5

NEWTON'S LAWS OF MOTION

NEWTON'S FIRST LAW OF MOTION (OR GALLEO'S LAW OF INERTIA)

Every body continues its state of rest or uniform motion in a straight line unless compelled by an external force to change its state. This fundamental property of body is called inertia at rest.

This law defines the force and states that the force is a factor which can change the state of object.

Definition of force from Newton's first law of motion "Force is the push or pull which changes or tends to change the state of rest or of uniform motion".

INERTIA

Inertia is the property of a body due to which it opposes the change in its state. Inertia of a body is measured by mass of the body.

Inertia $\propto$ mass

NEWTON'S SECOND LAW OF MOTION

Rate of change in momentum of a body is always equal to the unbalanced external force applied on it.

$$\vec{F} = \frac{d\vec{p}}{dt} = \frac{d}{dt}(m\vec{v}) \quad \text{or} \quad \vec{F} = m\frac{d\vec{v}}{dt} + \vec{v}\frac{dm}{dt}$$

If m = constant then

$$\frac{dm}{dt} = 0$$

i.e. $\vec{F} = m\frac{d\vec{v}}{dt} = m\vec{a}$

If $\vec{v}$ = constant then

$$\frac{d\vec{v}}{dt} = 0$$

i.e. $\vec{F} = v\frac{dm}{dt}$

(e.g. conveyor belt, rocket)

* The change in momentum always takes place in the direction of force.

* This law gives the magnitude of force.

Example 1 :

A force $\vec{F} = (6\hat{i} - 8\hat{j} + 10\hat{k})$ N produces acceleration of 1 ms^{-2} in a body. Calculate the mass of the body.

Sol. $\because$ Acceleration $a = \frac{|\vec{F}|}{m}$

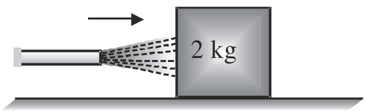
$$\therefore \quad m = \frac{|\vec{F}|}{a} = \frac{\sqrt{6^2 + 8^2 + 10^2}}{1} = 10\sqrt{2} \text{ kg}$$

Example 2 :

A block of 5 kg is resting on a frictionless plane. It is struck by a jet releasing water at a rate of 3 kg/s at a speed of 4 m/s. Calculate the initial acceleration of the block.

Sol. Force exerting on block

$$F = v\frac{dm}{dt} = 4 \times 3 = 12\text{N}$$



So acceleration of the block

$$a = \frac{F}{m} = \frac{12}{5} = 2.4 \text{ m/s}^2$$

IMPULSE

When a large force act for an extremely short duration, neither the magnitude of the force nor the time for which it acts is important. In such as case, the total effect of force is measured.

The total effect of force is called impulse (measure of the action of force).

This type of force is generally variable in magnitude and is sometimes called impulsive force.

If a large force act on a body or particle for a smaller time : then the impulse = product of force with time.

Suppose a force $\vec{F}$ acts for a short time dt then impulse= $\vec{F}$ dt

For a finite internal of time t_1 to t_2 then the impulse = $\int_{t_1}^{t_2} \vec{F}\, dt$

If constant force acts for an interval Δt then

Impulse = $\vec{F}\,\Delta t$

Example 3 :

A hammer of mass 1 kg moving with a speed of 6 m/s strikes a wall and comes to rest in 0.1s. Calculate.

(a) Impulse of the force

(b) Average retarding force that stops the hammer.

(c) Average retardation of the hammer.

Sol. (a) Impulse = F × t = m (v – u) = 1 (0 – 6) = – 6 Ns

(b) Average retarding force that stops the hammer

$$F = \frac{\text{Impulse}}{\text{time}} = \frac{6}{0.1} = 60\text{N}$$

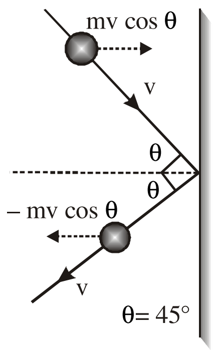
(c) Average retardation, $F = \frac{F}{m} = \frac{60}{1} = 60 \text{ m/s}^2$

Example 4 :

A ball of 0.20 kg hits a wall at an angle of 45° with a velocity of 25m/s. If the ball rebounds at 90° to the direction of incidence, calculate the change in momentum of the ball.

Sol. Change in momentum = (– mv cos 45°) – (mv cos 45°)

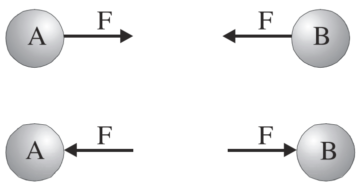
= – 2mv cos 45°



$$|\Delta\vec{p}| = 2mv\cos 45° = 2\times 0.2\times 25\times\frac{1}{\sqrt{2}} = 5\sqrt{2}\ \text{Ns}$$

NEWTON'S THIRD LAW OF MOTION

The first and second laws are statements about a single object, whereas the third law is a statement about two objects.



* According to this law, every action has equal and opposite reaction. Action and reaction act on different bodies and they are simultaneous. There can be no reaction without action.

* If an object A exerts a force F on an object B, then B exerts an equal and opposite force (–F) on A.

* Newton's III law contradicts theory of relativity, because it states that force signals can travel with infinite speed while theory of relatively states that nothing can travel with a velocity greater than velocity of light.

* Action and reaction never balance each other.

* Newton's III law can be derived from II law. (as given)

If two particles of masses m_1 and m_2 are moving under action of their mutually interacting forces with each other, such that no external force acts on the system.

Let force on 1st due to 2nd is

$$\vec{F}_{12} = \frac{d\vec{p}_1}{dt} \qquad \text{......... (i)}$$

and force on 2nd due to 1st is $\vec{F}_{21} = \frac{d\vec{p}_2}{dt}$ .... (ii)

Adding the two equations, we have

$$\vec{F}_{12} + \vec{F}_{21} = \frac{d\vec{p}_1}{dt} + \frac{d\vec{p}_2}{dt} = \frac{d}{dt}(\vec{p}_1 + \vec{p}_2)$$

Since no external force $\vec{F}_{12} + \vec{F}_{21} = \vec{0}$ acts on the system, the total of momentum of the system must be constant.

FREE BODY DIAGRAM

A free body diagram is a diagram showing the chosen body by itself, "free" of its surroundings, with vectors drawn to show the magnitudes and directions of all the forces applied to the body by the various other bodies that interact with it. Be careful to include all the forces acting on the body, but the equally careful not to include any forces that the body exerts on any other body. In particular, the two forces in an action-reaction pair must never appear in the same free-body diagram because they never act on the same body.
[Forces that a body exerts on itself are never included, since these can't affect the body's motion.]

CONTACT FORCE

Contact forces arises when one body is in physical contact with another.

Example : Forces exerted by ropes or springs, the force involved in collisions, the force of friction between two surfaces, and the force exerted by a fluid on its container.

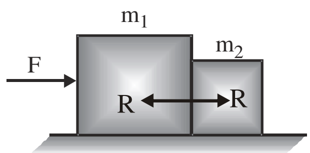
Two bodies in contact :

Two blocks of masses m_1 and m_2 placed in contact with each other on a frictionless horizontal surface.

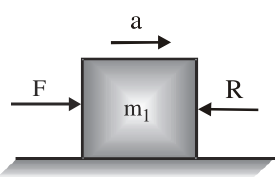
Case I :

Let a force F be applied on block of mass m_1.

Acceleration of both the blocks,



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



FBD of m_1

Let the force of contact = R

By FBD of m_1

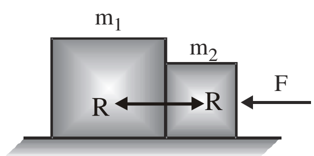
$F - R = m_1 a$

$$R = F - m_1 a = F - m_1\frac{F}{m_1 + m_2}$$

$$= \left(1 - \frac{m_1}{m_1 + m_2}\right) = \frac{m_2 F}{m_1 + m_2}$$

Case II :

If force F is applied on block of mass m_2

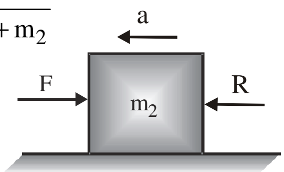


Common acceleration, $a = \dfrac{F}{m_1 + m_2}$

By FBD of m_2,

$F - R_1 = m_2 a$

or $R_1 = F - m_2 a$



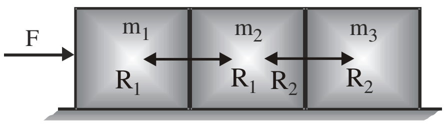
FBD of m_2

or $R_1 = F - m_2 \dfrac{F}{m_1 + m_2}$

$$= 1 - \frac{m_1}{m_1 + m_2} F = \frac{m_1 F}{m_1 + m_2}$$

Three bodies in contact :

Case I : Three blocks of masses m_1, m_2 and m_3 placed in contact on a smooth horizontal surface. Let a force F be applied on block of mass m_1. Let contact force between m_1 and m_2 is R_1 and the contact force between m_2 and m_3 is R_2.

