawn. And forces by the body on other bodies are not considered while drawing its FBD. This is the most important point in drawing FBD of a body.

Points to be remembered while drawing FBD’s:

(i) Represent the weight of the body.

(ii) If connected to a string represents "tension". Note that it always has pulling effect.

(iii) If connected to a spring, represent "spring force". If the spring is extended if has pulling effect and if it is compressed it has pushing effect.

(iv) If the body is in contact with a surface, represent normal reaction.

(The other contact force is frictional force and will be considered later). Note that the normal force is perpendicular to the surface of contact (or line of contact).

(v) If there any applied forces, represent them.

Note: if a pulley is massless or light, its weight is not drawn and the net force on it is zero.

[$\because$ F = ma and mass of the pulley, m = 0]

Problem solving strategy – Applying Newton's laws

The following steps are recommended while solving the problems using Newton's laws.

(i) Decide the system: The system, onto which laws of motion are to be applied, is to be indentified. If the system is not a single body, but a collection of two or more bodies, the only condition is that all the bodies must have same acceleration.

(ii) Note down the forces acting on the system

(iii) Draw the FBD of the system

(iv) Choose axes and write equations: If the forces are coplanar X and Y axes are chosen. The forces are resolved along X and Y axes. Then we have two equations.

$$\sum F_x = ma_x \text{ and } \sum F_y = ma_y$$

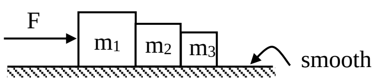
If the system is moving along x-axis, then $a_y = 0$.

$$\therefore \sum F_y = 0$$

If forces are collinear, we do not require the equation $\sum F_y = 0$.

Illustrations

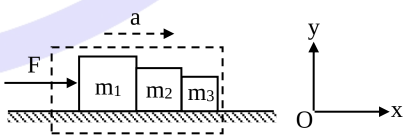
8. A system consists of three bodies of different masses, which are in contact, on a smooth surface as shown in the figure. A force 'F' is applied as shown. Find the acceleration of the system and normal force between m_1 and m_2 and between m_2 and m_3.



Solution

All the masses move with same acceleration, which we call acceleration of the system (a).

(see the following figure).



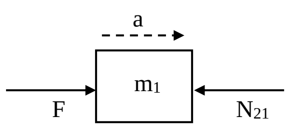
$F_{net} = ma \Rightarrow F = (m_1 + m_2 + m_3)a$

$$\therefore a = \frac{F}{m_1 + m_2 + m_3} \rightarrow \text{... (i)}$$

In y-direction, the normal force between each block and the floor is cancelled by its own weight.

So we can consider forces along x-direction only. Let N_{12} and N_{23} are normal forces between first and second blocks and between second and third blocks respectively.

FBD of m_1:

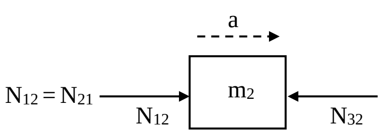


$F_{net} = F - N_{21}$

$\therefore F - N_{21} = m_1 a$ [from $F_{net} = ma$]

$$F - N_{21} = m_1\left[\frac{F}{m_1 + m_2 + m_3}\right] \text{......[from eqn (i)]}$$

$$N_{21} = F - \frac{m_1 F}{m_1 + m_2 + m_3}$$



$$N_{21} = \frac{(m_2 + m_3)F}{m_1 + m_2 + m_3} \qquad \text{... (ii)}$$

FBD of m_2:

$F_{net} = N_{12} - N_{32}$ ($N_{12} = N_{21}$)

$\therefore N_{12} - N_{32} = m_2 a$

$$= m_2\left[\frac{F}{m_1 + m_2 + m_3}\right] \text{.....[From eqn(i)]}$$

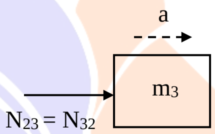
$$\therefore \frac{(m_2 + m_3)F}{m_1 + m_2 + m_3} - N_{32} = \frac{m_2 F}{m_1 + m_2 + m_3} \text{......[From eqn (ii)]}$$

$$N_{32} = \frac{(m_2 + m_3)F}{m_1 + m_2 + m_3} - \frac{m_2 F}{m_1 + m_2 + m_3}$$

$$N_{32} = \frac{m_3 F}{m_1 + m_2 + m_3} \qquad \text{... (iii)}$$

Alternatively

FBD of m_3:



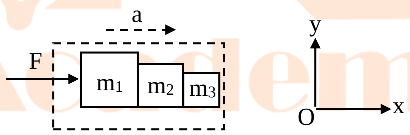
$F_{net} = N_{23}$ ($N_{23} = N_{32}$)

$\therefore N_{23} = m_3 a$

$$= m_3\left[\frac{F}{m_1 + m_2 + m_3}\right] \text{.....[from eqn (i)]}$$

or, $N_{23} = \dfrac{m_3 F}{m_1 + m_2 + m_3}$ which is same as equation (iii)

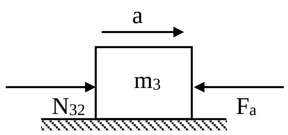
Alternatively



$F_{net} = ma \rightarrow (m_1 + m_2 + m_3)a$

$$\therefore \quad a = \left(\frac{F}{m + m_2 + m_3}\right)$$

Block 3

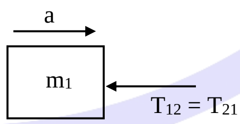


$F_{net} = (F_0 - N_{32}) = m_3.a$

$\therefore N_{32} = F - am_3 = (m_1 + m_2 + m_3)a - m_3 a$

$= \boxed{(m_1 + m_2)a}$

Block 1

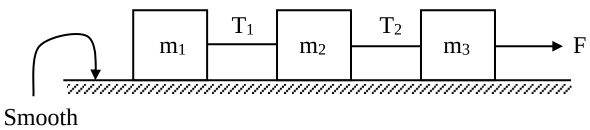


$F_{net} = T_{12} = T_{21}$

$\therefore T_{12} = m_1 a$

$$\therefore \boxed{\begin{aligned} T_{32} &= T_{23} = (m_1 + m_2)a \\ T_{21} &= T_{12} = m_1 a \end{aligned}}$$

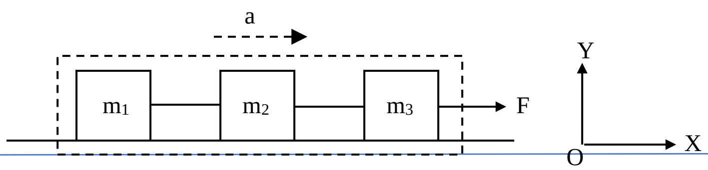
9. Three masses m_1, m_2 and m_3, kept on a smooth horizontal table, are connected by light, inextensible strings and are pulled as shown. Find the acceleration of the system and tensions T_1 and T_2 in the strings



Solution

Here also, we can consider only the forces in x-direction. As the string is inextensible all the masses have same acceleration, which we call acceleration of the system (a).

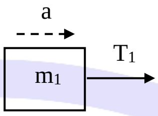
As the strings are light, tension through out a string is same.



$F = (m_1 + m_2 + m_3)a$ …. [From $F_{net} = ma$]

$$a = \frac{F}{m_1 + m_2 + m_3} \quad \ldots \text{(i)}$$

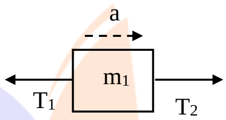
FBD of m_1:



$T_1 = m_1 a$ [$\because F_{net} = ma$]

$$T_1 = m_1\left[\frac{F}{m_1 + m_2 + m_3}\right] \ldots \text{(ii)}$$

FBD of m_2:



$F_{net} = T_2 - T_1$

$\therefore T_2 - T_1 = m_2 a$

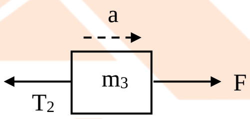
$$T_2 - T_1 = m_2 \frac{F}{m_1 + m_2 + m_3} \quad \text{... [From eqn (i)]}$$

$$T_2 - \frac{m_1 F}{m_1 + m_2 + m_3} = \frac{m_2 F}{m_1 + m_2 + m_3} \quad \text{... [From eqn (ii)]}$$

$$\therefore T_2 = \frac{(m_1 + m_2)F}{m_1 + m_2 + m_3} \quad \ldots \text{(iii)}$$

Alternatively

FBD of m_3



$F_{net} = F - T_2$

$$\therefore F - T_2 = m_3 a = m_3 \frac{F}{m_1 + m_2 + m_3} \text{.....[From eqn(i)]}$$

$\therefore T_2 = F - m_g a = (m_1 + m_2)a$

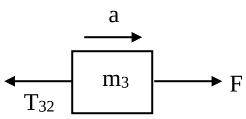
$$T_2 = F - \frac{m_3 F}{m_1 + m_2 + m_3}$$

or, $T_2 = \dfrac{(m_1 + m_2)F}{m_1 + m_2 + m_3}$, which is same as equation (iii)

Alternatively

$F_{net} = ma \rightarrow F = (m_1 + m_2 + m_3)a$

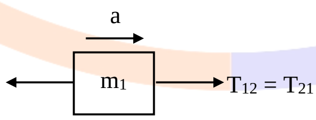
Block m_3



$F_{net} = (F - T_{32}) = m_3 a$

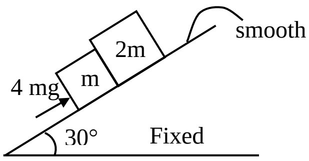
$\therefore T_{32} = F - m_3 a = (m_1 + m_2)a$

Block m_1



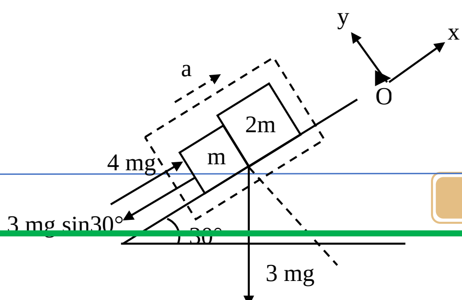
$F_{net} = \boxed{T_{12} = m_1 a}$

10. Two blocks of masses ‘m’ and ‘2 m’ are kept on a smooth inclined plane and the system is pushed using a force ‘4 mg’ as shown. Find out the contact force between the blocks.



Solution

Let N be the contact force between the blocks.



We need not consider the forces along Y-direction.

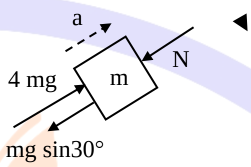
If the two blocks are considered as a system,

$F_{net} = 4mg - 3mg \sin 30°$ along OX

$= 4mg - \frac{3mg}{2} = \frac{5mg}{2}$

Acceleration of the system is $a = \frac{F_{net}}{m+2m} = \frac{5mg/2}{3m} = \frac{5}{6}g \rightarrow$ (i)

FBD of m



$F_{net} = 4mg - mg\sin 30 - N = \frac{7mg}{2} - N$

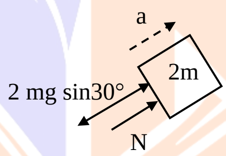
$\therefore \frac{7mg}{2} - N = ma....[\because F_{net} = ma]$

$= m.\frac{5}{6}g$ [From eqn (i)]

$N = \frac{7mg}{2} - \frac{5mg}{6} = \frac{16mg}{6} = \frac{8}{3}mg$ $\therefore N = \frac{8}{3}mg \rightarrow$ (ii)

Alternatively

FBD of 2m



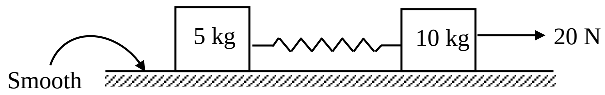
$F_{net} = N - 2mg \sin 30 = N - mg$

$N - mg = 2ma$ ..... $[\because F_{net} = ma]$

$= 2m.\frac{5}{6}g$

$N = \frac{5mg}{3} + mg = \frac{8mg}{3}$, which is same as eqn (ii)

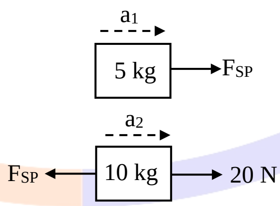
11. Two blocks of masses 5 kg and 10 kg are connected by a massless spring. A force of 20 N acts on 10 kg mass as shown. At the instant, 5 kg mass has an acceleration of 0.4 ms^{-2}, what is the acceleration of 10 kg mass?



Solution

Let the spring force at that instant is F_{sp}.

FBD of 5 kg



$F_{sp} = 5a_1$ .....$[\because F_{net} = ma]$

$= 5 \times 0.4 = 2$ N

FBD of 10 kg

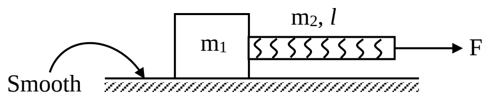
$F_{net} = 20 - F_{sp}$

$= 20 - 2 = 18$ N

As $F_{net} = ma$, $18 = 10 a_2 \Rightarrow a_2 = 1.8 ms^{-2}$

$\therefore$ Acceleration of 10 kg mass at the instant given is 1.8 ms^{-2}.

12. A block of mass m_1 is pulled with a string of mass m_2 and length l. The horizontal force applied on the string is F. The block is kept on a frictionless horizontal surface and the mass of the string is uniformly distributed over its length.



Find out:

(a) force exerted by the string on the block and acceleration of system

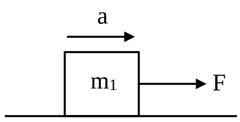
(b) tension at a distance x from the end at which force is applied.

$$a = \left(\frac{F}{m_1 + m_2}\right) \quad \text{or} \quad F = (m_1 + m_2)a \qquad \ldots(1)$$

Force exerted by the string

Block m_1

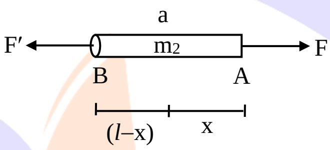
$F_{net} = \boxed{F = m_1 a}$



Tension at a distance x from the end at which the force is applied.

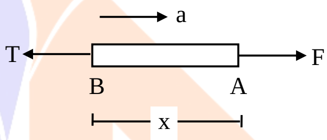
$$m_x = \left(\frac{m_2}{l}\right)x$$

$$m_{(l-x)} = \left(\frac{m_2}{l}\right)(l - x)$$



$$F_{net} = F - T = \left(\frac{m_2}{l}\right).x.a$$

$$\therefore\ T = F - \left(\frac{m_2}{l}\right).x.a$$

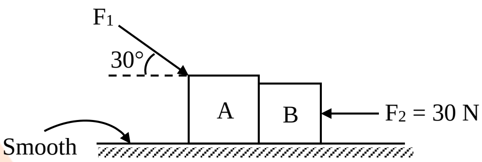


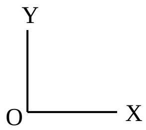
$$= m_1 a + m_2 a - \left(\frac{m_2}{l}\right).x.a$$

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

$$= a\left(m_1 + m_2\left(\frac{l - x}{l}\right)\right) = \left[F\frac{l - x}{l}\right]$$

13. Two blocks A and B at rest on a smooth horizontal surface in contact with each other. Forces F_1 and F_2 are applied as shown. Mass of A is 6 kg and of B is 4 kg. If after the application of forces A and B do not move, find the force F_1, and normal reactions between all the contact surfaces. [$g = 10\ ms^{-2}$]





Solution

The system is in static equilibrium

$F_{net} = 0$

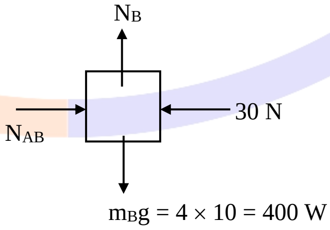
Block B

$F_{net} = 0$

$\therefore\ \boxed{N_{AB} = 30N}$

$F_{net} = 0$

$\therefore\ \boxed{N_B = 40N}$



Block A

$F_{x\ net} = 0$

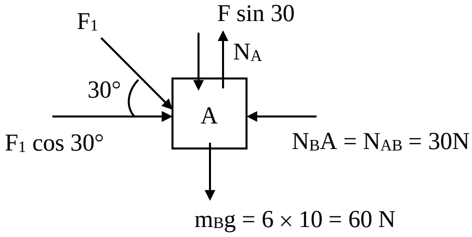
$F_1 \cos 30 = 30$

$\therefore\ F_1 = \dfrac{30}{c0s30} = [20\sqrt{3}]$

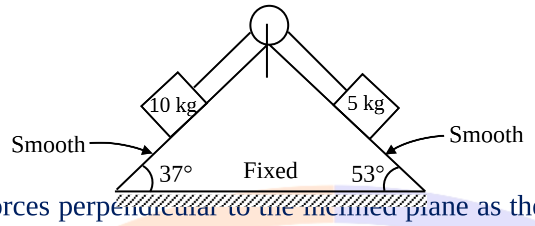
$F_{y\ net} = 0$

$N_A = 60 + 20\sqrt{3}\sin 30°$

$= (60 + 10\sqrt{3})$



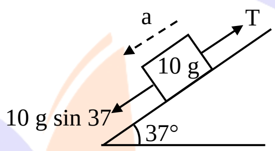
14. A 10 kg block and a 5 kg block are connected by a mass less string which passes over a pulley fixed to a wedge as shown in the figure. What is the acceleration of each block? What is the tension in the string? [g = 10 ms^{-2}]



Solution

We do not require the forces perpendicular to the inclined plane as the blocks have no motion in this direction. Let tension in the string is T.

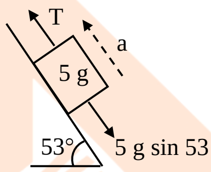
FBD of 10 kg



$F_{net} = ma \Rightarrow 10\text{ g} \sin 37 - T = 10\text{ a}$

$T = 60 - 10\text{ a} \rightarrow \text{(i)} \left[\because \sin 37° = \frac{3}{5}\right]$

FBD of 5 kg



$F_{net} = ma \Rightarrow T - 5g \sin 53 = 4a$

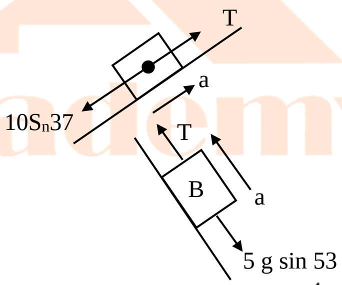
$T = 40 + 5a \rightarrow \text{(ii)} \left[\because \sin 53° = \frac{4}{5}\right]$

From eqn (i) and (ii), $60 - 10a = 40 + 5a$

$15\text{ a} = 20$

$a = \frac{4}{3}\text{ms}^{-2}$

Substituting in equation (ii), $T = 40 + 5\left(\frac{4}{3}\right) = \frac{140}{3}\text{N}$



$= 5 \times \frac{4}{3} = 4$

Alternatively

10 kg block

$F_{net} = 10g\sin 37 - T = 10a$

$\text{i.e.,} 10 \times \frac{3}{5} - T = 10a$

$T = 10a$ …(1)

$F_{net} = 4B - T = -5a$ …(2)

Sub (2) from (1) we have

25 = 15a

$a = \frac{2 \times 10}{15} = \left(\frac{4}{3}\right)\text{ms}^{-2}$

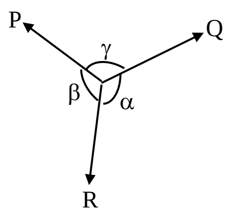
From (1)

$T = 65 - 10a = 60 - 10 \times \frac{4}{3} = \left(\frac{140}{3}\right)\text{N}$

Lami's theorem

It states that if three coplanar concurrent forces acting on a particle, keep it in equilibrium, then each force is directly proportion to the sine of the angle between the other two forces. OR The ratio of each force to the sine of the angle between other two force is a constant.

$$\frac{P}{\sin\alpha} = \frac{Q}{\sin\beta} = \frac{R}{\sin\gamma} = \text{a constant}$$



Where P, Q and R are magnitudes of forces and α, β and γ are the angles between RQ, PR and PQ respectively as shown in fig.

Here the equilibrium means static equilibrium (or the body is stationary)

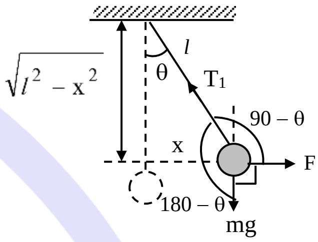
Illustrations

15. A bob (of mass m) of a simple pendulum is pulled to a side by a horizontal force F, such that the string makes an angle θ with the vertical. Let the length of simple pendulum is *l*. Find out the relation between tension (T), F and m using Lami's theorem.

Solution

The three forces i.e., tension in the string (T), applied horizontal force (F) and weight of the bob (mg) keep the bob in equilibrium.

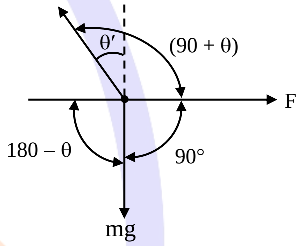
Using Lami's theorem, we have $\frac{F}{\sin(180-\theta)} = \frac{mg}{\sin(90-\theta)} = \frac{T}{\sin 90}$



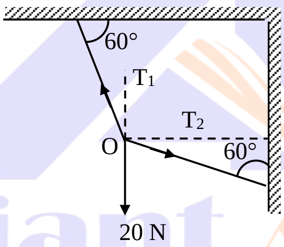
$$\frac{F}{\sin\theta} = \frac{mg}{\cos\theta} = T\ 5t$$

Also $\frac{F}{\frac{x}{l}} = \frac{mg}{\frac{\sqrt{l^2-x^2}}{l}} = T$ or $\frac{F}{x} = \frac{mg}{\sqrt{l^2-x^2}} = \frac{T}{l}$

[where 'x' is the distance shown in figure]



16. If 'O' is in equilibrium, what are the values of T_1 and T_2 in the figure?



Solution

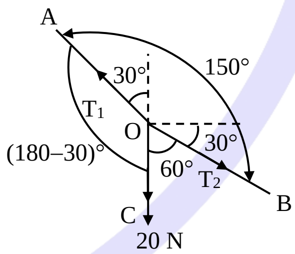
From the figure

$\angle AOB = 150°$

$\angle AOC = 150°$ and $\angle COB = 60°$

From Lami's theorem,

(Write unknown quantities and finally known quantities)



$$\frac{T_1}{\sin 60} = \frac{T_2}{\sin(180-30)°} = \frac{20}{\sin 150°}$$

$$\therefore\ T_1 = \frac{20}{\sin 150}\sin 60 = \frac{20}{\frac{1}{2}} \cdot \frac{\sqrt{3}}{2} = 20\sqrt{3}\ \text{N}$$

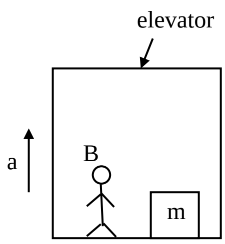
and $\quad T_2 = \frac{20}{\sin 150}\sin 150 = 20\ \text{N}$

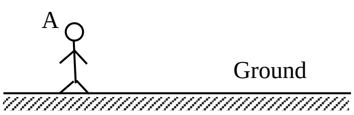
Inertial and non-inertial frames of reference

A reference frame at rest or moving with constant velocity with respect to a frame attached to an object at rest is called "inertial frame of reference". A reference frame that is accelerating is called "non-inertial frame of reference". A reference frame accelerating along a straight line or rotating is a non-inertial frame of reference. A reference frame attached to earth is approximately an inertial frame of reference.

Pseudo force:

Consider a block of mass 'm' resting on the floor of an elevator which is moving upwards with an acceleration 'a'. The block is observed by observer A who is on the ground i.e., in an inertial frame. The block is also observed by observer B, who is in the elevator i.e., from a non inertial frame.



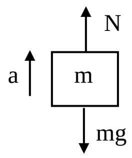


FDB of 'm' wrt A:

$F_{net} = N - mg$ (upwards)

$\therefore N - mg = ma$

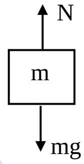
or $N = m(g + a)$



So, observer A would say that normal contact force between the block and floor of elevator is m(g + a) or apparent weight of block is m(g + a).

FBD of 'm' wrt B:

With respect to observer B, the block is at rest. So he would say N = mg.



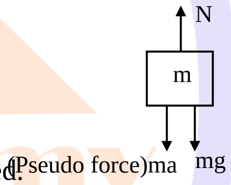
While the same block is observed by A and B, the normal reactions on the block are different. Actually the observation of A is correct and that of B is incorrect, because B is in a non-inertial frame of reference. Being in a non-inertial frame of reference, if one wants to apply Newton's laws, one has to include an additional force called 'pseudo force", in the free body diagram. If B includes a force 'ma' (which is a pseudo force) opposite to the direction of acceleration in the FBD of block, he would arrive at the right result.

Now, FBD of m wrt B:

Now, N = mg + ma

or, N =m(g + a), which is same as obtained by observer A.

So, it is concluded that whenever a problem is solved from a non-inertial frame of reference, pseudo force has to be included in the FBD of the body analysed.

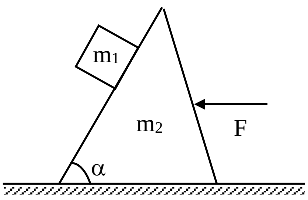


Important points

1. If a body of mass 'm', is in an elevator accelerating upwards, its apparent weight is N = m(g + a).
2. If the same body is in the elevator decelerating upwards, its apparent weight is N = m(g – a)
3. If the same body is in the elevator accelerating downwards, its apparent weight is N = m(g – a).
4. If the same body is in the elevator decelerating downwards, its apparent weight is N = m(g + a).
5. If a block suspended by a massless string from the ceiling of an elevator, in the above 4 points, N is replaced by tension (T) in the string.
6. Pseudo force on a body of mass 'm' is to be applied in a direction opposite to the acceleration of non-inertial frame.

Illustrations

17. A block of mass 'm_1' is kept on an inclined plane of a wedge of mass 'm_2'. A force F is applied as shown. If all surfaces are smooth, what is the value of F so that block remains stationary with respect to wedge?



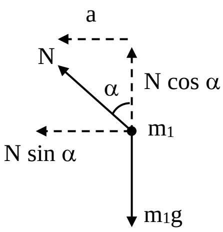
Solution

Acceleration of system is, $a = \dfrac{F}{m_1 + m_2}$ … (i)

Let at this acceleration, m_1 is stationary w.r.t. m_2

From the ground frame (i.e., inertial frame)

FBD of m_1:



N sin α gives acceleration to the block and N cos α balances its weight i.e., m_1g.

$\therefore N \sin\alpha = m_1 a$ … (ii)

$N \cos\alpha = m_1 g$ … (iii)

Dividing equation (ii) by (iii), $\tan\alpha = \frac{a}{g}$

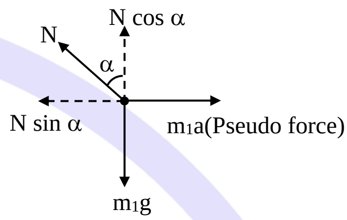
or $a = g\tan\alpha$

$\therefore$ $F = (m_1 + m_2)\, g\tan\alpha$ … (iv) [from (i)]

From the wedge frame (i.e., non-inertial frame)

If you imagine that, you sit on the wedge and observe the block, it would be stationary w.r.t. you. You have to include pseudo force (= m_1a) in the FBD of block, opposite to acceleration (a)

So, FBD of m_1:



$\Sigma F_x = 0 \Rightarrow N\sin\alpha = m_1a$

$\Sigma F_y = 0 \Rightarrow N\cos\alpha = m_1g$

Dividing, $\tan\alpha = \frac{a}{g}$ (or) $a = g\tan\alpha$

$\therefore$ $F = (m_1 + m_2)\,a = (m_1 + m_2)\, g\tan\alpha$, which is same as earlier result.

Law of conservation of linear momentum

The product of mass and the velocity of a particle is defined as its linear momentum $(\vec{p})$. So $\vec{p} = m\vec{v}$

The magnitude of linear momentum is $p = mv$

$p = \sqrt{2\,km}$ and $k = \frac{p^2}{2m}$, where k is kinetic energy of the particle.

From Newton's second law $\vec{F} = \frac{d\vec{p}}{dt}$

In case, the external force applied to a particle (or a body) is zero, then

$\vec{F} = \frac{d\vec{p}}{dt} = 0 \Rightarrow \vec{p} = \text{constant}$,

showing that in the absence of an external force (or $\vec{F}_{ext} = 0$), the linear momentum of a particle (or a body) remains constant. This law is called the law of conservation of linear momentum. This law can be extended to a system of particles or to the centre of mass of a system of particles.

Illustrations

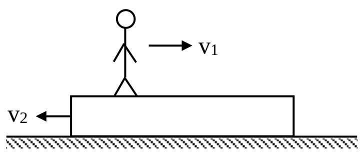
18. A man of mass m is standing on a platform of mass M kept on a smooth horizontal surface. The man starts moving in the platform with a velocity V relative to the platform. Find the recoil velocity of the platform.

Solution

Let the velocity of man is V_1 forwards and the velocity of the platform is V_2 backwards. (recoil velocity)

← –ve +ve →

$\vec{V}_{mM} = \vec{V}_m - \vec{V}_M = (+V_1) - (-V_2) = V_1 + V_2$



But $\vec{V}_{mM} = V$ (given)

$\therefore$ $V = V_1 + V_2 \Rightarrow V_1 = V - V_2$

$p_i = 0$ $\therefore$ $p_f = 0$

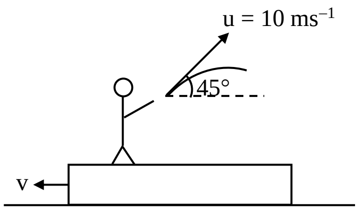
So, $mV_1 + M(-V_2) = 0$

$m(V - V_2) - MV_2 = 0$

$V_2(m + M) = mv \Rightarrow V_2 = \frac{mV}{m+M}$

19. A boy of mass 60 kg is standing over a platform of mass 40 kg placed over a smooth horizontal surface. He throws a stone of mass 1 kg with velocity V = 10 ms^{-1} at angle of 45° with respect to ground. Find the displacement of the platform (with boy) on the horizontal surface when the stone lands on the ground. Take = g = 10 ms^{-1}.

Solution



$u_x = u\cos 45° = 10\left(\frac{1}{\sqrt{2}}\right) = 5\sqrt{2}\ ms^{-1}$

In the horizontal direction, we use

$p_f = p_i$

$$\therefore\ (60+40)(-V)+(1)(5\sqrt{2}) = 0 \Rightarrow V = \frac{5\sqrt{2}}{100} = \frac{1}{10\sqrt{2}}\,ms^{-1}$$

$$T = \frac{2u\sin\theta}{g} = \frac{2\times 10\times\frac{1}{\sqrt{2}}}{10} = \sqrt{2}\ s$$

$\therefore$ Distance travelled by platform (+ boy) is $S = VT = \frac{1}{10\sqrt{2}}\sqrt{2} = 0.1\ m$

☞	In this problem, we have assumed that stone is projected from the ground level.

Friction

When two solid bodies slip over each other, the force of friction is called "Kinetic friction". When two bodies do not slip on each other, the force of friction is called "static friction". Friction always opposes relative motion between two bodies. Resistance to motion of a stationary object on a surface on the application of an external force is called **static friction.**

Resistance to increase in motion parameter of a moving object on a surface is called kinetic friction.

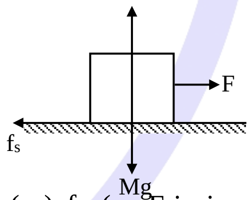
Static friction

The force of static friction which develops in the direction opposite to the applied force is a "self adjusting force".