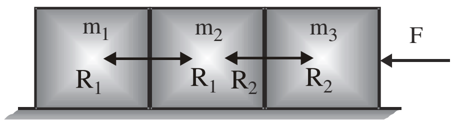


Acceleration of all the blocks,

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

From FBD, $R_1 = \dfrac{(m_2 + m_3)\,F}{m_1 + m_2 + m_3}$

Case II : If force is applied on mass m_3 :



Common acceleration,

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

From FBD, $R_2 = \dfrac{(m_1 + m_2)\,F}{m_1 + m_2 + m_3}$

SYSTEM OF MASSES TIED BY STRINGS

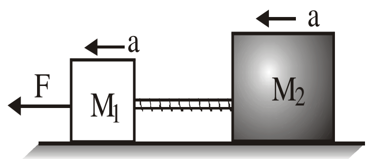
Tension in a string :

It is an intermolecular force between the atoms of a string, which acts or reacts when the string is stretched.

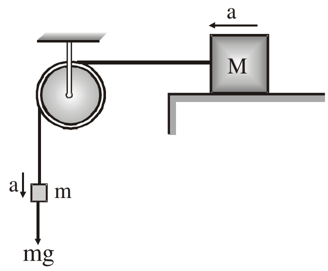
Important points about the tension in a string :

(a) Force of tension act on a body in the direction away from the point of contact or tied ends of the string.

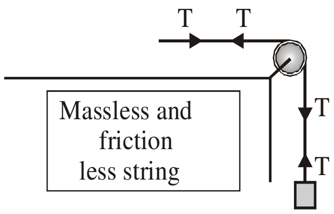
(b) (i) String is assumed to be inextensible so that the magnitude of acceleration of any number of masses connected through strings is always same.



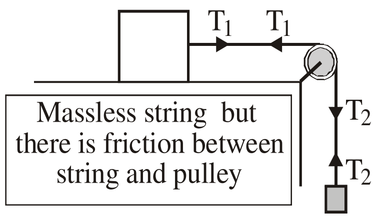
(ii) If the string is extensible the acceleration of different masses connected through it will be different until the string can stretch.



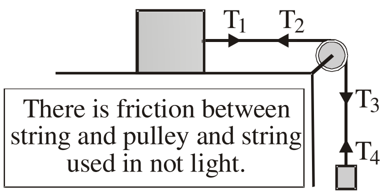
(c) (i) String is massless and frictionless so that tension throughout the string remains same.



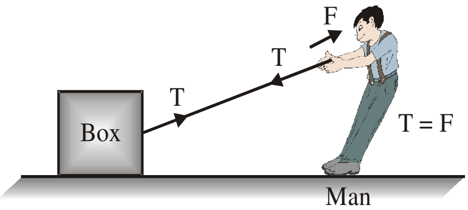
(ii) If the string is massless but not frictionless, at every contact tension changes.



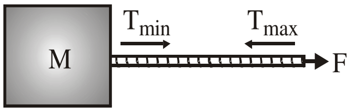
(iii) If the string is light tension at each point will be different depending on the acceleration of the string.



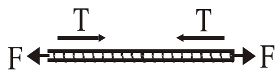
(d) If a force is directly applied on a string as say man is pulling a tied string from the other end with some force the tension will be equal to the applied force irrespective of the motion of the pulling agent, irrespective of whether the box will move or not, man will move or not.



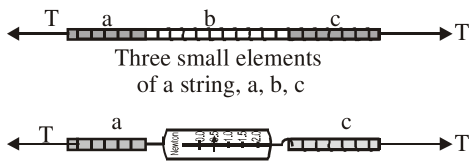
(e) String is assumed to be massless unless stated, hence tension in it every where remains the same and equal to applied force. However, if a string has a mass, tension at different points will be different being maximum (= applied force) at the end through which force is applied and minimum at the other end connected to a body.



(f) In order to produce tension in a string two equal and opposite stretching forces must be applied. The tension thus produced is equal in magnitude to either applied force (i.e. T = F) and is directed inwards opposite to F. Here it must be noted that a string can never be compressed like a spring.



(g) If string is cut so that element b is replaced by a string scale (the rest of the string being undisturbed), the scale reads the tension T.



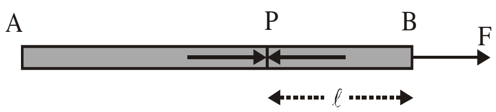
(h) Every string can bear a maximum tension, i.e. if the tension in a string is continuously increased it will break if the tension is increased beyond a certain limit. The maximum tension which a string can bear without breaking is called "breaking strength". It is finite for a string and depends on its material and dimension.

Example 5 :

A uniform rope of length L is pulled by a constant force F. What is the tension in the rope at a distance ℓ from the end where it is applied ?

Sol. Let T be tension in the rope at point P, then

acceleration of rope, $a = \frac{F}{M}$



Equation of motion of part PB is

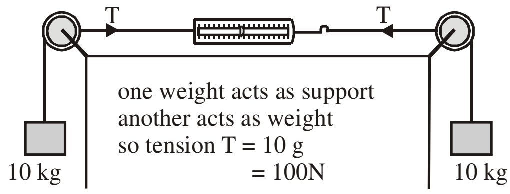
$F - T = (m\ell)\, a$

$\Rightarrow\ T = F - (m\ell)\, a = F - \frac{M}{L}(\ell)\frac{F}{M} = \left(1 - \frac{\ell}{L}\right) F$

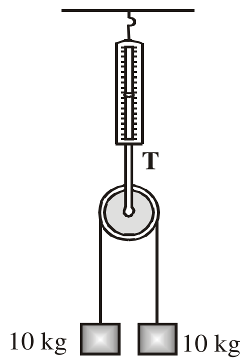
Example 6 :

The system shown in figure are in equilibrium. If the spring balance is calibrated in newtons, what does it record in each case ? ($g = 10\ m/s^2$)

Sol.

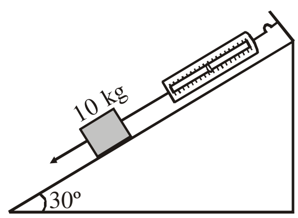


(A)



(B)

T = 2×10×g = 2×10×10 = 200N



(C)

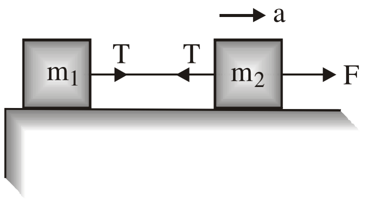
T = 10×10 sin30°

= 10 × 10 × ½ = 50 N

MOTION OF BODIES CONNECTED BY STRINGS

Two bodies : Let us consider the case of two bodies of masses m_1 and m_2 connected by a thread and placed on a smooth horizontal surface as shown in figure. A force F is applied on the body of mass m_2 in forward direction as shown. Our aim is to consider the acceleration of the system and the tension T in the thread. The force acting separately on two bodies are also shown in figure :

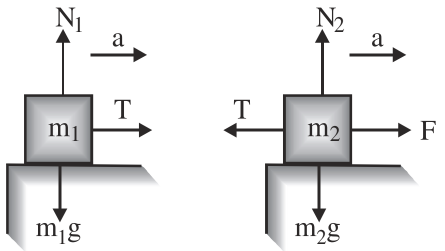
From figure



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

$F - T = m_2 a$ ....(ii)

$\Rightarrow F = (m_1 + m_2)a$

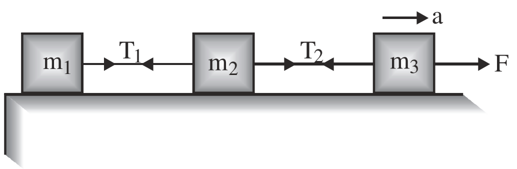


$\Rightarrow a = \dfrac{F}{m_1 + m_2}$ and $T = \dfrac{m_1 F}{m_1 + m_2}$

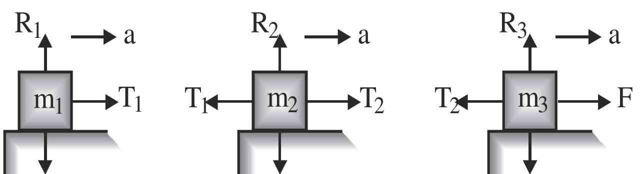
Three bodies :

In case of three bodies, the situation is shown in figure

Acceleration, $a = \dfrac{F}{m_1 + m_2 + m_3}$



$$T_1 = m_1 a = \frac{m_1 F}{m_1 + m_2 + m_3}$$



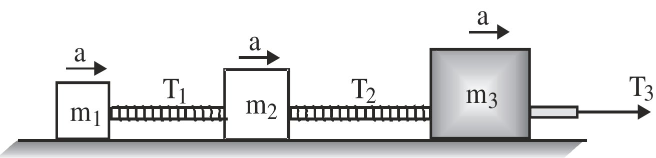
For block of mass m_3,

$F - T_2 = m_3 a$

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

Example 7 :

Three blocks are connected by string as shown in figure, and are pulled by a force $T_3 = 120N$. If $m_1 = 5$ kg, $m_2 = 10$ kg and $m_3 = 15$ kg. Calculate the acceleration of the system and T_1 and T_2.