F = applied force

f_s = static friction

Consider a block of weight, W = Mg placed on a rough horizontal surface.



It is found that

(a) When F = 0 then $f_s = 0$

(b) When $F \neq 0$ and small then $f_s = F$ till f_s becomes equal to some $(f_s)_{max}$ (or) f_L (as F is increased). Once $f_s = (f_s)_{max}$ or f_L, f_s does not increase further. It is found that

$(f_s)_{max}$ (or) $f_L = \mu_s N$ (where μ_s = coefficient of static friction)

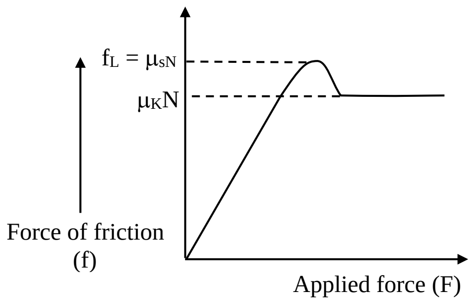
$(f_s)_{max}$ (or) f_L is called maximum value of static friction or limiting friction. μ_s is a dimensionless constant which depends on nature of the surfaces in contact. It does not depend on area of contact.

$$\mu_s = \frac{\text{Limiting friction}}{\text{Normal reaction}} = \frac{f_L}{N}$$

f_s is a self adjusting force in the sense that when $F < (f_s)_{max}$ or f_L then force of static friction $f_s = F$

Kinetic friction

When the applied force F exceeds the limiting friction i.e., $(f_s)_{max}$ then the body begins to move. During motion the force of friction decreases slightly. Now the frictional force is called kinetic friction (f_k). It can be expressed as $f_k = \mu_k N$, where μ_k is called the coefficient of kinetic friction. μ_k is a dimensionless constant. Usually $\mu_k < \mu_s$. Also μ_k is independent of relative velocities of the two objects.



When we try to slide an object on a surface, then the force of friction that develops as a function of applied force is shown in the figure.

Till $F < f_L$, the force of friction $f_s = F$.

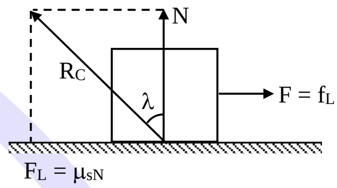
But as F exceeds f_L (= $\mu_s N$), the body begins to move and force of friction (slightly) decreases to $f_k = \mu_k N$ and remains so thereafter. Because limiting friction is higher than kinetic friction, we require more force to start a motion than to maintain it against friction.

When a body rolls on a surface, the resistance offered by the surface is called "rolling friction". In rolling the surfaces in contact do not rub each other. The velocity of the point of contact with respect to surface remains zero all the time, although the centre of the body moves forward.

Rolling friction is negligible as compared to static or kinetic friction and $\mu_r < \mu_k < \mu_s$.

Angle of friction (λ)

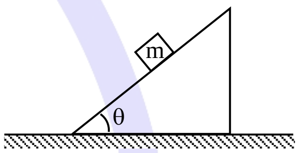
When applied force is equal to f_L, the block is about to slide. The contact forces acting on it are N and f_L. The resultant of these two is R_C. The angle that, this resultant makes with N is called angle of friction (λ). From the figure



$\tan\lambda = \frac{f_L}{N} = \frac{\mu_s N}{N} \Rightarrow \boxed{\lambda = \tan^{-1}(\mu_s)}$ …(i)

Angle of repose (α)

Suppose a block of mass 'm' is placed on a rough inclined plane whose inclination θ can be increased or decreased. At a general angle θ, (let μ_s be the coefficient of friction between the block and the plane)



Normal reaction, $N = mg\cos\theta$

Limiting friction, $f_L = \mu_s N = \mu_s mg\cos\theta$

and the driving force (or pulling force) is $F = mg\sin\theta$

From the above three equations, it is clear that, when θ is increased from 0° to 90°, normal reaction N and hence the limiting friction f_L is decreased, while the driving force F is increased. There is a critical angle called angle of repose (α) at which these two forces (i.e., F and f_L) are equal. Now, if θ is further increased, then the driving force F becomes more than the limiting friction f_L and the block starts sliding.

Thus, $f_L = F$ at $\theta = \alpha$ (or) $\mu_s mg\cos\alpha = mg\sin\alpha$

(or) $\tan\alpha = \mu_s \Rightarrow \alpha = \tan^{-1}(\mu_s)$ …(ii)

From equations (i) and (ii), we see that angle of friction (λ) is numerically equal to the angle of repose.

or, $\lambda = \alpha$

From the above discussion we can conclude that

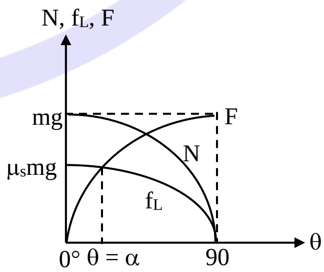
If $\theta < \alpha$, $F < f_L$ the block is stationary (and $f = mg\sin\theta$)

If $\theta = \alpha$, $F = f_L$ the block is on the verge of sliding (and $f = f_L = \mu_s mg\cos\alpha = mg\sin\alpha$)

and if $\theta > \alpha$, $F > f_L$ the block slides down with acceleration (and $f = f_k = \mu_k mg\cos\theta$) given by

$a = \frac{F - f_k}{m} = g(\sin\theta - \mu_k\cos\theta)$

How N, f_L and F vary with θ is shown in the graph.



$N = mg\cos\theta$ or $N \propto \cos\theta$

$F_L = \mu_s mg\cos\theta$ or $f_L \propto \cos\theta$

$F = mg\sin\theta$ or $F \propto \sin\theta$

Normally $\mu_s < 1$, ∴ $f_L < N$

Circular motion

In non-uniform circular motion, speed is not constant. The particle possesses angular acceleration (α). In non-uniform circular motion two cases arise (i) α is constant and (ii) α is varying. If α is constant, the following equations hold good.

$\omega = \omega_0 + \alpha t$

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

$\omega^2 - \omega_0^2 = 2\alpha\theta$

$$\theta_{nth} = \omega_0 + \alpha\left(n - \frac{1}{2}\right)$$

$$\theta = \frac{\omega + \omega_0}{2} \times t$$

In the above equations symbols have their usual meanings. In non-uniform circular motion linear acceleration has two components

(i) Centripetal acceleration, $a_r = r\omega^2 = \frac{v^2}{r}$

(ii) tangential acceleration, $a_t = \frac{dv}{dt}$ = rate of change of speed [Note that $a_t = r\alpha$]

These two components of acceleration are mutually perpendiculars. Therefore, net acceleration of the particle will be

$$a = \sqrt{a_r^2 + a_t^2} = \sqrt{(r\omega^2)^2 + \left(\frac{dv}{dt}\right)^2} = \sqrt{\left(\frac{v^2}{r}\right)^2 + \left(\frac{dv}{dt}\right)^2}$$

Following three points are important regarding the above discussion:

(i) In uniform circular motion, speed (v) of the particle is constant i.e., $\frac{dv}{dt} = 0$. Thus $a_t = 0$ and $a = a_r = r\omega^2$.

(ii) In accelerated circular motion, $\frac{dv}{dt}$ is + ve and tangential acceleration of particle is parallel to $\vec{v}$.

(iii) In decelerated circular motion, $\frac{dv}{dt}$ is negative and hence, tangent acceleration is anti-parallel to velocity $\vec{v}$.

> ☞ On any curved path (not necessarily a circular one) the acceleration of the particle has two components a_t and a_n in two mutually perpendicular directions, component of $\vec{a}$ along $\vec{v}$ is a_t and component of $\vec{a}$ perpendicular to $\vec{v}$ is a_n. Thus $|\vec{a}| = \sqrt{a_t^2 + a_n^2}$

Circular turning of roads

When vehicles go through turnings, they travel along a nearly circular arc. There must be some force which will produce the required centripetal acceleration. If the vehicles travel in a horizontal circular path, this resultant force is also horizontal. The necessary centripetal force can be provided to vehicles in three ways.

(i) By friction only

(ii) By banking of roads only

(iii) By friction and banking of roads both

In REAL LIFE, the necessary centripetal force is provided by FRICTION AND BANKING OF ROADS both.

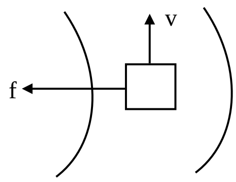
(i) By friction only

Suppose a car of mass 'm' is moving at a speed 'v' in a horizontal circular arc (or level turning) of radius r. In this case, the necessary centripetal force to the car is provided by force of friction (this is static friction) acting towards centre. Thus

$$f = \frac{mv^2}{r}$$

Maximum frictional force available is $f_L = \mu_s N = \mu_s mg$

So, for safe turning without sliding



$$\frac{mv^2}{r} \le f_L \quad \text{or} \quad \frac{mv^2}{r} \le \mu_s mg$$

$$\boxed{\mu_s \ge \frac{v^2}{rg} \quad \text{or} \quad v \le \sqrt{\mu_s rg}}$$

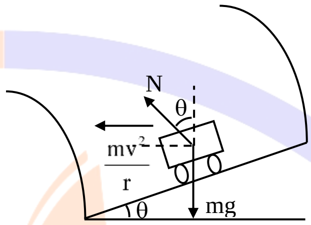
Here, two situations may arise. If μ_s and r are known to us, the speed of vehicle should not exceed $\sqrt{\mu_s rg}$ and if v and r are known to us, the coefficient of static friction should be greater than $\frac{v^2}{rg}$.

(ii) By banking of roads only

At the turnings, roads are banked i.e., the outer part of the road is somewhat lifted compared to the inner part. Applying Newton's second law along the radius and the first law in the vertical direction

$N\sin\theta = \frac{mv^2}{r}$ and $N\cos\theta = mg$

Thus, $\tan\theta = \frac{v^2}{rg} \Rightarrow \boxed{v = \sqrt{rg\tan\theta}}$

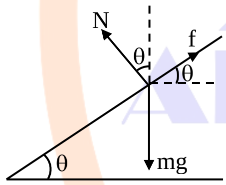


This $(v = \sqrt{rg\tan\theta})$ is the speed at which car does not slide down or up, even if the track is smooth. If track is smooth and speed is less than $\sqrt{rg\tan\theta}$, vehicle moves down so that 'r' gets reduced and if speed is more than this vehicle moves up increasing 'r'.

(iii) By friction and banking of roads both

Consider a vehicle moving on a circular road, which is rough and also banked.

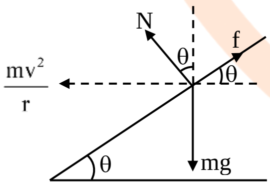
(i) Friction f is outwards if the vehicle is at rest or V = 0. Because in this case the component of weight mg sin θ is balanced by 'f'.



$N\sin\theta = f\cos\theta$

$N\cos\theta + f\sin\theta = mg$

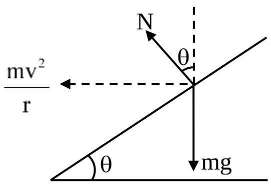
(ii) Friction f is outwards if $v < \sqrt{rg\tan\theta}$



$N\sin\theta - f\cos\theta = \frac{mv^2}{r}$

$N\cos\theta + f\sin\theta = mg$

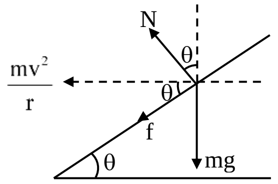
(iii) Friction f is zero if $v = \sqrt{rg\tan\theta}$



$N\sin\theta = \frac{mv^2}{r}$

$N\cos\theta = mg$

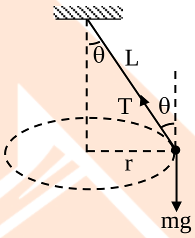
(iv) Friction f is inwards if $v > \sqrt{rg\tan\theta}$



$$N\sin\theta + f\cos\theta = \frac{mv^2}{r}$$

$$N\cos\theta - f\sin\theta = mg$$

Conical pendulum



$T\sin\theta = \frac{mv^2}{r}$ and $\quad T\cos\theta = mg$

Dividing, we get $\tan\theta = \frac{v^2}{rg} \Rightarrow v = \sqrt{rg\tan\theta}$

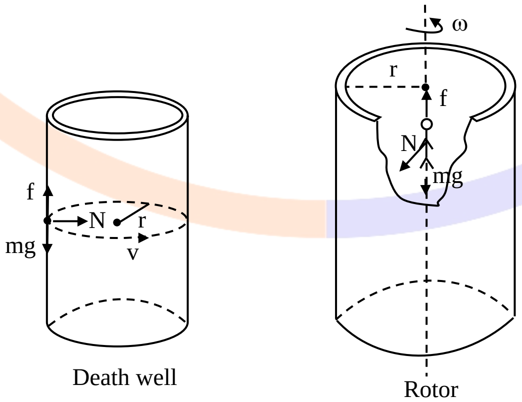
Angular speed, $\omega = \frac{v}{r} = \sqrt{\frac{g\tan\theta}{r}}$

Time period of conical pendulum is $T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{r}{g\tan\theta}}$ or

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

Well of Death or rotor

In case of 'death well', a person drives a bicycle on a vertical surface of a large wooden well, while in case of a rotor at a certain angular speed of rotor a person hangs resting against the wall without any support from the bottom. In death well walls are at rest and person revolves. In case of rotor person is at rest and the walls rotate.



Death well

Rotor

In both the cases friction balances weight of person and normal reaction provides the centripetal force required for circular motion.

$f = mg$

$$N = \frac{mv^2}{r} = mr\omega^2$$

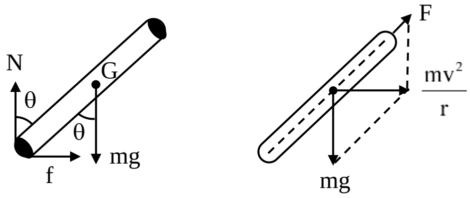
A cyclist on the bend of a road

Resultant of N and f is F and it should pass through centre of gravity, G

Resultant of F and mg provides centripetal force

$\tan\theta = \frac{f}{N}$ where $f = \frac{mv^2}{r}$ and $N = mg$

$\therefore$ $\boxed{\tan\theta = \frac{v^2}{rg}}$



Illustrations

20. A fire hose squirts 12 kg s^{-1} of water against a flat plate (normally). The velocity of stream is 10 ms^{-1}. If the water flows parallel to the plate after striking it, the average force on the plate is

(A) 120 N (B) 60 N (C) 150 N (D) 200 N

Ans (A)

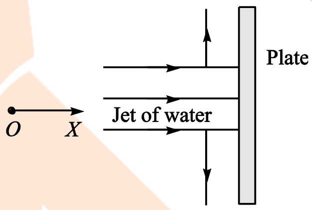
m = mass of water striking the plate = 12 kg in 1 second

So, time is taken as 1 second.

Velocity of jet = 10 ms^{-1}

$\therefore$ Initial momentum (along OX) is

$p_1 = mv = 12 \times 10 = 120$ kg ms^{-1}



Final momentum (along OX) is $p_f = 0$

$\therefore$ magnitude of change in momentum is $|\Delta\bar{p}| = 120$ kg ms^{-1}

So, average force is $F = \frac{|\Delta\bar{p}|}{t} = \frac{120}{1} = 120\,N$

This force, on water is along XO and on plate is along OX.

21. A net force of 200 N gives a body of mass m_1 an acceleration of 80 ms^{-2} and a body of mass m_2, an acceleration of 240 ms^{-2}. The acceleration that this force causes when the masses combine together is

(A) 50 ms^{-2} (B) 60 ms^{-2} (C) 120 ms^{-2} (D) 100 ms^{-2}

Ans (B)

We know that F = ma

$\therefore 200 = m_1 \times 80 \Rightarrow m_1 = \frac{200}{80} = 2.5$ kg and $200 = m_2 \times 240 \Rightarrow m_2 = \frac{200}{240} = 0.833$ kg

When joined together, $m = m_1 + m_2 = \frac{20}{6}$ kg

Final acceleration is $a = \frac{F}{m} = \frac{200}{20/6} = 60\ ms^{-2}$.

22. A car moves at a constant speed on a straight but hilly road. One section has a crest and dip of the same 250 m radius. As the car passes over the crest, the normal force on the car is one half the 16 KN weight of the car. The normal force on the car as it passes through bottom of the dip is [g = 10 ms^{-2}]

(A) 24×10^3 N (B) 12×10^3 N (C) 32×10^3 N (D) 16×10^3 N

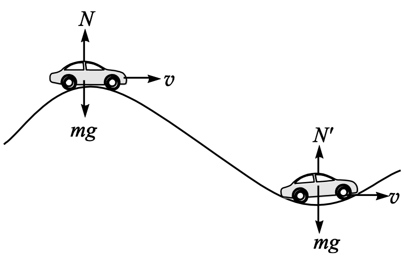
Ans (A)

Given that $N = \frac{16}{2}KN = 8000\ N$ and mg = 16000 N

Here $mg - N = \frac{mv^2}{r}$

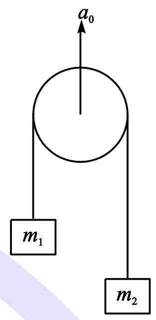
$16000 - 8000 = \frac{1600v^2}{250} \Rightarrow v = 35.35\ ms^{-1}$

$N' - mg = \frac{mv^2}{r}$



$$\Rightarrow N' = mg + \frac{mv^2}{r} = 16000 + \frac{1600(35.35)^2}{250} = 24000 \text{ N}$$

23. In the figure, if the pulley is massless and moves with an upward acceleration a_0, the tension in the string is



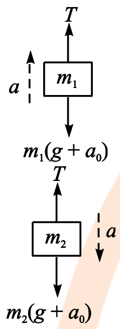
(A) $\frac{2m_1m_2}{m_1 - m_2}(g - a_0)$ (B) $\frac{m_1m_2}{m_1 + m_2}(g + a_0)$

(C) $\frac{2m_1m_2}{m_1 + m_2}(g + a_0)$ (D) $\frac{2m_1m_2}{m_1 - m_2}(g + a_0)$

Ans (C)

From non-inertial frame [i.e., reference frame of pulley]:-

a is a acceleration of system w.r.t pulley



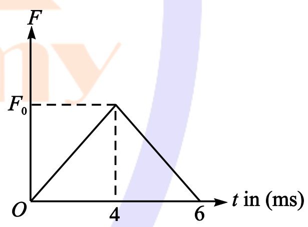
$$T - m_1(g + a_0) = m_1a \quad \ldots(i)$$

$$m_2(g + a_0) - T = m_2a \quad \ldots(ii)$$

From (i) and (ii)

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

24. A ball of mass 200 g is thrown with a speed 20 ms^{-1}. The ball strikes a bat and rebounds along the same line at a speed of 40 ms^{-1}. Variation in the interaction force, as long as the ball remains in contact with the bat is as shown in figure. Maximum force F_0 exerted by the bat on the ball is



(A) 4000 N (B) 5000 N

(C) 3000 N (D) 2500 N

Ans (A)

Area under $F \cdot t$ graph = Δp

$$\therefore \frac{1}{2} \times (6 \times 10^{-3}) \times F_0 = 0.2(40 + 20) \qquad \therefore F_0 = 4000 \text{ N}$$

25. Velocity a particle of mass 2 kg varies with time according to the equation $v = (2ti + 4j)ms^{-1}$. Here t is in second. The impulse imparted to the particle in the time interval from $t = 0$ to $t = 2s$ is

(A) 8 Ns (B) 10 Ns (C) 6 Ns (D) 4 Ns

Ans (A)

Impulse imparted to the particle by a force = Change in momentum

$J = m(v_f - v_i)$

$v = (2ti + 4j)ms^{-1}$ and $m = 2kg$ (given)

At $t = 0, v_i = 4j$ and at $t = 2s, v = 4i + 4j$

$\therefore J = 2[(4i + 4j) - 4j] = 8i \text{ N s}$

NCERT LINE BY LINE QUESTIONS

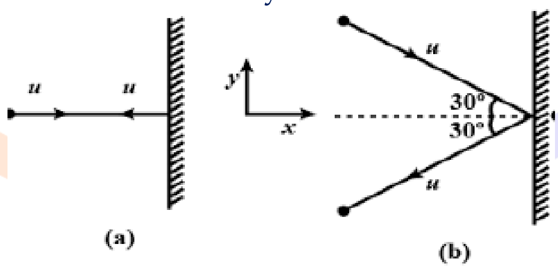
1. A constant retarding force 100 N is applied to a body of mass 20 kg, moving initially with speed 20 m/s. How long does the body take to stop? [NCERT-I, XI Pg. 110]
(1)2s (2) 3 s (3) 1s (4) 4s

2. A man of mass 60 kg stands on a weighing scale in a lift which is moving upward with a uniform speed of 10 m/s. The reading on the scale is. [NCERT-L XI Pg. 110]
(1) Zero (2) 120kgwt (3) 60kgwt (4) 90kgwt

3. A rocket with a lift-off mass 10000 kg is blasted upwards with an initial acceleration of 2 m/s^2. The initial thrust of the blast is [NCERT-L XI Pg 110)
(1) 120 kN (2) 80 kN (3) 100 kN (4) 140 kN

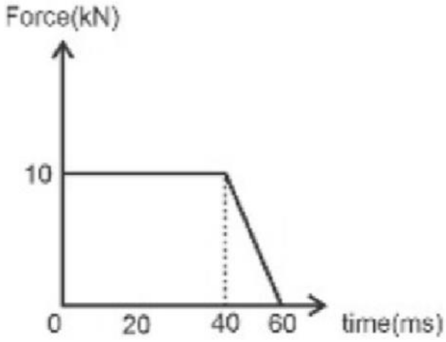
4. Consider the following statements
(a) Frictional force between block and contact surface depends on area of contact
(b) Frictional force may also act when there is no relative motion between the contact surfaces.
The correct statement is [NCERT-I, XI Pg. 110]
(1) (a)only (2) (b)only
(3) (a) and (b) both (4) Neither (a) nor (b)

5. Two identical billiard balls strike a rigid wall with same speed as shown in the figure. The ratio of magnitude of impulse imparted to the balls by the wall [NCERT-I, XI Pg. 98]



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

6. A force-time plot for a body is shown in the figure. The total change in momentum of the body is [NCERT-I, XI Pg. 98]



(1) 400 Ns (2) 300 Ns (3) 500 N s (4) 200 N s

7. For a given surface, the normal reaction and frictional force are inclined at [NCERT-I, XI Pg. 101)

(1) 0°to each other (2) 90° to each other
(3) 45° to each other (4) $\tan^{-1}(\mu)$ to each other

8. A machine gun fires 10 bullets per second each with speed 200 m/s. If the mass of each bullet is 20 g, then the force required to keep the gun stationary is [NCERT-I, XI Pg. 98)

(1) 40N (2) 04 N (3) 4N (4) 8N

9. A mass of 2 kg rests on a horizontal plane. The plane is gradually inclined until at an angle θ = 30° with the horizontal, the mass just begins to slide. The coefficient of static friction between the block and the surface is [NCERT-I, XI Pg. 102]

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

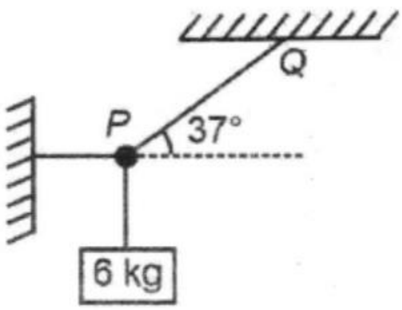
10. A cyclist speeding at 5 m/s on a level road takes a sharp circular turn of radius 2.5 m without reducing the speed. The minimum value of coefficient of static friction between tyre and road such that cyclist does not slip is [NCERT-I, XI Pg. 105]

(1) 0.5 (2) 1.5 (3) 1.0 (4) 0.8

11. A truck starts from rest and accelerates uniformly with 5 m/s^2. The minimum value of coefficient of static friction between surface of truck and a box placed on it such that box does not slip back, will be [NCERT-I, XI Pg. 110]

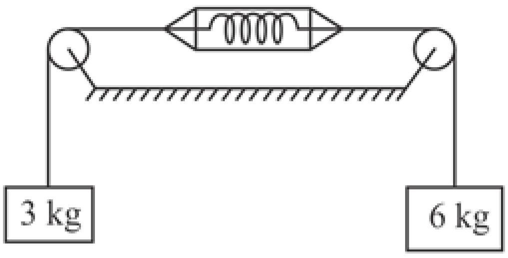
(1) 0.4 (2) 0.6 (3) 0.5 (4) 0.2

12. The tension in string PQ as shown in the figure is (g = 10 m/s^2) [NCERT-I, XI Pg. 99)



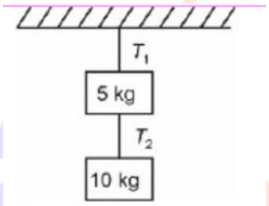
(1) 100 N (2) 150N (3) 130 N (4) 50 N

13. In the given figure, the reading of spring balance is (g = 10 m/s^2) [NCERT-I, XI Pg. 100)



(1) 10N (2) 20 N (3) 80 N (4) 40 N

14. The ratio of tension T_1 and T_2 as shown in the figure is NCERT-I, XI Pg. 100]



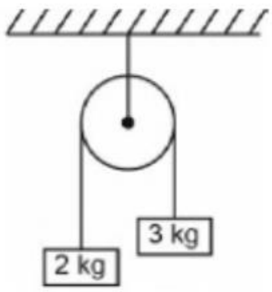
1) $\frac{3}{2}$ 2) $\frac{1}{2}$ 3) $\frac{1}{3}$ 4) $\frac{4}{3}$

15. A car is moving on a curved road of radius *R*. The road is banked at an angle θ . The coefficient of friction between tyres of the car and road is μ . The minimum safe velocity on this road is [NCERT-I, XI Pg. 104]

(1) $\sqrt{\frac{gR(\mu+\tan\theta)}{(1-\mu\tan\theta)}}$ (2) $\sqrt{\frac{gR(\tan\theta-\mu)}{(1+\mu\tan\theta)}}$

(3) $\sqrt{\frac{gR^2(\tan\theta-\mu)}{(1+\mu\tan\theta)}}$ (4) $\sqrt{\frac{gR(\tan\theta-\mu)}{(1-\mu\tan\theta)}}$

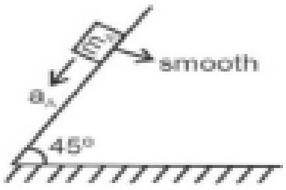
16. Two masses as shown in the figure are suspended from a smooth massless pulley. The acceleration of 3 kg mass, when system is released, will be [NCERT-I. XI Pg. 106)

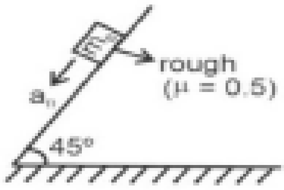


(1) 2.5 m/s^2 (2) 2.0 m/s^2 (3) 4.0 m/s^2 (4) 5.0 m/s^2

17. A body is acted upon by unbalanced forces, then body [NCERT-I, XI Pg. 95]
(1) Will be at rest
(2) Will keep moving with uniform speed
(3) Will accelerate
(4) Will be at rest if even number of forces will act

18. Two blocks *A* and B are released from rest on two inclined plane as shown in the figure. [NCERT-I, XI Pg. 102]





The ratio of the accelerations (a_A / a_8) is

(1) 1 (2) 2 (3) 1.5 (4) 0.8

19. A 60 kg monkey, climbs on a rope which can withstand a maximum tension of 900 N. The case in which the rope will break if the monkey [NCERT-L XI Pg. 113]

(1) Climbs up with acceleration of 6 m/s^2

(2) Climbs down with acceleration of 4 m/s^2

(3) Climbs up with uniform speed of 5 m/s

(4) Falls down the rope nearly freely under gravity

20. Which of the following is self adjusting force? [NCERT-I, XI Pg. 101]

(1) Static friction (2) Limiting friction (3) Kinetic friction (4) All of these.

NCERT BASED PRACTICE QUESTIONS

1. The First law of motion is also called

(a) law of inertia (b) law of gravitation

(c) law of weak force (d) law of electrostatics

2. Inertia of a body is

(a) Basic property of a body (b) arise due to force

(c) due to shape of body (d) none of above

3. If two bodies A and B has mass m_A and m_B such that $m_A > m_B$ then inertia of body A is

(a) greater then B (b) samaller then B

(c) equal to B (d) cannot be said

4. Newton's second law of motion can be represented by

(a) F = ma (b) $F = \frac{dp}{dt}$ (c) $F = m\frac{d\upsilon}{dt}$ (d) all above

5. Newton's law of motion are valid in

(a) inertial frame of reference

(b) Non inertial frame of reference

(c) applicable to all frame of reference

(d) Not applicable in any frame of reference

6. Every action has equal and opposite reaction is Newton's

(a) First law (b) second law (c) third law (d) not Newton's law

7. Dimension of impulse is same as

(a) momentum (b) force (c) energy (d) acceleration

8. A body is called in translational equilibirium when net force on the body is

(a) zero (b) Non-zero

(c) do not depend on force (d) variable

9. Main law of motion is

(a) First law (b) second law (c) third law (d) none

10. If a body is acted upon by three forces $\overline{F}_1, \overline{F}_2, \overline{F}_3$ then for equilibrium of the body which condition must be correct?
(a) $\overline{F}_1 + \overline{F}_2 + \overline{F}_3 = 0$ (b) $(\overline{F}_1) = |\overline{F}_2| = |\overline{F}_3|$ (c) $\overline{F}_1 = \overline{F}_2 + \overline{F}_3$ (d) $\overline{F}_2 = \overline{F}_1 + \overline{F}_3$

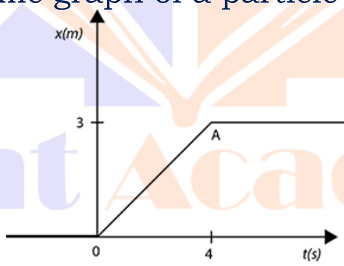
11. If u_s, u_k and u_r are coefficient of static friction, kinetic friction and rolling friction than.
(a) $u_k > u_s > u_r$ (b) $u_s > u_r > u_k$ (c) $u_s > u_k > u_r$ (d) $u_r > u_k > u_s$

12. Two blocks are connected by a string one block is bept on friction less table then acceleration of each block is
(a) $\frac{2m_2 g}{m_1 + m_2}$ (b) $\frac{m_2 g}{m_1 + m_2}$ (c) $\frac{m_1 g}{m_1 + m_2}$ (d) g

13. Which of the following is true for static friction force (f?)
(a) f max $\leq \mu_s$ N (b) f max $\geq \mu_s N$
(c) f max = o (d) f max $\geq \frac{\mu_s N}{2}$

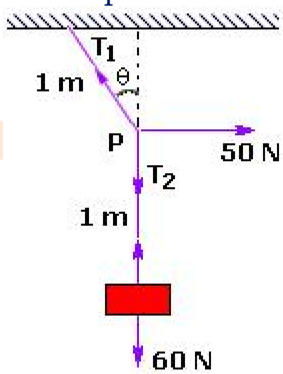
14. Two masses 8 kg and 12kg are connected at the two ends of a light inex tensible string that goes over a friction less pulley. Then tension in the string is
(a) 96N (b) 90N (c) 85N (d) 80N

15. Figure shows the position time graph of a particle of mass 4 kg for O< t< 4s?



(a) 0 (b) ¾ N (c) 3 N (d) 4N

16. A mass of 6 kg is suspended by a rope of length 2m from the ceiling . A force of 50 N in the horizontal direction is applied at the midpoint P of the rope. What is the angel the rope makes with the vertical in equilibrium?