Sol. (i) Acceleration of the system

$$a = \frac{F}{m_1 + m_2 + m_3} = \frac{120}{5+10+15} = 4 \text{ m/s}^2$$

(ii) $T_1 = m_1 a = 5 \times 4 = 20$ N

$T_2 = (m_1 + m_2)\, a = (5 + 10)\, 4 = 60$ N

FRAME OF REFERENCE

(i) Inertial frames of reference :

A reference frame which is easier at rest or in uniform motion along the straight line. A non-accelerating frame of reference is called an inertial frame of reference.

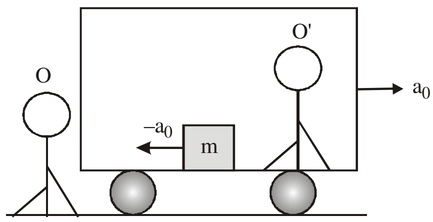
(ii) Non-inertial frame of reference :

A accelerating frame of reference is called a non-inertial frame of reference. Newton's law of motion are not directional applicable in such frames, before application we must use pseudo force.

Note : A rotating frame of references is a non-inertial frame of reference, because it is also an acceleration one due to its centripetal acceleration.

PSEUDO FORCE

The force on a body due to acceleration of non-inertial frame is called fictitious or apparent or pseudo force and is given by $\vec{F} = -m\vec{a}_0$ where $\vec{a}_0$ is acceleration of non-inertial frame with respect to an inertial frame and m is mass of the particle or body.



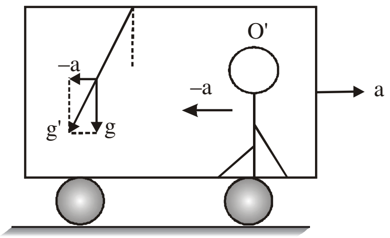
The direction of pseudo force must be opposite to the direction of acceleration of the non-inertial frame.

When we draw the free body diagram of a mass, with respect to an inertial frame of reference we apply only the real forces (forces which are actually acting on the mass).

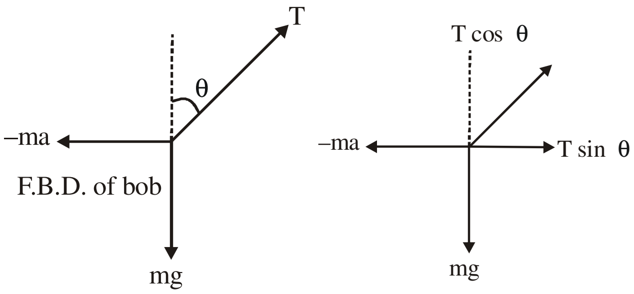
But when the free body diagram is drawn from a non-inertial frame of reference a pseudo force (in addition to all real forces) has to be applied to make the equation $\vec{F} = m\,\vec{a}$ to be valid in this frame also.

Example 8 :

A pendulum of mass m is suspended from the ceiling of a train moving with an acceleration 'a' as shown in figure. Find the angle θ in equilibrium position.



Sol. F.B.D. of bob



Non-inertial frame of reference (Train)

F.B.D. of bob w.r.t. train (real forces + pseudo force) :

with respect to train, bob is in equilibrium

$\therefore\ \Sigma F_y = 0 \Rightarrow T\cos\theta = mg$

and $\Sigma F_x = 0 \Rightarrow T\sin\theta = ma$

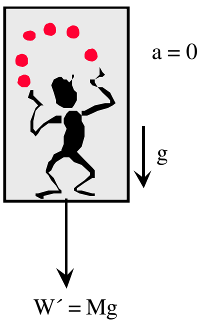
$\Rightarrow \tan\theta = \dfrac{a}{g} \Rightarrow \theta = \tan^{-1}\dfrac{a}{g}$

MOTION IN A LIFT

The weight of a body is simply the force exerted by earth on the body. If body is on an accelerated platform, the body experiences fictitious force, so the weight of the body appears changed and this new weight is called apparent weight. Let a man of weight W = Mg be standing in a lift.

Case (a) :

If the lift moving with constant velocity v upwards or downwards.



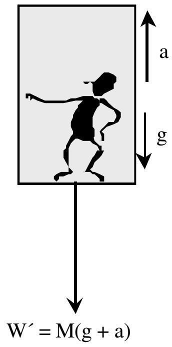
In this case there is no accelerated motion hence no pseudo force experienced by observer O' in side the lift.

So apparent weight

W' = Actual weight W

Case (b) :

If the lift is accelerated (i.e., a = constant upward)



Then net forces acting on the man are

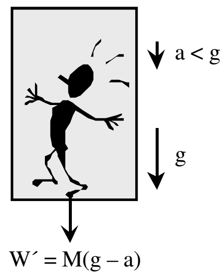
(i) weight W = Mg downward

(ii) fictitious force F_0 = Ma downward.

So apparent weight,

$W' = W + F_0 = Mg + Ma = M(g + a)$

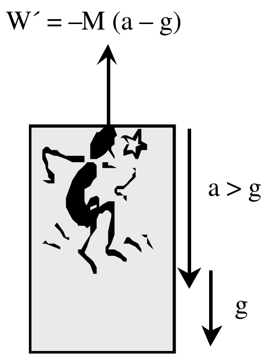
Case (c) : If the lift is accelerated downward with acceleration a < g :



The fictitious force F_0 = Ma acts upward while weight of a man W = Mg always acts downward, therefore so apparent weight, $W' = W + F_0 = Mg - Ma = M(g - a)$

Special case : If g=a then W '=0 condition of weightlessness. Thus, in a freely falling lift the man will experience weightlessness.

Case (d) : If lift accelerated downward with acceleration a > g:



Then as in Case C

Apparent weight $W' = M(g - a)$ is negative.

i.e., the man will be accelerated upward and will stay at the ceiling of the lift.

Example 9 :

A spring weighing machine inside a stationary lift reads 50kg when a man stands on it. What would happen to the scale reading if the lift is moving upward with (i) constant velocity, and (ii) constant acceleration ?

Sol. (ii) In the case of constant velocity of lift, there is no fictitious force, therefore the apparent weight = actual weight. Hence the reading of machine is 50 kg wt.

(ii) In this case the acceleration is upward, the fictitious force R = ma acts downward, therefore apparent weight is more than actual weight i.e. $W' = W + R = m(g + a)$

Hence scale shows a reading = m (g + a)

$$= \frac{mg\left(1+\frac{a}{g}\right)}{g} = 50 + \frac{50a}{g} \text{ kg. wt.}$$

Example 10 :

Two objects of equal mass rest on the opposite pans of an arm balance. Does the scale remain balanced when it is accelerated up or down in a lift ?

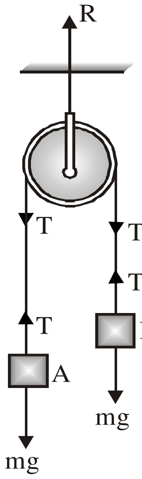
Sol. Yes, since both mass experience equal fictitious forces in magnitude as well as direction.

PULLEY

* Ideal pulley is considered weightless and frictionless.
* Ideal string is massless and inextensible.
* The pulley may change the direction of force in the string but not the tension.

Some cases of pulley

Case I : $m_1 = m_2 = m$



Tension in the string

$T = mg$

Acceleration 'a' = zero

Reaction at the suspension of the pulley.

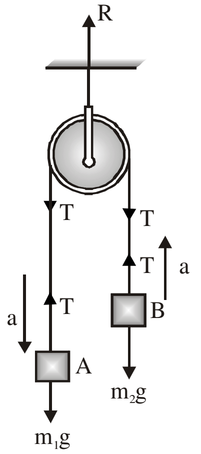
$R = 2T = 2mg$

$$\text{Acceleration} = \frac{\text{net pulling force}}{\text{total mass to be pulled}}$$

$$\text{Tension} = \frac{2 \times \text{Product of masses}}{\text{Sum of two masses}} g$$

Case II :

$m_1 > m_2$



Now for mass m_1,

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

for mass m_2

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

By (i) and (ii)

$$a = \frac{m_1 - m_2}{m_1 + m_2} g$$

$$\text{and} \quad T = \frac{(2m_1m_2)\, g}{(m_1 + m_2)}$$

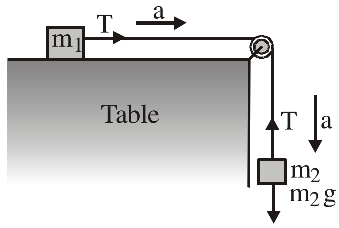
Reaction at the suspension of pulley

$$R = 2T = \frac{4m_1m_2\, g}{(m_1 + m_2)}$$

Case III : For mass m_1 : $T = m_1a$

For mass m_2 :

$mg_2 - T = m_2a$

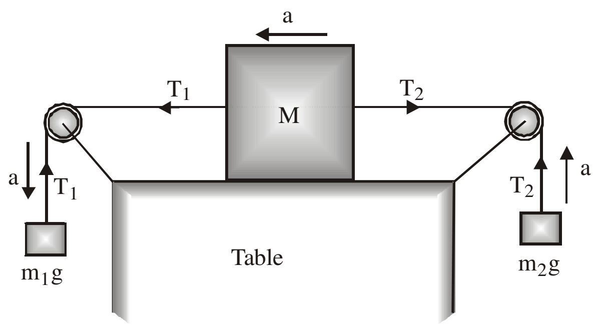


Acceleration,

$$a = \frac{m_2g}{(m_1 + m_2)}$$

$$\text{and} \quad T = \frac{m_1m_2g}{(m_1 + m_2)}$$

Case IV : $(m_1 > m_2)$



$m_1g - T_1 = m_1a$ .....(i)

$T_2 - m_2g = m_2a$ .....(ii)

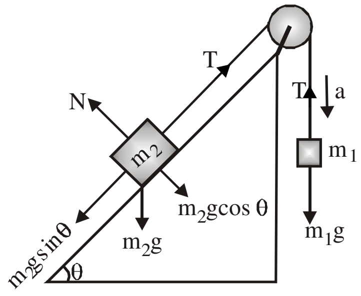
$T_1 - T_2 = Ma$ .....(iii)

By (i), (ii) and (iii)

$$a = \frac{(m_1 - m_2)\, g}{(m_1 + m_2 + M)}$$

Case V : Mass suspended over a pulley from another on an inclined plane.