(a) $\tan^{-1}\left(\frac{5}{6}\right)$ (b) $\tan^{-1}\left(\frac{6}{5}\right)$
(c) $\tan^{-1}\left(\frac{1}{6}\right)$ (d) $\tan^{-1}\left(\frac{3}{4}\right)$

17. The maximum acceleration of the train in which a box lying on its floor will remain stationary coefficient of static friction between box and train's floor is 0.15

(a) 2.5 m/s^2 (b) 1.0 m/s^2
(c) 1.5 m/s^2 (d) 2.0 m/s^2

18. A batsmen deflects a ball by an angle of 45^0 without changing its initial speed which is equal to 54 km/h . What is impulse imparted to the ball (mass of the ball 0.15 kg)

(a) 2.1 kg m/s (b) 4.2 kg m/s
(c) 8.4 kg m/s (d) 5.4 kg m/s

19. A stone of mass 0.25kg tied to the end of a string is a round in a circle of radius 1.5m with a speed of 40rev/min in a horizontal pane. What is the tension in the string?

(a) 5.6 N (b) 4.6 N
(c) 6.6 N (d) 13.2N

20. A block of mass 15 kg is placed on a long trolley. The coefficient of static friction between the block and trolley is 0.18. The trolley accelerates from rest with 0.5 m/s^2 acceleration of the block with respect to trolley is

(a) 1.8 m/s^2 (b) 0.5 m/s^2
(c) 0 (d) 1.2 m/s^2

21. A shell of mass 0.02 kg is fired by a gun of mass 100kg. If the muzzle speed of the shell is 80m/s. The recoil speed of the gun is?

(a) 3.2 cm/s (b) 1.6 m/s
(c) 3.2 m/s (d) 1.6 cm/s

22. One end of a string of length l is connected to a particle of mass m and the other to a small peg on a smooth horizontal table It the particle moves in a circle with speed υ the net force on the particle is

(a) T (b) $T-\frac{m\upsilon^2}{l}$
(c) $T+\frac{m\upsilon^2}{l}$ (d) 0

23. A monkey of mass 40kg climbs on a rope which can stand a maximum tension of 600N. Then the maximum acceleration with which the monkey can climb the rope

(a) 6 cm/s (b) 5 m/s
(c) 7 m/s (d) 8 cm/s

24. Reaction due to body depends on its

(a) velocity (b) mass
(c) acceleration (d) none of these

25. A man weighing mg in a rocket moves up with acceleration 4g. His weight in the rocket is

(a) zero (b) 4mg
(c) 5 mg (d) mg

26. A shell is fired from a canon it explodes in mid air its total

(a) Momentum increases (b) Momentum decreases
(c) KE increases (d) KE decreases

27. In an elevator moving vertically up with an acceleration 'g' the force exerted on the floor by a passenger of mass M is

(a) Mg (b) $\frac{1}{2}Mg$ (c) zero (d) 2 Mg

28. A particle of mass m moving with velocity υ strikes a stationary particle of mass 2m and sticks to it. The speed of the system will be

(a) $\upsilon/2$ (b) 2υ

(c) $\upsilon/3$ (d) 3υ

29. A mass placed on an inclined plane is just in equilibirium. It μ is coefficient of friction of the surface. Then maximum inclination of the plane with the horizontal is

(a) $\tan^{-1}\mu$ (b) $\tan^{-1}(\mu/2)$

(c) $\sin^{-1}\mu$ (d) $\cos^{-1}\mu$

30. The proper use of lubricants cannot reduce

(a) static friction (b) inertia

(c) sliding friction (d) rolling friction

31. A ball with an initial momentum P collides normally with a rigid wall. If P' is its linear momentum after the perfectly elastic collision, then

(a) P' = P (b) P' = – P

(c) P' = 2P (d) P' = - 2P

32. A block of mass M is pulled along a horizontal surface by a rope of mass m by applying a force F at one end of the rope. The force which the rope exerts on the block is

(a) $\frac{FM}{m+M}$ (b) $\frac{mF}{m+M}$

(c) $\frac{mF}{M-m}$ (d) $\frac{MF}{M-m}$

33. A 60kg man goes around earth in a satellite. In the satellite, his weight will be

(a) zero (b) 60 kg (c) 600N (d) 60N

34. A bomb at rest explodes into 3 parts of the same mass the momentum of the 2 parts are – 2p $\hat{i}$ and $P\hat{j}$ the momentum of the third part will have a magnitude of

(a) P (b) $\sqrt{3P}$ (c) $P\sqrt{5}$ (d) zero

35. A body of mass 10kg is sliding on a frictionless horizontal surface with a velocity of 2 m/s. The force required to move it with the same velocity is

(a) 10 N (b) 5N (c) 20N (d) zero

36. A block of mass 2kg is pushed by a horizontal force of 2.5N on a floor. What is the force of the friction between the block and the floor if coefficient of static friction is 0.4

(a) 7.84 N (b) 8N (c) 2.5 N (d) 5N

37. A block of metal weighing 2kg is resting on a frictionless plans. If is struck by a jet releasing water at a rate of 1 kg/s and at a speed of 5m/s then acceleration of the black is:

(a) 5 m/s^2 (b) 2.5 m/s^2 (c) 7.5 m/s^2 (d) 10 m/s^2

38. A cyclist speeding at 18 km/h on a level road takes a sharp circular turn of radius 3m without reducing the speed then minimum coefficient of static friction so that cyclist do not slip?

(a) .1 (b) .83 (c) .63 (d) .53

39. Momentum conservation principle is followed when external force acting on the body or system is

(a) zero (b) non zero

(c) constant (d) do not depend on force

40. A stone of mass m tied to the end of a string revolves in a vertical circle of radius R. The net force at the lowest point of the circle is

(a) mg – T (b) mg + T

(c) $mg + T - \frac{m\upsilon^2}{R}$ (d) $mg - T - \frac{m\upsilon^2}{R}$

TOPIC WISE PRACTICE QUESTIONS

Topic 1: I, II & III Laws of Motion

1. A rider on a horse back falls forward when the horse suddenly stops. This is due to

1) inertia of horse 2) inertia of rider 3) large weight of the horse 4) losing of the balance

2. Which of the following is not an illustration of Newton's third law ?

1) Flight of a jet plane 2) A cricket player lowering his hands while catching a cricket ball

3) Walking on floor 4) Rebounding of a rubber ball

3. A particle of mass 0.3 kg subject 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 ?

1) 15 m/s2 2) 3 m/s2 3) 10 m/s2 4) 5 m/s2

4. A ship of mass 3×10^7 kg initially at rest, is pulled by a force of 5×10^4 N through a distance of 3m. Assuming that the resistance due to water is negligible, the speed of the ship is

1) 1.5 m/sec. 2) 60 m/sec. 3) 0.1 m/sec. 4) 5 m/sec.

5. A 600 kg rocket is set for a vertical firing. If the exhaust speed is 1000 ms^{-1} , the mass of the gas ejected per second to supply the thrust needed to overcome the weight of rocket is

1) 117.6 kg s^{-1} 2) 58.6 kg s^{-1} 3) 6 kg s^{-1} 4) 76.4 kg s^{-1}

6. An object of mass 20 kg moves at a constant speed of 5 ms^{-1}. A constant force, that acts for 2 sec on the object,

gives it a speed of 3 ms^{-1} in opposite direction. The force acting on the object is

1) 8 N 2) –80 N 3) –8 N 4) 80 N

7. A satellite in a force free space sweeps stationary interplanetary dust at a rate (dM/dt) = αv. The acceleration of satellite is

1) $\frac{-2\alpha v^2}{M}$ 2) $\frac{-\alpha v^2}{M}$ 3) $\frac{-\alpha v^2}{2M}$ 4) $-\alpha v^2$

8. An object will continue moving uniformly when, the resultant force

1) on it is increasing continuously 2) is at right angles to its rotation

3) on it is zero 4) on it begins to decrease

9. 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

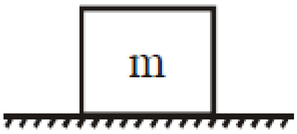
10. A ball of mass 0.2 kg is thrown vertically upwards by applying a force by hand. If the hand moves 0.2 m while applying the force and the ball goes upto 2 m height further, find the magnitude of the force. (Consider g = 10 m/s^2).
1) 4 N 2) 16 N 3) 20 N 4) 22 N

11. A block of mass 5kg is moving horizontally at a speed of 1.5 ms^{-1}. A vertically upward force 5N acts on it for 4 seconds. What will be the distance of the block from the point where the force starts acting?
1) 2 m 2) 6 m 3) 8 m 4) 10 m

12. 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

13. A particle of mass 10 kg is moving in a straight line. If its displacement, x with time t is given by $x = (t^3 - 2t - 10)$ m, then the force acting on it at the end of 4 seconds is
1) 24 N 2) 240 N 3) 300 N 4) 1200 N

14. A block of mass m is placed on a smooth horizontal surface as shown. The weight (mg) of the block and normal reaction (N) exerted by the surface on the block



1) form action-reaction pair m 2) balance each other
3) act in same direction 4) both 1) and 2)

Topic 2: Momentum, Law of Conservation of Momentum and Impulse

15. A ball of mass 150 g, moving with an acceleration 20 m/s^2, is hit by a force, which acts on it for 0.1 sec. The impulsive force is
1) 0.5 N 2) 0.1 N 3) 0.3 N 4) 1.2 N

16. A hammer weighing 3 kg strikes the head of a nail with a speed of 2 ms^{-1} drives it by l cm into the wall. The impulse imparted to the wall is
1) 6Ns 2) 3Ns 3) 2Ns 4) 12 Ns

17. A ball is thrown up at an angle with the horizontal. Then the total change of momentum by the instant it returns to ground is
1) acceleration due to gravity × total time of flight 2) weight of the ball × half the time of flight
3) weight of the ball × total time of flight 4) weight of the ball × horizontal range

18. 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) 10 N 2) 5 N 3) 15 N 4) 30 N

19. A body whose momentum is constant must have constant
1) velocity 2) force 3) acceleration 4) All of the above

20. 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.

21. A 50 kg ice skater, initially at rest, throws a 0.15 kg snowball with a speed of 35 m/s. What is the approximate recoil speed of the skater?
1) 0.10 m/s 2) 0.20 m/s 3) 0.70 m/s 4) 1.4 m/s

22. A bag of sand of mass m is suspended by a rope. A bullet of mass $\frac{m}{20}$ is fired at it with a velocity v and gets embedded into it. The velocity of the bag finally is
1) $\frac{v}{20} \times 21$ 2) $\frac{20v}{21}$ 3) $\frac{v}{20}$ 4) $\frac{v}{21}$

23. A ball of mass m falls vertically to the ground from a height h_1 and rebounds to a height h_2. The change in momentum of the ball of striking the ground is

1) $m\sqrt{2}g(h_1+h_2)$ 2) $m\sqrt{2g(m_1+m_2)}$ 3) $mg(h_1-h_2)$ 4) $m\left(\sqrt{2gh_1}-\sqrt{2gh_2}\right)$

24. A ball of mass 10 g moving perpendicular to the plane of the wall strikes it and rebounds in the same line with the same velocity. If the impulse experienced by the wall is 0.54 Ns, the velocity of the ball is

1) 27 ms^{-1} 2) 3.7 ms^{-1} 3) 54 ms^{-1} 4) 37 ms^{-1}

25. The rate of mass of the gas emitted from rear of a rocket is initially 0.1 kg/sec. If the speed of the gas relative to the rocket is 50 m/sec and mass of the rocket is 2 kg, then the acceleration of the rocket in m/sec2 is

1) 5 2) 5.2 3) 2.5 4) 25

26. The linear momentum p of a body moving in one dimension varies with time according to the equating P = a + bt^2 where a and b are positive constants. The net force acting on the body is

1) proportional to t^2 2) a constant 3) proportional to t 4) inversely proportional to t

27. A balloon has 8gm of air. A small hole is pierced into it. The air escapes at a uniform rate of 7 cm^{-1}. If the balloon shrinks in 5.6 seconds then the average force acting on the balloon is:

1) 10^{-4}N 2) 10^{-2}dyne 3) 56dyne 4) 10^{-6}N

28. An object of mass 3M splits into three equal fragments. Two fragments have velocities $v\hat{j}$ and $v\hat{i}$. The velocity of the third fragment is

1) $v(\hat{j}-\hat{i})$ 2) $v(\hat{i}-\hat{j})$ 3) $v(\hat{i}+\hat{j})$ 4) $\frac{v(\hat{i}+\hat{j})}{\sqrt{2}}$

29. A shell at rest at the origin explodes into three fragments of masses 1 kg, 2 kg and m kg. The1 kg and 2 kg pieces fly off with speeds of 12 m/s along x-axis and 16 m/s along y-axis respectively. If the m kg piece flies off with a speed of 40 m/s, the total mass of the shell must be

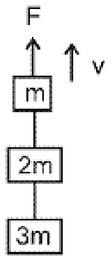
1) 3.8 kg 2) 4 kg 3) 4.5 kg 4) 5 kg

Topic 3: Equilibrium of Forces, Motion of Connected Bodies and Pulley

30. Block A is moving with acceleration A along a frictionless horizontal surface. When a second block, B is placed on top of Block A the acceleration of the combined blocks drops to 1/5 the original value. What is the ratio of the mass of A to the mass of B?

1) 5 : 1 2) 1 : 4 3) 3 : 1 4) 2 : 1

31. Three blocks with masses m, 2 m and 3 m 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 2m? (g is the acceleration due to gravity)



1) 2 mg 2) 3 mg 3) 6 mg 4) zero

32. Two mass m and 2m are attached with each other by a rope passing over a frictionless and massless pulley. If the pulley is accelerated upwards with an acceleration 'a', what is the value of tension?