For mass m_1 : $m_1g - T = m_1a$ .....(i)



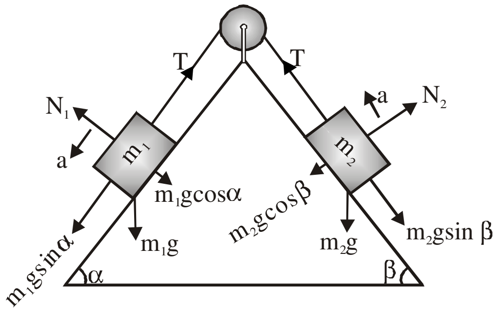
For mass m_2 :

$T_2 - m_2 g \sin\theta = m_2 a$ .....(ii)

Acceleration,

$$a = \frac{(m_1 - m_2 \sin\theta)\,g}{(m_1 + m_2)} \quad ; \quad T = \frac{m_1 m_2 (1 + \sin\theta)\,g}{(m_1 + m_2)}$$

Case VI : Masses m_1 and m_2 are connected by a string passing over a pulley ($m_1 > m_2$)



Acceleration, $a = \dfrac{(m_1 \sin\alpha - m_2 \sin\beta)}{(m_1 + m_2)} g$

Tension, $T = \dfrac{m_1 m_2 (\sin\alpha + \sin\beta)}{(m_1 + m_2)} g$

Case VII : For mass m_1 :

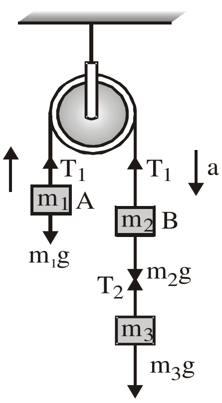
$T_1 - m_1 g = m_1 a$ .....(i)

For mass m_2 :

$m_2 g + T_2 - T_1 = m_2 a$ .....(ii)

For mass m_3 :

$m_3 g - T_2 = m_3 a$ .....(iii)

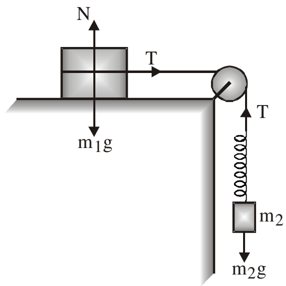


Acceleration, $a = \dfrac{(m_2 + m_3 - m_1)}{(m_1 + m_2 + m_3)} g$

We can calculate tensions T_1 and T_2 from above equations.

Case (VIII) :

From case (III)



Tension $T = \dfrac{m_1 m_2}{(m_1 + m_2)} g$

If x is the extension in the spring then $T = kx$

$$x = \frac{T}{k} = \frac{m_1 m_2 g}{k(m_1 + m_2)}$$

FRICTION

TYPES OF FRICTION

Friction
- Static friction (No relative motion between objects)
- Dynamic friction (There is relative motion between objects)
  - Sliding friction (Kinetic friction)
  - Rolling friction

STATIC FRICTION

* It is the frictional force which is effective before motion starts between two planes in contact with each other.
* It's nature is self adjusting.
* Numerical value of static friction is equal to external force which creates the tendency of motion of body.
* Maximum value of static friction is called limiting friction.

LAWS OF LIMITING FRICTION

* The magnitude of the force of limiting friction (f_L) between any two bodies in contact is directly proportional to the normal reaction (N) between them $f_L \propto N$
* The direction of the force of limiting friction is always opposite to the direction in which one body is on the verge of moving over the other.
* The force of limiting friction is independent of the apparent contact area, so long as normal reaction between the two bodies in contact remains the same.
* Limiting friction between any two bodies in contact depends on the nature of material of the surfaces in contact and their roughness and smoothness.
* Its value is more than the other types of frictional force.

DYNAMIC FRICTION

If the body is in motion, the friction opposing its motion is called dynamic friction.

This is always slightly less than the limiting friction.

COEFFICIENT OF FRICTION

The frictional coefficient is a dimensionless scalar value which describes as the ratio of the force of friction between two bodies and the normal force pressing them together.

Coefficient of static friction $\mu_s = \dfrac{f_L}{N}$

Coefficient of sliding (kinetic) friction $\mu_k = \dfrac{f_k}{N}$

The values of μ_s and μ_k depend on the nature of both the surfaces in contact.

Note :

* Friction always opposes the tendency of relative motion.
* The force of static friction exactly balances the applied force during the stationary state of the body therefore it is known as self adjusting.
* μ_s and μ_k can exceed unity, although commonly they are less than one.
* Static friction is a self-adjusting force, the kinetic friction is not a self adjusting force.
* The frictional force is a contact force parallel to the surfaces in contact and directed so as to oppose the relative motion or attempted relative motion of the surfaces.
* When two highly polished surfaces are pressed hard, then a situation similar to welding occurs. It is called cold welding.
* When two copper plates are highly polished and placed in contact with each other, then instead of decreasing, the force of friction increases. This arises due to the fact that for two highly polished surfaces in contact, the number of molecules coming in contact increases and as a result the cohesive/ adhesive forces increases. This in turn, increases the force of friction.

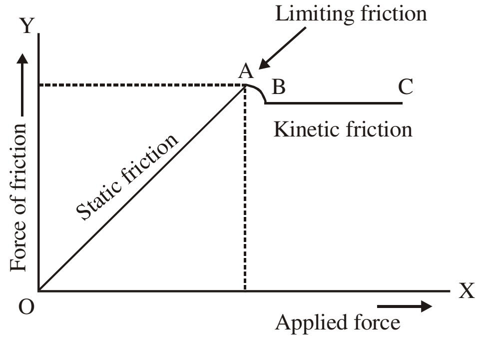
Note : Let f is the force and N is the normal reaction, then the net force applied by the surface on the object is

$$F_{surface} = \sqrt{N^2 + f^2}$$

Its minimum value (when f = 0) is Mg and maximum value (when f = μN) is $Mg\sqrt{1+\mu^2}$

Graph between applied force and force of friction :

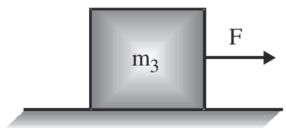
If we slowly increase the force with which we are pulling the box, graph shows that the friction force increases with our force upto a certain critical value, f_L, the box suddenly begins to move, and as soon as it starts moving, a smaller force is required to maintain its motion as in motion friction is reduced. The friction value from 0 to f_L is known as static friction, which balances the external force on the body and prevent it from sliding. The value f_L is the maximum limit up to which the static friction acts is known as limiting friction, after which body starts sliding and friction reduces to kinetic friction.



Example 11 :

A block of mass 1 kg is at rest on a rough horizontal surface having coefficient of static friction 0.2 and kinetic friction 0.15, find the frictional forces if a horizontal force,

(a) F = IN (b) F = 2.5 N , is applied on the block



Sol. Maximum force of friction or limiting friction

$f_L = 0.2 \times 1 \times 9.8\,N = 1.96\,N$

(a) For $F_{ext} = 1N$, $F_{ext} < f_L$

So, body is in rest means static friction is present and hence

$f_s = F_{ext} = 1N$

(b) For $F_{ext} = 2.5\,N$ so $F_{ext} > f_L$

Now body is in moving condition

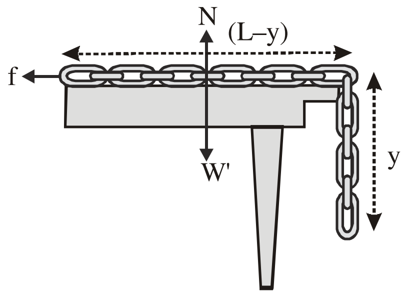
∴ Frictional force

$f_L = F_k = \mu_k N = \mu_k\, mg = 0.15 \times 1 \times 9.8 = 1.47\,N$

Example 12 :

Length of a chain is L and coefficient of static friction is μ. Calculate the maximum length of the chain which can be hung from the table without sliding.

Sol. Let y be the maximum length of the chain can be hold outside the table without sliding.