1) $\frac{g+a}{3}$ 2) $\frac{g-a}{3}$ 3) $\frac{4m(g+a)}{3}$ 4) $\frac{m(g-a)}{3}$

33. A lift is moving down with acceleration *a*. A man in the lift drops a ball inside the lift. The acceleration of the ball as observed by the man in the lift and a man standing stationary on the ground are respectively

1) g, g 2) g-a, g-a 3) g-a, g 4) a, g

34. A 4000 kg lift is accelerating upwards. The tension in the supporting cable is 48000 N. If g = $10 ms^{-2}$ then the acceleration of the lift is
1) 1 ms^{-2} 2) 2 ms^{-2} 3) 4 ms^{-2} 4) 6 ms^{-2}

35. 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
1) 24 N 2) 74 N 3) 15 N 4) 49 N

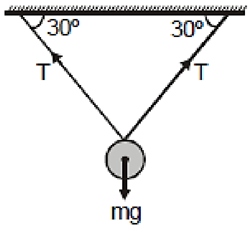
36. A triangular block of mass M with angles 30°, 60°, and 90° rests with its 30°–90° side on a horizontal table. A cubical block of mass m rests on the 60°–30° side. The acceleration which M must have relative to the table to keep m stationary relative to the triangular block assuming frictionless contact is
1) g 2) $\frac{g}{\sqrt{2}}$ 3) $\frac{g}{\sqrt{3}}$ 4) $\frac{g}{\sqrt{5}}$

37. A uniform chain of length *l* and mass *m* is hanging vertically from its ends A and B which are close together. At a given instant the end B is released. What is the tension at A when B has fallen a distance?
1) $\frac{mg}{2}\left[1+\frac{3x}{\ell}\right]$ 2) $mg\left[1+\frac{2x}{\ell}\right]$ 3) $\frac{mg}{2}\left[1+\frac{x}{\ell}\right]$ 4) $\frac{mg}{2}\left[1+\frac{4x}{\ell}\right]$

38. Two blocks of masses 2 kg and 1 kg are placed on a smooth horizontal table in contact with each other. A horizontal force of 3 newton is applied on the first so that the block moves with a constant acceleration. The force between the blocks would be
1) 3 newton 2) 2 newton 3) 1 newton 4) zero

39. A rope of length 4 m having mass 1.5 kg/m lying on a horizontal frictionless surface is pulled at one end by a force of 12N. What is the tension in the rope at a point 1.6 m from the other end?
1) 5N 2) 4.8N 3) 7.2N 4) 6N

40. 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 $\left(g = 10 ms^{-2}\right)$



1) 30 N 2) 20 N 3) 10 N 4) 5 N

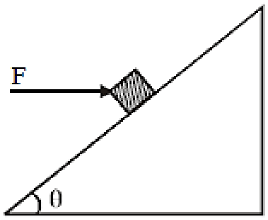
41. A light string passing over a smooth light pulley connects two blocks of masses m_1 and m_2 (vertically). If the acceleration of the system is *g*/8, then the ratio of the masses is
1) 8 : 1 2) 9 : 7 3) 4 : 3 4) 5 : 3

42. 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
1) $\frac{Pm}{M+m}$ 2) $\frac{Pm}{M-m}$ 3)P 4) $\frac{PM}{M+m}$

Topic 4: Friction

43. Consider a car moving on a straight road with a speed of 100 m/s . The distance at which car can be stopped is $[\mu_k = 0.5]$
1) 1000 m 2) 800 m 3) 400 m 4) 100 m

44. A horizontal force F is applied on block of mass m placed on a rough inclined plane of inclination θ . The normal reaction N is



1) $mg\cos\theta$ 2) $mg\sin\theta$ 3) $mg\cos\theta - F\cos\theta$ 4) $mg\cos\theta + F\cos\theta$

45. 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 $\left(g = 10ms^{-2}\right)$

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

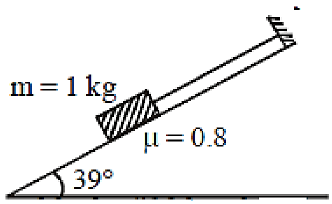
46. A block rests on a rough inclined plane making an angle of 30° with the horizontal. The coefficient of static friction between the block and the plane is 0.8. If the frictional force on the block is 10 N, the mass of the block (in kg) is take $\left(g = 10ms^{2}\right)$

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

47. A body starts from rest on a long inclined plane of slope 45°. The coefficient of friction between the body and the plane varies as μ =0.3xwhere *x* is distance travelled down the plane. The body will have maximum speed for $\left(g = 10ms^{2}\right)$ when x =

1) 9.8 m 2) 27 m 3) 12 m 4) 3.33 m

48. For the arrangement shown in the Figure the tension in the string is $\left[\text{Given} : \tan^{-1}(0.8) = 39^0\right]$



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

49. A 100 N force acts horizontally on a block of 10 kg placed on a horizontal rough surface of coefficient of friction $\mu = 0.5$ If the acceleration due to gravity (g) is taken as10ms^{-2}. The acceleration of the block(in ms^{-2}), the acceleration of the block (in ms^{-2}) is

(a) 2.5 (b) 10 (c) 5 (d) 7.5

50. A block of mass 0.1kg is held against a wall applying a horizontal force of 5 N on the block. If the coefficient of friction between the block and the wall is 0.5, the magnitude of the frictional force acting on the block is:

(a) 2.5 N (b) 0.98 N (c) 4.9 N (d) 0.49 N

51. A block of mass m is placed on a surface with a vertical cross section given by $y = \frac{x^3}{6}$ = If the coefficient of friction is 0.5, the maximum height above the ground at which the block can be placed without slipping is:

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

52. Starting from rest, a body slides down a 45° inclined plane in twice the time it takes to slide down the same distance in the absence of friction. The coefficient of friction between the body and the inclined plane is:

(a) 0.33 (b) 0.25 (c) 0.75 (d) 0.80

Topic 5: Circular Motion and Banking of Road

53. A cane filled with water is revolved in a vertical circle of radius 4 meter and the water just does not fall down. The time period of revolution will be

(a) 1 sec (b) 10 sec (c) 8 sec (d) 4 sec

54. The coefficient of friction between the rubber tyres and the road way is 0.25. The maximum speed with which a car can be driven round a curve of radius 20 m without skidding is
(g = 9.8 m/s2)
(a) 5 m/s (b) 7 m/s (c) 10 m/s (d) 14 m/s

55. A bucket tied at the end of a 1.6 m long string is whirled in a vertical circle with constant speed. What should be the minimum speed so that the water from the bucket does not spill when the bucket is at the highest position?
(a) 4 m/sec (b) 6.25 m/sec (c) 16 m/sec (d) None of the above

56. A body of mass 0.4 kg is whirled in a vertical circle making 2 rev/sec. If the radius of the circle is 1.2 m, then tension in the string when the body is at the top of the circle, is
(a) 41.56 N (b) 89.86 N (c) 109.86 N (d) 115.86 N

57. A body of mass '*m*' is tied to one end of a spring and whirled round in a horizontal plane with a constant angular velocity. The elongation in the spring is 1 cm. If the angular velocity is doubled, the elongation in the spring is 5 cm. The original length of the spring is :
(a) 15 cm (b) 12 cm (c) 16 cm (d) 10 cm

58. A person with his hands in his pockets is skating on ice at the velocity of 10 m/s and describes a circle of radius 50 m. What is his inclination with vertical
1) $\tan^{-1}\left(\frac{1}{10}\right)$ 2) $\tan^{-1}\left(\frac{3}{5}\right)$ 3) $\tan^{-1}(1)$ 4) $\tan^{-1}\left(\frac{1}{5}\right)$

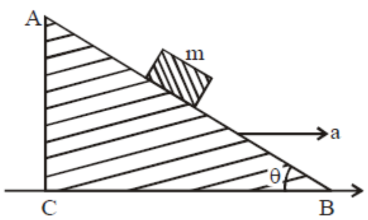
59. The minimum velocity (in ms–1) with which a car driver must traverse a flat curve of radius 150 m and coefficient of friction 0.6 to avoid skidding is
(a) 60 (b) 30 (c) 15 (d) 25

60. The string of a pendulum of length l is displaced through 90º from the vertical and released. Then the minimum strength of the string in order to withstand the tension as the pendulum passes through the mean position is
(a) 3 m g (b) 4 m g (c) 5 m g (d) 6 m g

NEET PREVIOUS YEARS QUESTIONS

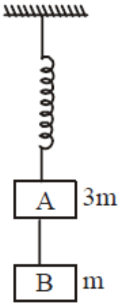
1. Which one of the following statements is incorrect? **[2018]**
1) Rolling friction is smaller than sliding friction.
2) Limiting value of static friction is directly proportional to normal reaction.
3) Coefficient of sliding friction has dimensions of length.
4) Frictional force opposes the relative motion.

2. A block of mass m is placed on a smooth inclined wedge ABC of inclination q as shown in the figure. The wedge is given an acceleration 'a' towards the right. The relation between a and q for the block to remain stationary on the wedge is **[2018]**



1) $a = \frac{g}{\operatorname{cosec}\theta}$ 2) $a = \frac{g}{\sin\theta}$ 3) $a = g\tan\theta$ 4) $a = g\cos\theta$

3. Two blocks A and B of masses 3 m and m respectively are connected by a massless and inextensible string. The whole system is suspended by a massless spring as shown in figure. The magnitudes of acceleration of A and B immediately after the string is cut, are respectively : **[2017]**



1) g/3,g 2) g, g 3) g/3, g/3 4) g,g/3

4. 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 'v' the net force on the particle (directed towards centre) will be (T represents the tension in the string) **[2017]**

1) $T+\frac{mv^2}{1}$ 2) $T-\frac{mv^2}{1}$ 3) zero 4) T

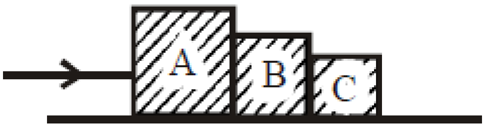
5. What is the minimum velocity with which a body of mass m must enter a vertical loop of radius R so that it can complete the loop ? **[2016]**

1) $\sqrt{gR}$ 2) $\sqrt{2gR}$ 3) $\sqrt{3gR}$ 4) $\sqrt{5gR}$

6. A block A of mass m_1 rests on a horizontal table. A light 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 μk. When the block A is sliding on the table, the tension in the string is **[2015]**

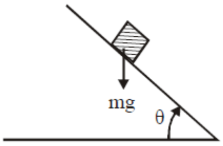
1) $\frac{(m_2-\mu k m_1)g}{(m_1+m_2)}$ 2) $\frac{m_1 m_2(1+\mu_k)}{(m_1+m_2)}$ 3) $\frac{m_1 m_2(1-\mu_k)g}{(m_1+m_2)}$ 4) $\frac{(m_2+\mu_k m_1)g}{(m_1+m_2)}$

7. 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 **[2015]**



1) 6 N 2) 8 N 3) 18 N 4) 2 N

8. 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 30° the box starts to slip and slides 4.0 m down the plank in 4.0s. The coefficients of static and kinetic friction between the box and the plank will be, respectively : **[2015]**

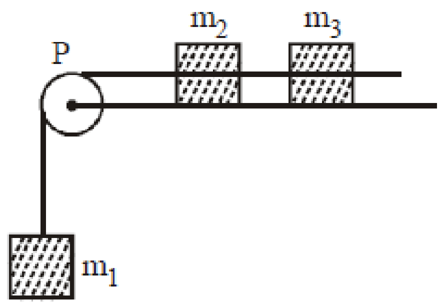


1) 0.6 and 0.5 2) 0.5 and 0.6 3) 0.4 and 0.3 4) 0.6 and 0.6

9. Two stones of masses m and 2 m are whirled in horizontal circles, the heavier one in radius r/2 and the 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 : **[2015]**

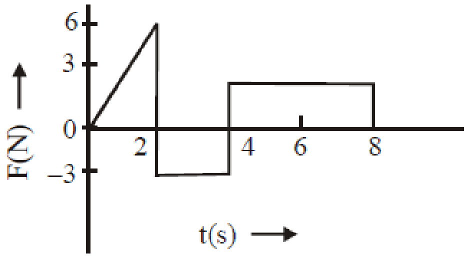
1) 3 2) 4 3) 1 4) 2

10. 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 a 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 $m_1 = m_2 = m_3 = m$) **[2014]**



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

11. 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 : **[2014]**

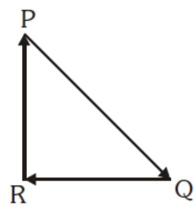


1) 24 Ns 2) 20 Ns 3) 12 Ns 4) 6 Ns

12. 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'? **[2014]**

1) $\frac{2ma}{g+a}$ 2) $\frac{2ma}{g-a}$ 3) $\frac{ma}{g+a}$ 4) $\frac{ma}{g-a}$

13. A particle moving with velocity $\vec{V}$ is acted by three forces shown by the vector triangle PQR. The velocity of the particle will : **[NEET- 2019]**



(1) increase (2) decrease (3) remain constant (4) change according to the smallest force $\overrightarrow{OR}$

14. 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 : ($g = 10\ m/s^2$) **[NEET- 2019]**

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

15. When an object is shot from the bottom of a long smooth inclined plane kept at an angle 60° with horizontal, it can travel a distance x_1 along the plane. But when the inclination is decreased to 30° and the same object the shot with the same velocity, it can travel x_2 distance. Then $x_1 : x_2$ will be **[NEET- 2019]**

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

16. A person standing on the floor of an elevator drops a coin. The coin reaches the floor in time t_1 if the elevator is at rest and in time t_2 if the elevator is moving uniformly. Then :- **[NEET – 2019 (ODISSA)]**

(1) $t_1 < t_2$ or $t_1 > t_2$ depending upon whether the lift is going up or down

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

17. A truck is stationary and has a bob suspended by a light string, in a frame attached to the truck. The truck, suddenly moves to the right with an acceleration of a. The pendulum will **tilt** **[NEET – 2019 (ODISSA)]**

(1) to the left and angle of inclination of the pendulum with the vertical is $\sin^{-1}\left(\frac{g}{a}\right)$

(2) to the left and angle of inclination of the pendulum with the vertical is $\tan^{-1}\left(\frac{a}{g}\right)$

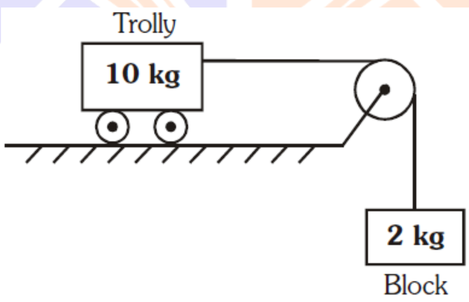
(3) to the left and angle of inclination of the pendulum with the vertical is $\sin^{-1}\left(\frac{a}{g}\right)$

(4) to the left and angle of inclination of the pendulum with the vertical is $\tan^{-1}\left(\frac{g}{a}\right)$

18. A body of mass m is kept on a rough horizontal surface (coefficient of friction = μ) A horizontal force is applied on the body, but it does not move. The resultant of normal reaction and the frictional force acting on the object is given by F, where F is : **[NEET – 2019 (ODISSA)]**

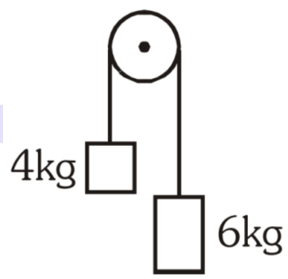
1) $|\vec{F}| = mg + \mu mg$ 2) $|\vec{F}| = \mu mg$ 3) $|\vec{F}| \le mg\sqrt{1+\mu^2}$ 4) $|\vec{F}| = mg$

19. Calculate the acceleration of the block and trolly system shown in the figure. The coefficient of kinetic friction between the trolly and the surface is 0.05. (g = 10 m/s^2, mass of the string is negligible and no other friction exists). **[NEET – 2020 (COVID-19]**



(1) 1.25 m/s^2 (2) 1.50 m/s^2 (3) 1.66 m/s^2 (4) 1.00 m/s^2

20. Two bodies of mass 4kg and 6kg are tied to the ends of a massless string. The string passes over a pulley which is frictionless (see figure). The acceleration of the system in terms of acceleration due to gravity **[NEET – 2020]**



1) g/10 2) g 3) g/2 4) g/5

21. 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 (g = 10 m/s^2) nearly **[NEET-2021]**

1) 4.2 kg m/s 2) 2.1 kg m/s 3) 1.4 kg m/s 4) 0 kg m/s

22. An electric lift with a maximum load of 2000 kg (lift + passengers) is moving up with a constant speed of 1.5 ms^{-1}. The frictional force opposing the motion is 3000N. The minimum power delivered by the motor to the lift in watts is : $\left(g = 10ms^{-1}\right)$ **[NEET-2022]**

1) 23000 2) 20000 3) 34500 4) 23500

NCERT LINE BY LINE QUESTIONS – ANSWERS

NCERT LINE BY LINE ANSWERS

1) d 2) c 3) a 4) b 5) a 6) c 7) b 8) a 9) b 10) c
11) c 12) a 13) d 14) a 15) b 16) b 17) c 18) b 19) a 20) a

NCERT BASED QUESTIONS

1) a 2) a 3) a 4) d 5) a 6) d 7) a 8) a 9) b 10) a
11) c 12) b 13) a 14) a 15) a 16) a 17) c 18) b 19) c 20) c
21) d 22) d 23) b 24) c 25) c 26) c 27) d 28) c 29) d 30) b
31) a 32) a 33) c 34) d 35) c 36) b 37 b 38) a 39) a 40) a

TOPIC WISE PRACTICE QUESTIONS - ANSWERS

1) 2	2) 2	3) 3	4) 3	5) 3	6) 2	7) 2	8) 3	9) 4	10) 4
11) 4	12) 3	13) 2	14) 2	15) 3	16) 1	17) 3	18) 1	19) 1	20) 2
21) 1	22) 1	23) 4	24) 1	25) 3	26) 3	27) 1	28) 4	29) 1	30) 2
31) 4	32) 3	33) 3	34) 2	35) 1	36) 3	37) 1	38) 3	39) 2	40) 2
41) 2	42) 4	43) 1	44) 4	45) 4	46) 3	47) 4	48) 4	49) 3	50) 2
51) 1	52) 3	53) 4	54) 2	55) 1	56) 1	57) 1	58) 4	59) 2	60) 1

NEET PREVIOUS YEARS QUESTIONS-ANSWERS

1) 3	2) 3	3) 1	4) 4	5) 4	6) 2	7) 1	8) 1	9) 4	10) 3
11) 3	12) 1	13) 3	14) 3	15) 3	16) 4	17) 2	18) 3	19) 1	20) 4
21) 1	22) 3								

TOPIC WISE PRACTICE QUESTIONS - SOLUTIONS

1. (2) Inertia is resistance to change.
2. (2) A cricketer lower his hands while catching a ball to increase the time so as to decrease the force exerted by the ball on cricketer's hands. This is not an example of Newton's third law of motion.
3. 3) Mass (m) = 0.3kg $\Rightarrow F = m.a = -15x$

$$a = -\frac{15}{0.3}x = \frac{-150}{3}x = -50x \;;\; a = -50\times 0.2 = 10 m/s^2$$

4. 3) $F = ma \Rightarrow a = \frac{F}{m} = \frac{5\times 10^4}{3\times 10^7} = \frac{5}{3}\times 10^{-3} ms^{-2}$

Also, $v^2 - u^2 = 2as \Rightarrow v^2 - 0^2 = 2 \times \frac{5}{3} \times 10^{-3} \times 3 = 10^{-2} \Rightarrow v = 0.1ms^{-1}$

5. 3)Thrust = $\frac{udM}{dt} = mg \Rightarrow \frac{dM}{dt} = \frac{mg}{u} = \frac{600 \times 10}{1000} = 6kgs^{-1}$

6. 2) Here $u = 5ms^{-1}, v = -3ms^{-1}, t = 2s, a = ?$ using $a = \frac{v-u}{t} = \frac{-3-5}{2} = -4m/s^2$

$\therefore$ Force, $F = ma = 20 \times -4 = -80N$

7. 2) Thrust on the satellite, $F = \frac{-vdM}{dt} = -v(\alpha v) = -\alpha v^2$; Acceleration = $\frac{F}{M} = \frac{-\alpha v^2}{M}$

8. 3) The body will continue accelerating until the resultant force acting on the body becomes zero

9. 4) Here m = 0.5kg; u -10m/s; t = 1/50s; v = +15ms^{-1}

Force = m(v-u)/t=0.5(10+15) $\times$50=625N

10. 4)

Mass ,m = 0.2kg

Total height, h = 0.2 + 2 = 2.2m

Work done =Difference in potential energy.

F.S = mgh where S is the distance for ehich the force is applied by hand,

S = 0.2m

$F = \frac{mgh}{S} = \frac{0.2 \times 10 \times 2.2}{0.2}$

F = 22N

11. 4)

Assume initial velocity of 1.5 m/s is in the x-direction

Since there are no forces on it in this direction, there will be no acceleration.

So, distance $S_x = 1.5 \times 4 = 6m$

In the y-direction, F = 5N and m = 5kg

Acceleration in y=direction,

$a_y = \frac{F}{m} = \frac{5}{5} = 1m/s^2$

$S_y = \frac{1}{2}a_y t^2 = \frac{1}{2} \times 1 \times 4^2 = 8m$

Resolving the x and y vector we get,

$S^2 = S_x^2 + S_y^2$

$S^2 = 6^2 + 8^2$

$S = \sqrt{36 + 64}$

$S = \sqrt{100}$

S = 10m

12. 3) From Newton's second law, $F = \frac{dp}{dt} = m\frac{dv}{dt}$

When the external force is zero, $m\frac{dv}{dt} = 0$

or v = constant, this is Newton's first law of motion. That is if the net force acting on the system of mass is zero. Then, the velocity of the system remains constant. Let two objects moving with momentum p_1 and p_2 respectively. Thus, net momentum, p = p_1+p_2 If the total momentum is constant , then $\frac{dp}{dt} = 0$ or $\frac{dp_1}{dt} + \frac{dp_2}{dt} = 0$

Thus, F_1+F_2 = 0 or F_1= −F_2, this is the third law.

13. 2) m = 10kg, $x = (t^3 - 2t - 10)$m

$\frac{dx}{dt} = v = 3t^2 - 2$ $\frac{d^2x}{dt^2} = a = 6t$

At the end of 4 seconds, a = $6 \times 4 = 24 m/s^2$

$F = ma = 10 \times 24 = 240N$ because F_1 is equal to the vector sum of F_2 & F_3

14. 2) Balance each other

mg and N cannot form action - reaction pair as they are acting on same body. They balance each other to keep the block at rest.

15. 3) Mass $= 150gm = \frac{150}{1000}kg$

$Force = Mass \times acceleration = \frac{150}{1000} \times 20N = 3N$

Impulsive force $= F.\Delta t = 3 \times 0.1 = 0.3N$

16. 1) As we know, $|impulse| = |change\ in\ momentum| = |p_2 - p_1| = |0 - mv_1| = |0 - 3 \times 2| = 6Ns$

17. 3) Change in momentum of the ball

$= mv\sin\theta - (-mv\sin\theta) = 2mv\sin\theta = mg \times \frac{2v\sin\theta}{g}$ = weight of the ball × total time of flight

18. 1) Force required = $\frac{change\ in\ momentum}{time\ taken} = \frac{(50 \times 10^{-3} \times 30) \times 400 - (5 \times 0)}{60} = 10N$

19. 1) For a given mass $P \propto V$ If the momentum is constant then its velocity must be constant.

20. 2) Total momentum = $2p\hat{i} + p\hat{j}$ Magnitude of total momentum = $\sqrt{(2p)^2 + p^2} = \sqrt{5p^2} = \sqrt{5}p$

This must be equal to the momentum of the third part.

21. 1) $P_{skater} + P_{snowball} = 0 = \frac{-(0.15kg)(35m/s)}{(50kg)} = -0.10m/s$

The negative sign indicates that the momenta of the skater and the snowball are in opposite directions

22. 1) $\frac{m}{20}v = \left(m + \frac{m}{20}\right)V = \frac{21}{20}mV$

23. 4) Let v_1 = velocity when height of free fall is h_1

v_2 = velocity when height of free rise is h_2

$\therefore v_1^2 = u^2 + 2gh_1$ for free fall or For free rise after impact on ground

$0 = v_2^2 - 2gh_2$ or $v_2^2 = 2gh_2$

Initial momentum = mv1

Final momentum = mv2

$\therefore$ Change in momentum = $m(v_1 - v_2) = m\left(\sqrt{2gh_1} - \sqrt{2gh_2}\right)$

24. 1) As the ball, m = 10 g = 0.01 kg rebounds after striking the wall

$\therefore$ Change in momentum = *mv* – (–*mv*) = 2 *mv*

Inpulse = Change in momentum = 2*mv*

$\therefore v = \frac{Impulse}{2m} = \frac{0.54Ns}{2 \times 0.01kg} = 27ms^{-1}$

25. 3) $\frac{dM}{dt} = 0.1kg/s, v_{gas} = 50m/s$

Mass of the rocket = 2 kg. Mv = constant

$-v\frac{dM}{dt} + M\frac{dv}{dt} = 0$

$\therefore \frac{dv}{dt} = \frac{1}{M} v \frac{dM}{dt} \Rightarrow \text{acceleration} = \frac{1}{2} \times 50 \times 0.1 = 2.5 m/s^2$

26. 3)

$\text{Given, } p = a + bt^2$

$\frac{dp}{dt} = 2bt$

$\because \quad F = \frac{dp}{dt}$

$\therefore \quad F = 2bt$

or $F \propto t$

27. 1) Force acting on the ballon,

$F = 7 \times \frac{8}{5.6} = 10 \text{dynes} = 10^{-4} N$

28. 4) Applying law of conservation of momentum

$Mv_3 = Mv \frac{(\hat{i} + \hat{j})}{\sqrt{1^2 + 1^2}} \Rightarrow v_3 = v \frac{(\hat{i} + \hat{j})}{\sqrt{2}}$

29. 1)

Initial momenut of the system $\vec{P} = 0$

Final momentum $= \vec{P}_1 \vec{P}_2 + \vec{P}_3$

By the law of conservation of momentum br> $\vec{P} = \vec{P}_1 + \vec{P}_2 + \vec{P}_3$ or $, 0 = \vec{P}_1 + \vec{P}_2 + \vec{P}_3$ or $, \vec{P}_1 + \vec{P}_2 = -\vec{P}_3$

Thus the magnitude of $(\vec{P}_1 + \vec{P}_2)$ will be equal to the magnitude of $\vec{P}_3$

$|\vec{P}_1 \times \vec{P}_2)| = \sqrt{P_1^2 + P_2^2} = \sqrt{(2 \times 12)^2 + (2 \times 16)^2} = 34$

$|\vec{P} + \vec{P}_1| = |\vec{P}_3|$

$= 34 = 40m$ or $, m = 0.8 kg$

So the total m ass of the sell $= 1 + 2 + 0.9 = 3.8 kg$

30. 2) Apply Newton's second law

$F_A = f_{AB}$, therefore:

$m_A a_A = (m_A + m_B) a_{AB}$ and $a_{AB} = a_A / 5$

Therefore: $m_A a_A = (m_A + m_B) a_A / 5$ which reduces to

$4m_A = m_B \text{or} 1:4$

31. 4) $\because v = \text{constant}$

So, $a = 0$, Hence, $F_{net} = ma = 0$

32. 3) The equations of motion are 2mg – T = 2ma

T-mg=ma $\Rightarrow$ T= 4ma & a = g/3 so T = 4mg/3

If pulley is accelerated upwards with an accleration a, then tension in string is

$T = \frac{4m}{3}(g + a)$

33. 3) For the man standing in the left, the acceleration of the ball $\vec{a}_{bm} = \vec{a}_b - \vec{a}_m \Rightarrow a_{bm} = g - a$

Where '*a*' is the acceleration of the mass (because the acceleration of the lift is '*a*')

For the man standing on the ground, the acceleration of the ball

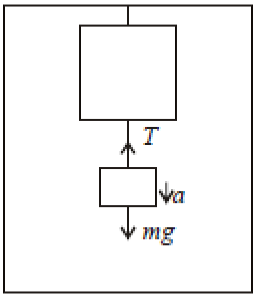
$\vec{a}_{bm} = \vec{a}_b - \vec{a}_m \Rightarrow a_{bm} = g - 0 = g$

34. 2) $T = m(g + a)$

$48000 = 4000(10 + a) \Rightarrow a = 2ms^{-2}$

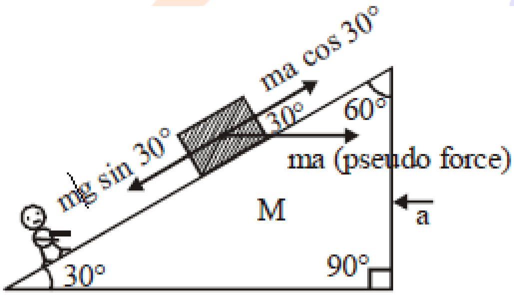
35. 1) For the bag accelerating down

$mg - T = ma$



$\therefore T = m(g-a) = \frac{49}{10}(10-5) = 24.5N$

36. 3) $ma\cos 30^0 = mg\sin 30^0$



$\therefore a = \frac{g}{\sqrt{3}}$

37. 1)

Let the chain fall through distance 'dn' in the time 'Δt'

initial momentum of $\frac{dx}{2}$ part going towards end A of the chain

$= \left(\frac{dx}{2}\right)\left(\frac{W}{Lg}\right)v$

Now as the chain has slanted falling freely

$v = \sqrt{2g\left(\frac{dx}{2}\right)}$

final momentum as the = 0 (as the chain stops waning as it woven on the A end)

Change in momentum $= \left(\frac{dx}{2}\right)\left(\frac{W}{Lg}\right)v$

As all this happens in Δt time

force $= \left(\frac{W}{Lg}\right)\left(\frac{dx}{2\Delta t}\right)v$

$= \frac{W}{Lg}\left(v^2\right)$

This in the force due to change in momentum at the end of the chain attached at point A.

force due to weight of $\frac{dx}{2} = \frac{W}{L}\frac{dx}{2}$

Total force due to $\left(\frac{dx}{2}\right)$ length $= \frac{W}{L}\frac{dx}{2} + \frac{W}{Lg}v^2$

$= \frac{W}{L}\frac{dx}{2} + \frac{W}{Lg}dx$

$\frac{3}{2}\frac{W}{L}dx$

Now weight due to initially hanging $\frac{L}{2}$ length of chain

$= \frac{W}{L}\left(\frac{L}{2}\right)$

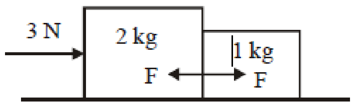
Total force =Total weight

$\frac{W}{L}\left(\frac{L}{2}\right) + \frac{3}{2}\frac{W}{L}dx$

for 'x' length of fall $f_{total} = \frac{W}{L}\left(\frac{L}{2}\right) + \frac{3}{2}\frac{3}{2}\frac{W}{L}x$

$\rightarrow f_{total} = \frac{W}{2}\left(1 + \frac{3x}{L}\right)$

38. 3) See fig. Let F be the force between the blocks and a their common acceleration. Then for 2 kg block,



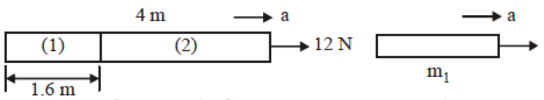
$3 - F = 2a$ ...(1)

for 1 kg block, $F = 1 \times a = a$ ...(2)

$\therefore 3 - F = 2F$ or $3F = 3$ or $F = 1$ newton

39. 2) As in fig. the mass of the rope : $m = 4 \times 1.5 = 6kg$

Acceleration : a = 12/6 = 2m/s^2



Mass of part 1 as in fig. : $m_1 = 1.6 \times 1.5 = 2.4\,kg$ $T = m_1 a$ $= 2.4 \times 2 = 4.8\,N$

40. 2) $2T\cos 60^0 = mg$ or $T = mg = 2 \times 10 = 20N$

41. 2)

For mass m1

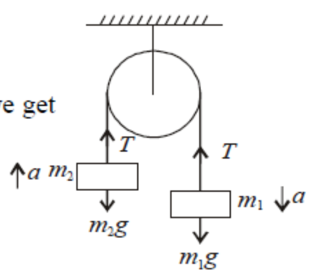
$m_1 g - T = m_1 a$

For mass m2

$T - m_2 g = m_2 a$

Adding the equations we get

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



Here $a = \frac{g}{8}$

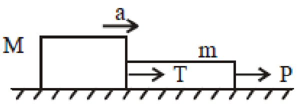
$\therefore \frac{1}{8} = \frac{\frac{m_1}{m_2} - 1}{\frac{m_1}{m_2} + 1} \Rightarrow \frac{m_1}{m_2} + 1 = 8\frac{m_1}{m_2} - 8 \Rightarrow \frac{m_1}{m_2} = \frac{9}{7}$

42. 4)

Taking the rope and the block as a system

we get $P = (m+M)\,a$

$\therefore\ a = \dfrac{P}{m+M}$



Taking the block as a system,

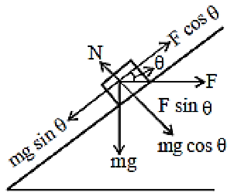
we get $T = Ma$ $\quad \therefore\ T = \dfrac{MP}{m+M}$

43. 1) $v^2 - u^2 = 2as$ or $0^2 - u^2 = 2(-\mu k g)s$

$-100^2 = 2 \times -\dfrac{1}{2} \times 10 \times s$

$s = 1000m$

44. 4)



From figure $N = mg\cos\theta + F\sin\theta$

45. 4) Limiting friction= $0.5 \times 2 \times 10 = 10N$

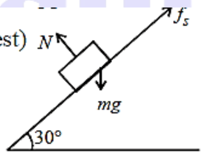
The applied force is less than force of friction, therefore the force of friction is equal to the applied force.