Length of chain on the table = (L – y)

Weight of part of the chain on table

$$W' = \frac{M}{L}(L - y)\,g$$

Weight of hanging part of the chain

$$W = \frac{M}{L}\,yg$$

For equilibrium : Limiting force of friction = weight of hanging part of the chain

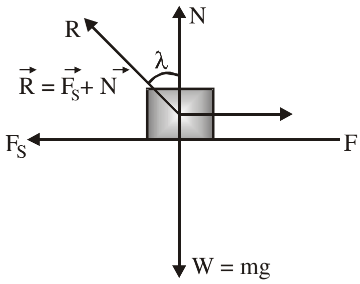
$\mu N = W$

$\Rightarrow \mu W' = W \Rightarrow \mu \frac{M}{L}(L-y)g = \frac{M}{L} yg$

$\Rightarrow \mu L - \mu y = y \Rightarrow \quad y = \frac{\mu L}{1+\mu}$

ANGLE OF FRICTION

The angle of friction is the angle which the resultant of limiting friction f_L and normal reaction N makes with the normal reaction. It is represented by λ.

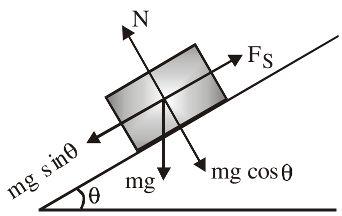


$\tan\lambda = \frac{F_L}{N} = \frac{\mu N}{N} = \mu$

For smooth surface $\lambda = 0$

ANGLE OF REPOSE (θ)

If a body is placed on an inclined plane and if its angle of inclination is gradually increased, then at some angle of inclination θ the body will just on the point to slide down. The angle is called angle of repose (θ).



$\therefore \; F_L = mg\sin\theta$ and $N = mg\cos\theta$

So, $\frac{F_L}{N} = \tan\theta$ or $\quad \mu = \tan\theta$

Relation between angle of friction (λ) and angle of repose (θ) : We know that $\tan\lambda = \mu$ and$\mu = \tan\theta$

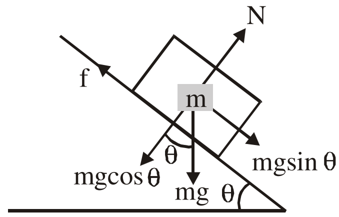
hence $\tan\lambda = \tan\theta \Rightarrow \theta = \lambda$

Thus, angle of repose = angle of friction

ACCELERATION OF A BLOCK ON A ROUGH INCLINE

Case 1: When a plane is inclined to the horizontal at an angle θ, which is greater than the angle of repose, the mass m placed on the inclined plane slides down with an acceleration a.

$f = \mu N = \mu\, mg\cos\theta$



From FBD of block

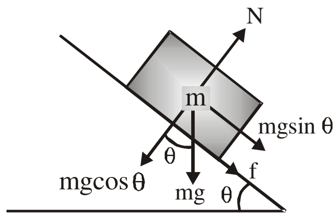
$mg\sin\theta - f = ma$

$mg\sin\theta - \mu\, mg\cos\theta = ma$

$\Rightarrow \; a = g\sin\theta - \mu g\cos\theta$

here $a < g$

Case 2 : When a plane is inclined to the horizontal at an angle θ, which is less than the angle of repose, then the minimum force required to move the body up the inclined plane is



$F = mg\sin\theta + f = mg\sin\theta + \mu mg\cos\theta$

where $f = \mu N = \mu\, mg\cos\theta$

and its upwards acceleration

$a = \frac{\text{Net force}}{n} = g(\sin\theta + \mu\cos\theta)$

Note :

(i) Pedaling: In the cycling, rear wheel move by the force communicated to it by pedaling, while front wheel moves by itself, therefore, like in walking force of friction on rear wheel is in forward direction and acts as a supporting force. As front wheel moves by itself, force of friction on front wheel is in the backward direction (nature opposing force).

(ii) Non-Pedaling : When pedaling is stopped, both the wheels moves by themselves so the force of friction on both the wheels is in backwards direction.

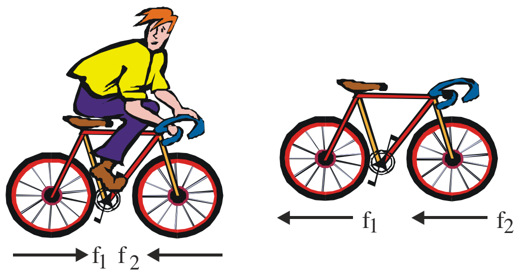


Figure : Pedaling **Non-Pedaling**

ADDITIONAL EXAMPLES

Example 1 :

A cricket ball of mass 150g is moving with a velocity of 12m/s and is hit by a bat so that the ball is turned back with a velocity of 20m/s. If the duration of contact between the ball and bat is 0.01s, find their impulse and the average force exerted on the ball by the bat.

$\Delta p = p_f - p_i = m(v - u)$

$= 150 \times 10^{-3} [20 - (-12)]$

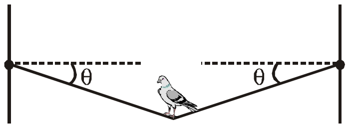
So by time averaged definition of force in case of impulse

$$F_{av} = \frac{I}{\Delta t} = \frac{\Delta p}{\Delta t} = \frac{4.80}{0.01} = 480N$$

Example 2 :

A bird with mass m perches at the middle of a stretched string. Show that the tension in the string is given by $T = \frac{mg}{2\sin\theta}$.

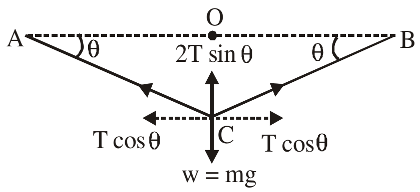
Assume that each half of the string is straight.



Sol. Initial position of wire = AOB.

Final position of wire = ACB.

Let θ be the angle made by wire with horizontal, which is very small.



Resolving tension T of string in horizontal and vertical directions, we note that the horizontal components cancel while vertical components add and balance the weight.

For equilibrium

$2T\sin\theta = W = mg$

$$\therefore \quad T = \frac{W}{2\sin\theta}$$

Example 3 :

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

Sol. Let f is the force of friction and N is the normal reaction, then the net force by the surface on the body is

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

Let the applied force is F ' (varying), applied horizontally then $f \le \mu_s N$ (adjustable with f = F ').

Now if F ' is zero, f = 0 and $F_{min} = N = Mg$

and when F ' is increased to maximum value permissible for no motion $f = \mu_s N$,

giving $F_{max} = \sqrt{N^2 + \mu_s^2 N^2} = Mg\sqrt{1+\mu_s^2}$

therefore we can $Mg \le F \le Mg\sqrt{1+\mu_s^2}$

Example 4 :

A motor car has a width 1.1 m between wheels. Its centre of gravity is 0.62 m above the ground and the coefficient of friction between the wheels and the road is 0.8. What is the maximum possible speed, if the centre of gravity inscribes a circle of radius 15 m ? (Road surface is horizontal)

(A) 7.64 m/s (B) 6.28 m/s

(C) 10.84 m/s (D) 11.23 m/s

Sol. **(C).** $v = \sqrt{\mu g r} = \sqrt{0.8 \times 9.8 \times 1.5} = 10.84$ m/s

Example 5 :

A child weighing 25 kg slides down a rope hanging from the branch of a tall tree. If the force of friction acting against him is 2 N, what is the acceleration of the child

(Take g = 9.8 m/s^2)

(A) 22.5 m/s^2 (B) 8 m/s^2

(C) 5 m/s^2 (D) 9.72 m/s^2

Sol. **(D).** Net downward force = Weight – Friction

$\therefore \; ma = 2.5 \times 9.8 - 2$

$$\Rightarrow a = \frac{2.5 \times 9.8 - 2}{25} = 9.72 \text{ m/s}^2$$

QUESTION BANK

EXERCISE - 1

Q.1 Newton's first law of motion describes the following
(A) Energy (B) Work
(C) Inertia (D) Moment of inertia

Q.2 A particle is moving with a constant speed along a straight line path. A force is not required to
(A) Increase its speed
(B) Decrease the momentum
(C) Change the direction
(D) Keep it moving with uniform velocity

Q.3 A body of mass 2 kg is hung on a spring balance mounted vertically in a lift. If the lift descends with an acceleration equal to the acceleration due to gravity 'g', the reading on the spring balance will be
(A) 2 kg (B) $(4 \times g)$ kg
(C) $(2 \times g)$ kg (D) Zero

Q.4 If the tension in the cable of 1000 kg elevator is 1000 kg weight, the elevator
(A) Is accelerating upwards
(B) Is accelerating downwards
(C) May be at rest or accelerating
(D) May be at rest or in uniform motion

Q.5 An elevator weighing 6000 kg is pulled upward by a cable with an acceleration of $5 m/s^2$. Taking g to be $10 m/s^2$, then the tension in the cable is –
(A) 6000 N (B) 9000 N
(C) 60000 N (D) 90000 N

Q.6 A body is imparted motion from rest to move in a straight line. If it is then obstructed by an opposite force, then –
(A) The body may necessarily change direction
(B) The body is sure to slow down
(C) The body will necessarily continue to move in the same direction at the same speed
(D) None of these

Q.7 A body of mass 2 kg is moving with a velocity 8 m/s on a smooth surface. If it is to be brought to rest in 4 seconds, then the force to be applied is
(A) 8 N (B) 4 N
(C) 2 N (D) 1 N

Q.8 A 30 gm bullet initially travelling at 120 m/s penetrates 12cm into a wooden block. The average resistance exerted by the wooden block is
(A) 2850N (B) 2200 N
(C) 2000N (D) 1800 N

Q.9 If rope of lift breaks suddenly, the tension exerted by the surface of lift (a = acceleration of lift)
(A) mg (B) m (g + a)
(C) m (g – a) (D) 0

Q.10 A monkey of mass 20kg is holding a vertical rope. The rope will not break when a mass of 25 kg is suspended from it but will break if the mass exceeds 25 kg. What is the maximum acceleration with which the monkey can climb up along the rope ($g = 10 m/s^2$)
(A) $10 m/s^2$ (B) $25 m/s^2$
(C) $2.5 m/s^2$ (D) $5 m/s^2$

Q.11 The linear momentum p of a body moving in one dimension varies with time according to the equation $p = a + bt^2$ where a and b are positive constants. The net force acting on the body is –
(A) A constant
(B) Proportional to t^2
(C) Inversely proportional to t
(D) Proportional to t

Q.12 A force of 100 dynes acts on a mass of 5 gram for 10 sec. The velocity produced is –
(A) 2000 cm/sec (B) 200 cm/sec
(C) 20 cm/sec (D) 2 cm/sec

Q.13 A body of mass m collides against a wall with a velocity v and rebounds with the same speed. Its change of momentum is –
(A) 2 mv (B) mv
(C) – mv (D) Zero

Q.14 When we jump out of a boat standing in water it moves
(A) Forward (B) Backward
(C) Sideways (D) None of the above

Q.15 Two forces of magnitude F have a resultant of the same magnitude F. The angle between the two forces is –
(A) 45° (B) 120°
(C) 150° (D) 60°

Q.16 If two forces of 5 N each are acting along X and Y axes, then the magnitude and direction of resultant is –
(A) $5\sqrt{2}, \pi/3$ (B) $5\sqrt{2}, \pi/4$
(C) $-5\sqrt{2}, \pi/3$ (D) $-5\sqrt{2}, \pi/4$

Q.17 Two bodies of mass 3 kg and 4 kg are suspended at the ends of massless string passing over a frictionless pulley. The acceleration of the system is ($g = 9.8 m/s^2$)
(A) $4.9 m/s^2$ (B) $2.45 m/s^2$
(C) $1.4 m/s^2$ (D) $9.5 m/s^2$

Q.18 The mass of a body measured by a physical balance in a lift at rest is found to be m. If the lift is going up with an acceleration a, its mass will be measured as –
(A) $m \; 1-\frac{a}{g}$ (B) $m \; 1+\frac{a}{g}$
(C) m (D) Zero

Q.19 A car is moving with uniform velocity on a rough horizontal road. Therefore, according to Newton's first law of motion
(A) No force is being applied by its engine
(B) A force is surely being applied by its engine
(C) An acceleration is being produced in the car
(D) The kinetic energy of the car is increasing

Q.20 A man of weight mg is moving up in a rocket with acceleration 4 g. The apparent weight of the man in the rocket is
(A) Zero (B) 4 mg
(C) 5 mg (D) mg

Q.21 A player kicks a football of mass 0.5 kg and the football begins to move with a velocity of 10 m/s. If the contact between the leg and the football lasts for 1/50 sec, then the force acted on the football should be
(A) 2500 N (B) 1250 N
(C) 250 N (D) 625 N

Q.22 If the normal force is doubled, the coefficient of friction is
(A) Not changed (B) Halved
(C) Doubled (D) Tripled

Q.23 A stone weighing 1 kg and sliding on ice with a velocity of 2 m/s is stopped by friction in 10 sec. The force of friction (assuming it to be constant) will be
(A) –20N (B) – 0.2 N
(C) 0.2 N (D) 20 N

Q.24 A lift is moving downwards with an acceleration equal to acceleration due to gravity. A body of mass M kept on the floor of the lift is pulled horizontally. If the coefficient of friction is μ, then the frictional resistance offered by the body is
(A) Mg (B) μMg
(C) 2μMg (D) Zero

Q.25 A body of mass 2 kg is moving on the ground comes to rest after some time. The coefficient of kinetic friction between the body and the ground is 0.2. The retardation in the body is
(A) 9.8 m/s^2 (B) 4.73 m/s^2
(C) 2.16 m/s^2 (D) 1.96 m/s^2

Q.26 A cyclist moves in a circular track of radius 100 m. If the coefficient of friction is 0.2, then the maximum velocity with which the cyclist can take the turn with leaning inwards is
(A) 9.8 m/s (B) 1.4 m/s
(C) 140 m/s (D) 14 m/s

Q.27 A block of mass 5 kg lies on a rough horizontal table. A force of 19.6 N is enough to keep the body sliding at uniform velocity. The coefficient of sliding friction is
(A) 0.5 (B) 0.2
(C) 0.4 (D) 0.8

Q.28 A boy standing on a weighing machine observes his weight as 200 N. When he suddenly jumpes upwards, his friend notices that the reading increased to 400 N. The acceleration by which the boy jumped will be-
(A) 9.8 m/s^2 (B) 29.4 m/s^2
(C) 4.9 m/s^2 (D) 14.7 m/s^2

Q.29 A force of $(6\hat{i} + 8\hat{j})$ N acted on a body of mass 10 kg. The displacement after 10 sec, if it starts from rest, will be -
(A) 50 m along $\tan^{-1}$ 4/3 with x axis
(B) 70 m along $\tan^{-1}$ 3/4 with x axis
(C) 10 m along $\tan^{-1}$ 4/3 with x axis
(D) None

Q.30 A body whose mass 6 kg is acted upon by two forces $(8\hat{i}+10\hat{j})$ N and $(4\hat{i}+8\hat{j})$ N. The acceleration produced will be - (in m/s^2)
(A) $(3\hat{i}+2\hat{j})$ (B) $12\hat{i}+18\hat{j}$
(C) $\frac{1}{3}(\hat{i}+\hat{j})$ (D) $2\hat{i}+3\hat{j}$

Q.31 A car of 1000 kg moving with a velocity of 18 km/hr is stopped by the brake force of 1000 N. The distance covered by it before coming to rest is -
(A) 1 m (B) 162 m
(C) 12.5 m (D) 144 m

Q.32 A man fires the bullets of mass m each with the velocity v with the help of machine gun, if he fires n bullets every sec, the reaction force per second on the man will be -
(A) $\frac{m}{v}n$ (B) m n v
(C) $\frac{mv}{n}$ (D) $\frac{vn}{m}$

Q.33 A body of mass 15 kg moving with a velocity of 10 m/s is to be stopped by a resistive force in 15 sec, the force will be -
(A) 10 N (B) 5 N
(C) 100 N (D) 50 N

Q.34 A force of 2 N is applied on a particle for 2 sec, the change in momentum will be -
(A) 2 Ns (B) 4 Ns
(C) 6 Ns (D) 3 Ns

Q.35 A cricket ball of mass 150 g is moving with a velocity of 12m/sec and is hit by a bat so that the ball is turned back with a velocity of 20 m/sec, the force on the ball acts for 0.01 sec, the average force exerted by the bat on the ball-
(A) 48 N (B) 40 N
(C) 480 N (D) 400 N

Q.36 A body of mass 20 kg moving with a velocity of 3 m/s, rebounds on a wall with same velocity. The impulse on the body is -
(A) 60 Ns (B) 120 Ns
(C) 30 Ns (D) 180 Ns

Q.37 A mass of 10 kg is hung to a spring balance in lift. If the lift is moving with an acceleration g/3 in upward & downward directions. Choose the correct options related to the reading of the spring balance.
(1) 13.3 kg (2) 6.67 kg
(3) 32.6 kg (4) 0
(A) 1, 2 and 3 are correct (B) 1 and 2 are correct
(C) 2 and 4 are correct (D) 1 and 3 are correct

Q.38 Choose the correct options –
(1) A reference frame in which Newton's first law is valid is called an inertial reference frame.
(2) Frame moving at constant velocity relative to a known inertial frame is also an inertial frame.
(3) Idealy, no inertial frame exists in the universe for practical purpose, a frame of reference may be considered as Inertial if its acceleration is negligible with respect to the acceleration of the object to be observed.
(4) To measure the acceleration of a falling apple, earth cannot be considered as an inertial frame.