46. 3)

$mg\sin\theta = f_s$ (for body to be at rest)

$\Rightarrow m \times 10 \times \sin 30° = 10$

$\Rightarrow m \times 5 = 10 \Rightarrow m = 2.0$ kg



47. 4) When the body has maximum speed then

$\mu = 0.3x = \tan 45^0 \therefore x = 3.33m$

48. 4) Here $\tan\theta = 0.8$

Where θ is angle of repose

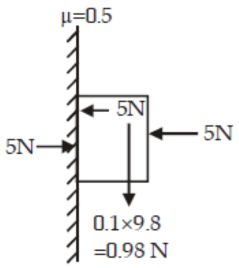
$\theta = \tan^{-1}(0.8) = 39^0$

The given angle of inclination is equal to the angle of repose. So the 1 kg block has no tendency to move.

$\therefore mg\sin\theta =$ force of friction $\Rightarrow T = 0$

49. 3) $a = \dfrac{F - \mu R}{m} = \dfrac{100 - 0.5 \times (10 \times 10)}{10} = 5ms^{-2}s$

50. 2) The magnitude of the frictional force f has to balance the weight 0.98 N acting downwards. Therefore the frictional force = 0.98 N



51. 1) At limiting equilibrium, $\mu = \tan\theta$

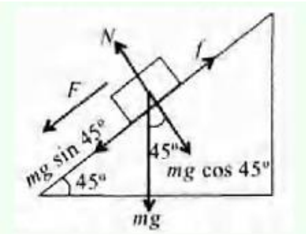
$\tan\theta = \mu = \dfrac{dy}{dx} = \dfrac{x^2}{2}$ (from question)

$\because$ Coefficient of friction $\mu = 0.5$

$\therefore 0.5 = \frac{x^2}{2} \Rightarrow x = \pm 1$

Now, $y = \frac{x^3}{6} = \frac{1}{6} m$

52. 3) The various forces acting on the body have been shown in the figure. The force on the body down the inclined plane in presence of friction μ is



$F = mgsin\theta - f = mgsin\theta - \mu N = ma$

or $a = gsin\theta - \mu gcos\theta$.

Since block is at rest thus initial velocity u = 0

$\therefore$ Time taken to slide down the plane

$t_1 = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2s}{g\sin\theta - \mu g\cos\theta}}$

In absence of friction time taken will be $t_2 = \sqrt{\frac{2s}{g\sin\theta}}$

Given : $t_1 = 2t_2$.

$\therefore t_1^2 = 4t_2^2$ or $\frac{2s}{g(\sin\theta - \mu\cos\theta)} = \frac{2s \times 4}{g(\sin\theta)}$

or $\sin\theta = 4\sin\theta - 4\mu\cos\theta$ or $\mu = \frac{3}{4}\tan\theta = 0.75$

53. 4) The speed at the highest point must be $v \geq \sqrt{rg}$

Now $v = r\omega = r(2\pi/T)$

$\therefore r(2\pi/T) > \sqrt{rg}$ or $T < \frac{2\pi r}{\sqrt{rg}} < 2\pi\sqrt{\left(\frac{r}{g}\right)}$

$\therefore T = 2\pi\sqrt{\left(\frac{4}{9.8}\right)} = 4 sec$

54. 2) $\mu mg = mv^2/r$ or $v = \sqrt{\mu gr}$ or $v = \sqrt{(0.25 \times 9.8 \times 20)} = 7 m/s$

55. 1) Since water does not fall down, therefore the velocity of revolution should be just sufficient to provide centripetal acceleration at the top of vertical circle. So, $v = \sqrt{(gr)} = \sqrt{\{10 \times (1.6)\}} = \sqrt{(16)} = 4 m/sec$

56. 1) Given: Mass(m) = 0.4kg
It frequency (n) = 2rev/sec
Radius (r) = 1.2m. we know that linear velocity of the body (v) = $\omega t = (2\pi n)r = 2 \times 3.14 \times 1.2 \times 2 = 15.08 m/s$
Therefore, tension in the string when the body is at the top of the circle (T)

$= \frac{mv^2}{r} - mg = \frac{0.4 \times (15.08)^2}{2} - (0.4 \times 9.8) = 45.78 - 3.92 = 41.56N$

57. 1)

Given,

Centrifugal force will stretch the string

$m(l+1)\omega^2 = kx$

At elongation $(x = 1)$

$m(l+1)\omega^2 = k \times 1$ ......(1)

At elongation $(x = 5)$

$m(l+5)(2\omega)^2 = K \times 5$ ...... (2)

From (1) and (2)

$l = 15$ cm

58. 4) The inclination of person from vertical is given by

$\tan\theta = \frac{v^2}{rg} = \frac{(10)^2}{50\times10} = \frac{1}{5} \therefore \theta = \tan^{-1}(1/5)$

59. 2) For negotiating a circular curve on a levelled road, the maximum velocity of the car is $v_{max} = \sqrt{\mu rg}$ Here $\mu = 0.6, r = 150m, g = 9.8$

$\therefore v_{max} = \sqrt{0.6\times150\times9.8} \approx 30 m/s$

60. 1) The velocity at the lowest point is given by v = $\sqrt{(2gr)}$ Further, $T - mg = \frac{mv^2}{r}$(at lowest point)

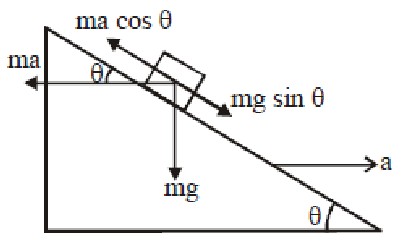
$\therefore T = mg + \frac{mv^2}{r} = mg + \frac{m(2gr)}{r} = mg + 2mg = 3mg$

NEET PREVIOUS YEARS QUESTIONS-SOLUTIONS

1. 3) Coefficient of friction or sliding friction has no dimension

$f = \mu_s N \Rightarrow \mu_s = \frac{f}{N}$

2. 3) Let the mass of block is m. It will remains stationary if forces acting on it are in equilibrium. i.e., ma cos $\theta = mg\sin\theta \Rightarrow a = g\tan\theta$



Here ma = Pseudo force on block, mg = weight.

3. 1)

Before cutting the strip

$T = mg$

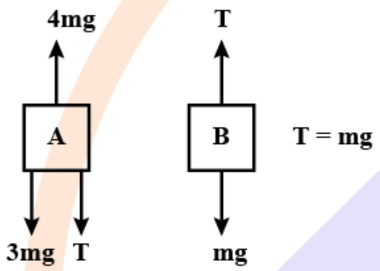
after cutting the strip

$$a_A = \frac{4mg - 3mg}{3m} = \frac{mg}{3m} = \frac{g}{3}$$

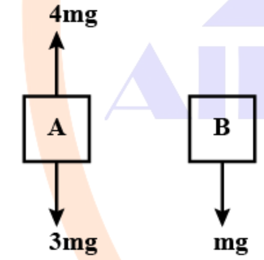
$$a_B = \frac{mg}{m} = g$$

$\frac{g}{3}, g.$

Before cutting the strip



after cutting the strip



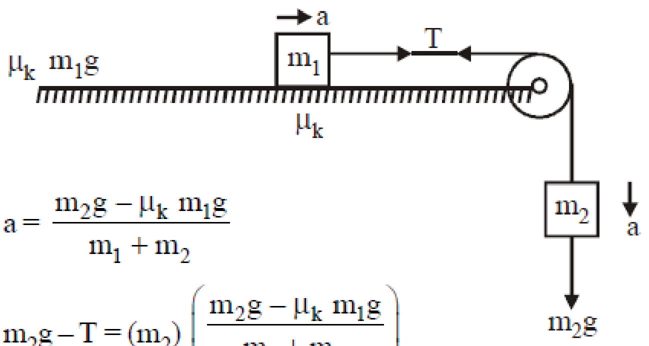
4. 4) Net force on particle in uniform circular motion is centripetal force $\left(\frac{mv^2}{1}\right)$ which is provided by tension in string so the net force will be equal to tension i.e., T.

5. 4) To complete the loop a body must enter a vertical loop of radius R with the minimum velocity $v = \sqrt{5gR}$

6. 2) For the motion of both the blocks

$m_1 a = T - \mu_k m_1 g$

$m_2 g - T = m_2 a$



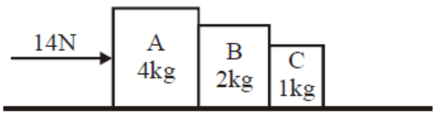
$$a = \frac{m_2g - \mu_k m_1g}{m_1 + m_2}$$

$$m_2g - T = (m_2)\left(\frac{m_2g - \mu_k m_1g}{m_1 + m_2}\right)$$

solving we get tension in the string

$$T = \frac{m_1m_2g(1+\mu_k)g}{m_1 + m_2}$$

7. 1) Acceleration of system $a = \frac{F_{net}}{M_{total}} = \frac{14}{4+2+1} = \frac{14}{7} = 2\,m/s^2$



The contact force between A and B $= (m_B + m_C) \times a = (2+1) \times 2 = 6N$

8. 1)

Static coefficient of friction is $\mu_s = \tan 30° = 0.577 \approx 0.6$

For kinetic friction, $ma = mg\sin 30 - f = mg\sin 30 - \mu_k mg\cos 30$

$$a = g\sin 30 - \mu_k g\cos 30 \ldots (1)$$

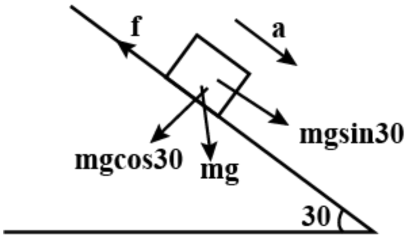
and also using $S = ut + 1/2at^2$,

$$\Rightarrow 4 = 0 + (1/2)a(4)^2$$

or $a = 0.5 m/s^2$

Now from (1) we get, $0.5 = 10(1/2) - \mu_k(10)(\frac{\sqrt{3}}{2})$

or $\mu_k = \frac{4.5}{5\sqrt{3}} = 0.5$



9. 4) According to question, two stones experience same centripetal force

i.e. $F_{C1} = F_{C2}$ or, $\frac{mv_1^2}{r} = \frac{2mv_2^2}{(r/2)}$ or, $V_1^2 = 4V_2^2$ so, $V_1 = 2V_2$ i.e., $n = 2$

10. Acceleration $= \frac{\text{net force in the direction of motion}}{\text{Total mass of system}} = \frac{m_1 g - \mu(m_2 + m_3)g}{m_1 + m_2 + m_3} = \frac{g}{3}(1 - 2\mu)$

$(\because m_1 = m_2 = m_3 = m \text{ given})$

11. 3) Change in momentum,

$\Delta p = \int F dt = \text{Area of } F - t \text{ graph} = \text{ar of } \Delta - \text{ar of } \square + \text{ar of } \square = \frac{1}{2} \times 2 \times 6 - 3 \times 2 + 4 \times 3 = 12 N - s$

12. 1) Let upthrust of air be Fa then
For downward motion of balloon
Fa = mg – ma
mg – Fa = ma
For upward motion
Fa – (m – Δm)g = (m – Δm)a
Therefore Δm = 2ma/g+a

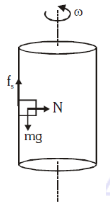
13. 3)

$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 = \vec{0}$

$\Rightarrow \vec{a} = 0$

$\Rightarrow \vec{v}$ = constant

14. 3) $f_L = \mu N = \mu m r \omega^2$



$f_s = mg$

As $f_s \le f_L$

$\Rightarrow mg \le \mu m r \omega^2 \Rightarrow \omega \ge \sqrt{\frac{g}{\mu r}}$

$\Rightarrow \omega_{min} = 10 rad/s$

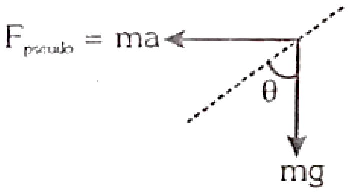
15. 3) $v^2 = u^2 - 2as$

$\Rightarrow \quad s = \frac{u^2}{2a} = \frac{u^2}{2g\sin\theta}$

$\frac{x_1}{x_2} = \frac{\sin\theta_2}{\sin\theta_1} = \frac{\sin 30^\circ}{\sin 60^\circ} = \frac{1/2}{\sqrt{3}/2} \Rightarrow \frac{x_1}{x_2} = \frac{1}{\sqrt{3}}$

16. 4) As the elevator is moving at uniform speed, so it's acceleration is zero, so, no pseudo force. Thus it can not affect the motion of the coin. Thus in both cases, the coin takes the same time. i.e, t1= t2

17. 2)



$\tan\theta = \frac{F_{pseudo}}{mg} = \frac{a}{g}$ towards left

18. 3)

If R is normal reaction,

Maximum force by surface when friction work

$F = \sqrt{f^2 + R^2} = \sqrt{\mu R^2 + R^2} \quad (\because f = \mu R)$

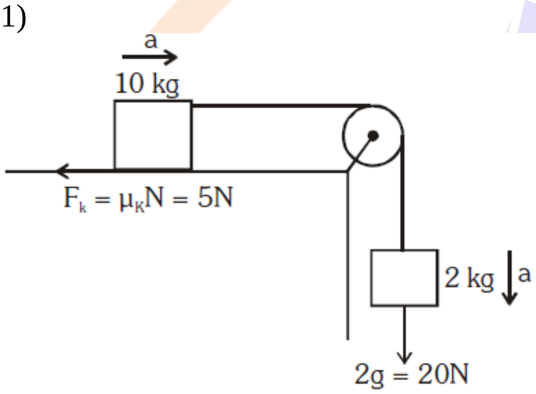
$= R\sqrt{\mu^2 + 1}$

Maximum force = R, when there is no friction.

Hence, ranging from R to $R\sqrt{\mu^2 + 1}$

we get $Mg \le f \le mg\sqrt{\mu^2 + 1}$

19. 1)



$a = \frac{\text{net force}}{\text{total mass}} = \frac{20-5}{12} = 1.25\,m/s^2$

20. 4)

$a = \frac{(m_2 - m_1)g}{m_2 + m_1} = \frac{(6-4)g}{6+4} = \frac{g}{5}$

21. 1)Given that :

Mass of ball = 0.15 kg

Height from which ball is dropped = 10 m

Impulse, $\vec{I}$ = Change in linear momentum = = $\Delta \bar{P} = \bar{P_f} - \bar{P_i}$

Velocity of ball at ground (v) $= \sqrt{2gh} = \sqrt{2\times10\times10} = 10\sqrt{2}\,m/s$

$\vec{I} = 0.15\times10\sqrt{2}(-\hat{j}) - 0.15\times10\sqrt{2}(\hat{j})$

$\vec{I} = 2\times0.15\times10\sqrt{2}(-\hat{j}) = 4.2(-\hat{j})$

magnitude of impulse = 4.2 kg m/s

22. $P = (mg + F)V$

$= (20000 + 3000)\times1.5 = 34500$