(A) 1, 2 and 3 are correct (B) 1 and 2 are correct
(C) 2 and 4 are correct (D) 1 and 3 are correct

Q.39 A block of mass M is pulled along a horizontal frictionless surface by a rope of mass m . If a force P is applied at the free end of the rope. The force exerted by the rope on the block will be -

(A) P (B) $\frac{Pm}{M+m}$

(C) $\frac{MP}{M+m}$ (D) $\frac{mP}{M+m}$

Q.40 A body of mass 50 kg is pulled by a rope of length 8 m on a surface by a force of 108N applied at the other end. The force that is acting on 50 kg mass, if the linear density of rope is 0.5 kg/m will be -

(A) 108 N (B) 100 N
(C) 116 N (D) 92 N

EXERCISE - 2

Q.1 A disc of mass 10 gm is kept horizontally in air by firing bullets of mass 5 g each at the rate of 10/s. If the bullets rebound with same speed. The velocity with which the bullets are fired is -

(A) 49 cm/s (B) 98 cm/s
(C) 147 cm/s (D) 196 cm/s

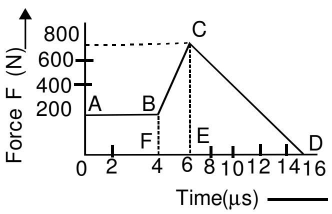
Q.2 A fire man has to carry an injured person of mass 40 kg from the top of a building with the help of the rope which can withstand a load of 100 kg. The acceleration of the fireman if his mass is 80 kg, will be-

(A) 8.17 m/s^2 (B) 9.8 m/s^2
(C) 1.63 m/s^2 (D) 17.97 m/s^2

Q.3 A body of 0.02 kg falls from a height of 5 metre into a pile of sand. The body penetrates the sand a distance of 5 cm before stoping. What force has the sand exerted on the body ?

(A) 1.96 N (B) –19.6 N
(C) –0.196 N (D) 0.0196 N

Q.4 The magnitude of the force (in Newtons) acting on a body varies with time t (in microseconds) as shown in fig. AB, BC, and CD are straight line segments. The magnitude of the total impulse of the force on the body from t = 4 μs to t = 16 μs is .... N-s.



(A) 5×10^{-4} N.s (B) 5×10^{-3} N.s
(C) 5×10^{-5} N.s (D) 5×10^{-2} N.s

Q.5 A cricket ball of mass 250 gm moving with velocity of 24 m/s is hit by a bat so that it acquires a velocity of 28 m/s in the opposite direction. The force acting on the ball, if the contact time is 1/100 of a second, will be -

(A) 1300 N in the final direction of ball
(B) 13 N in the initial direction of ball
(C) 130 N in the final direction of ball
(D) 1.3 N in the initial direction of ball

Q.6 A block of mass 2 kg is placed on the floor. The coefficient of static friction is 0.4.A force F of 2.5 N is applied on the block, as shown. Calculate the force of friction between the block and the floor. (g = 9.8 ms^{-2})

(A) 2.5 N (B) 25 N
(C) 7.84 N (D) zero

Q.7 Two cars of unequal masses use similar tyres. If they are moving at the same initial speed, the minimum stopping distance -

(A) is smaller for the heavier car
(B) is smaller for the lighter car
(C) is same for both cars
(D) depends on the volume of the car

Q.8 Mark the correct statements about the friction between two bodies -

(a) static friction is always greater than the kinetic friction
(b) coefficient of static friction is always greater than the coefficient of kinetic friction
(c) limiting friction is always greater than the kinetic friction
(d) limiting friction is never less than static friction

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

Q.9 A block is placed on a rough floor and a horizontal force F is applied on it. The force of friction f by the floor on the block is measured for different values of F and a graph is plotted between them –

(a) The graph is a straight line of slope 45°
(b) The graph is straight line parallel to the F axis
(c) The graph is a straight line of slope 45° for small F and a straight line parallel to the F-axis for large F.
(d) There is small kink on the graph

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

Q.10 The contact force exerted by a body A on another body B is equal to the normal force between the bodies. We conclude that -

(a) the surfaces must be smooth
(b) force of friction between two bodies may be equal to zero
(c) magnitude of normal reaction is equal to that of friction
(d) bodies may be rough

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

Q.11 It is easier to pull a body than to push, because -

(A) the coefficient of friction is more in pushing than that in pulling
(B) the friction force is more in pushing than that in pulling
(C) the body does not move forward when pushed
(D) None of these

Q12 A block of metal is lying on the floor of a bus. The maximum acceleration which can be given to the bus so that the block may remain at rest, will be -

(A) μg (B) μ/g
(C) $\mu^2 g$ (D) μg^2

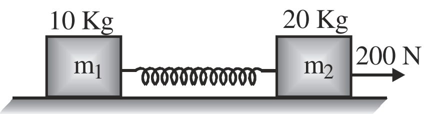
Q.13 A 600 kg rocket is set for a vertical firing. If the exhaust speed is 1000 m/s. Then calculate the mass of gas ejected per second to supply the thrust needed to overcome the weight of rocket.

(A) 5.88 kg/s (B) 4.88 kg/s
(C) 2.88 kg/s (D) 3.88 kg/s

Q.14 A force of 50N acts in the direction as shown in figure. The block of mass 5 kg, resting on a smooth horizontal surface. Find out the acceleration of the block.

(A) $3\sqrt{3}\ m/s^2$ (B) $2\sqrt{3}\ m/s^2$
(C) $5\sqrt{3}\ m/s^2$ (D) None of these

Q.15 Two masses 10 kg and 20 kg respectively are connected by a massless spring as shown in figure force of 200N acts n the 20 kg mass. At the instant shown in figure the 10 kg mass has acceleration of 12 m/s^2, what is the acceleration of 20 kg mass.



(A) 2 m/s^2 (B) 6 m/s^2
(C) 3 m/s^2 (D) 4 m/s^2

Q.16 Choose the correct options –
(1) Inertia $\propto$ mass
(2) 1 Newton = 10^5 dyne
(3) Thrust on rocket $\vec{F} = \frac{\Delta M}{\Delta t}\vec{v} - M\vec{g}$
(4) Apparent weight of a body in the accelerated lift is W = m (g + a).
(A) 1, 2 and 3 are correct (B) 1 and 2 are correct
(C) 2 and 4 are correct (D) 1 and 3 are correct

Q.17 Choose the correct options –
(1) For equilibrium of a body under the action of concurrent forces $\vec{F}_1 + \vec{F}_2 + \vec{F}_3 + ...\vec{F}_n = 0$
(2) If the downward acceleration of the lift is a = g, then the body will enjoy weightlessness.
(3) If the downward acceleration of the body is a > g, then the body will rise up to the ceiling of lift
(4) If the downward acceleration of the lift is a > g, then the body will enjoy weightlessness.
(A) 1, 2 and 3 are correct (B) 1 and 2 are correct
(C) 2 and 4 are correct (D) 1 and 3 are correct

Q.18 A rope of length 15 m and linear density 2 kg/m is lying length wise on a horizontal smooth table. It is pulled by a force of 25 N. The tension in the rope at the point 7 m away from the point of application, will be -
(A) 11.67 N (B) 13.33 N
(C) 36.67 N (D) None of these

Q.19 Two blocks of mass m = 1 kg and M = 2 kg are in contact on a frictionless table. A horizontal force F(= 3N) is applied to m. The force of contact between the blocks, will be-
(A) 2 N (B) 1 N
(C) 4 N (D) 5 N

Passage (Q.20-Q.22)

Pseudo Force is a imaginary force which is recognised only by a non-Inertial observer to explain the physical situation according to Newton's Laws. Magnitude of pseudo force F_p is equal to the product of the mass m of the object and the acceleration a of the frame of reference. The direction of the force is opposite to the direction of acceleration. $F_p = -ma$

Q.20 A spring weighing machine inside a stationary lifts reads 50 kg when a man stand on it. What would happen to the scale reading if the lift is moving upward with (i) constant velocity (ii) constant acceleratioin -
(A) 50 kg wt, $50 + \frac{50a}{g}$ kg wt
(B) 50 kg wt, $50 + \frac{50g}{a}$ kg wt
(C) 50 kg wt, $\frac{50a}{g}$ kg wt (D) 50 kg wt, $\frac{50a}{g}$ kg wt

Q.21 A 25 kg lift is supported by a cable. The acceleration of the lift when the tension in the cable is 175 N, will be -
(A) – 2.8 m/s^2 (B) 16.8 m/s^2
(C) – 9.8 m/s^2 (D) 14 m/s^2

Q.22 A body is suspended by a string from the celling of an elevator. It is observed that the tension in the string is doubled when the elevator is accelerated. The acceleration will be -
(A) 4.9 m/s^2 (B) 9.8 m/s^2
(C) 19.6 m/s^2 (D) 2.45 m/s^2

Directions : Assertion-Reason type questions.

Each questions contain STATEMENT-1 (Assertion) and STATEMENT-2 (Reason). Each question has 4 choices (A), (B), (C) and (D) out of which ONLY ONE is correct.
(A) Statement- 1 is True, Statement-2 is True, Statement-2 is a correct explanation for Statement -1
(B) Statement -1 is True, Statement -2 is True ; Statement-2 is NOT a correct explanation for Statement - 1
(C) Statement - 1 is True, Statement- 2 is False
(D) Statement -1 is False, Statement -2 is True

Q.23 **Statement 1 :** A man standing in a lift which is moving upward, will feel his weight to be greater than when the lift was at rest.
Statement 2 : If the acceleration of the lift is 'a' upward, then the man of mass m shall feel his weight to be equal to normal reaction (N) exerted by the lift given by N = m (g + a) (where g is acceleration due to gravity).

Q.24 **Statement 1 :** According to the Newton's third law of motion, the magnitude of the action and reaction force in an action reaction pair is same only in an inertial frame of reference.
Statement 2 : Newton's laws of motion are applicable in every inertial reference frame.

Q.25 **Statement 1 :** A body is lying at rest on a rough horizontal surface. A person accelerating with acceleration $a\hat{i}$ (where a is positive constant and $\hat{i}$ is a unit vector in horizontal direction) observes the body. With respect to him, the block experience a kinetic friction.
Statement 2 : Whenever there is relative motion between the contact surfaces then kinetic friction acts.

EXERCISE - 3

PREVIOUS YEAR AIEEE QUESTIONS

SECTION-1

Q.1 Three point masses A, B and C are 66 gram each are connected as shown. The acceleration of system is 5 m/s^2. Tension between B and C is approximately-**[AIEEE-2002]**

(A) 0.33 Newton (B) 4 Newton
(C) 5 Newton (D) 6 Newton

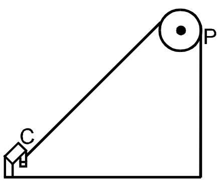
Q.2 A person in an aeroplane which is coming, down at acceleration a releases a coin. After release, the accleration of coin with respect to observer on ground and in aeroplane both will be respectively- **[AIEEE-2002]**

(A) g and (g –a) (B) (g – a), g
(C) (g + a), g (D) g, (g + a)

Q.3 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 – **[AIEEE-2002]**

(A) 8 : 1 (B) 9 : 7
(C) 4 : 3 (D) 5 : 3

Q.4 One end of massless rope, which passes over a massless and frictionless pulley P is tied to a hook C while the other end is free. Maximum tension that the rope can bear is 360 N. With what value of minimum safe acceleration (in ms^{-2}) can a man of 60 kg slide down the rope ? **[AIEEE-2002]**



(A) 16 (B) 6
(C) 4 (D) 8

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

(A) 74 N (B) 15 N
(C) 49 N (D) 24 N

Q.6 Let $\vec{F}$ be the force acting on a particle having position vector $\vec{r}$, and $\vec{T}$ be the torque of this force about the origin. Then – **[AIEEE-2003]**

(A) $\vec{r}.\vec{T} \neq 0$ and $\vec{F}.\vec{T} = 0$ (B) $\vec{r}.\vec{T} \neq 0$ and $\vec{F}.\vec{T} \neq 0$
(C) $\vec{r}.\vec{T} = 0$ and $\vec{F}.\vec{T} = 0$ (D) $\vec{r}.\vec{T} = 0$ and $\vec{F}.\vec{T} \neq 0$

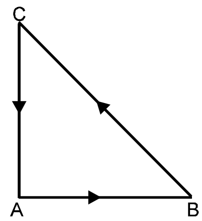
Q.7 A block of mass M is pulled along a horizontal frictionless surface by a rope of mass m. If a force P is applied at the free end of the rope, the force exerted by the rope on the block is – **[AIEEE-2003]**

(A) $\frac{Pm}{M-m}$ (B) P
(C) $\frac{PM}{M+m}$ (D) $\frac{Pm}{M+m}$

Q.8 One end of a light spring balance hangs from the hook of the other light spring balance attached to roof and a block of mass M kg hangs from the other end. Then the true statement about the scale reading is – **[AIEEE-2003]**

(A) The scale of the lower one reads M kg and of the upper one zero
(B) The reading of the two scales can be anything but the sum of the reading will be M kg
(C) Both the scales read M/2 kg each
(D) both the scales read M kg each

Q.9 Three forces start acting simultaneously on a particle moving with velocity $\vec{v}$. these forces are represented in magnitude and direction by the three sides of a triangle ABC (as shown). The particle will now move with velocity– **[AIEEE-2003]**



(A) Greater than $\vec{v}$
(B) |v| in the direction of the largest force BC
(C) $\vec{v}$, remaining unchanged
(D) Less than $\vec{v}$

Q.10 A machine gun fires a bullet of mass 40 g with a velocity 1200 ms^{-1}. The man holding it can exert a maximum force of 144 N on the gun. How many bullets can he fire per second at the most ? **[AIEEE-2004]**

(A) One (B) Four
(C) Two (D) Three

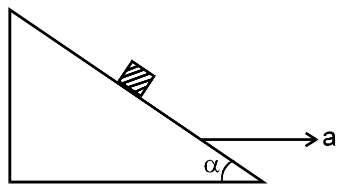
Q.11 Two masses m_1 = 5 kg and m_2 = 4.8 kg tied to a string are hanging over a light fricitionless pulley. What is the acceleration of the masses when left free to move ? (g = 9.8 m/s^2) **[AIEEE-2004]**

(A) 0.2 m/s^2 (B) 9.8 m/s^2
(C) 5 m/s^2 (D) 4.8 m/s^2

Q.12 A parachutist after bailing out falls 50 m without friction. When parachute opens, it decelerates at 2 m/s^2. He reaches the ground with a speed of 3 m/s. At what height, did he bail out ? **[AIEEE-2005]**

(A) 91 m (B) 182 m
(C) 293 m (D) 111 m

Q.13 A block is kept on a frictionless inclined surface with angle of inclination 'α'. The incline is given an acceleration 'a' to keep the block stationary. Then 'a' is equal to **[AIEEE-2005]**



(A) $g / \tan \alpha$ (B) $g \operatorname{cosec} \alpha$
(C) g (D) $g \tan \alpha$

Q.14 A particle of mass 0.3 kg is subjected to a force $F = -kx$ with $k = 15$ N/m. What will be its initial acceleration if it is released from a point 20 cm away from the origin ? **[AIEEE-2005]**

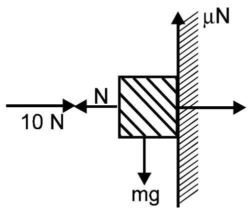
(A) 3 m/s^2 (B) 15 m/s^2
(C) 5 m/s^2 (D) 10 m/s^2

Q.15 A player caught a cricket ball of mass 150 g moving at a rate of 20 m/s. If the catching process is completed in 0.1 s, the force of the blow exerted by the ball on the hand of the player is equal to – **[AIEEE 2006]**

(A) 30 N (B) 300 N
(C) 150 N (D) 3 N

SECTION-2

Q.16 A horizontal force of 10 Newton is necessary to just hold a block stationary against a wall. The coefficient of friction between the block and the wall is 0.2. The weight of block is – **[AIEEE-2003]**



(A) 50 N (B) 100 N
(C) 2 N (D) 20 N

Q.17 A marble block of mass 2 kg lying on ice when given a velocity of 6 m/s is stopped by friction is 10 s. Then the coefficient of friction is – **[AIEEE-2003]**

(A) 0.03 (B) 0.04
(C) 0.06 (D) 0.02

Q.18 A block rests on a rough indined 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 block (in kg) is (Take $g = 10\ m/s^2$) **[AIEEE-2004]**

(A) 2.0 (B) 4.0
(C) 1.6 (D) 2.5

Q.19 A smooth block is released at rest on a 45° incline and then slides a distance 'd'. The time taken to slide is 'n' times as much to slide on rough incline than on a smooth incline. The coefficient of friction is **[AIEEE-2005]**

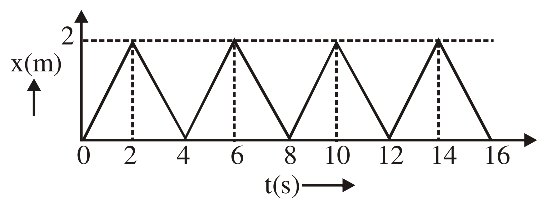
(A) $\mu_K = 1 - \frac{1}{n^2}$ (B) $\mu_k = \sqrt{1 - \frac{1}{n^2}}$

(C) $\mu_S = 1 - \frac{1}{n^2}$ (D) $\mu_S = \sqrt{1 - \frac{1}{n^2}}$

Q.20 The upper half of an inclined plane with inclination φ is perfectly smooth while the lower half is rough. A body starting from rest at the top will again come to rest at the bottom if the coefficient of friction for the lower half is given by **[AIEEE-2005]**

(A) $2 \sin \phi$ (B) $2 \cos \phi$
(C) $2 \tan \phi$ (D) $\tan \phi$

Q.21 The figure shows the position – time (x – t) graph of one-dimensional motion of a body of mass 0.4 kg. The magnitude of each impulse is – **[AIEEE 2010]**



(A) 0.4 Ns (B) 0.8 Ns
(C) 1.6 Ns (D) 0.2 Ns

ANSWER KEY

EXERCISE - 1

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

EXERCISE - 2

Q	1	2	3	4	5	6	7	8	9	10	11
A	B	C	B	B	A	A	C	A	A	A	B
Q	12	13	14	15	16	17	18	19	20	21	22
A	A	A	C	D	A	A	B	A	A	A	B
Q	23	24	25								
A	D	D	D								

EXERCISE - 3

Q.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Ans.	A	A	B	C	D	C	C	D	C	D	A	C	D	D	A	C	C	A	A	C	B