Chapter

4

Newton's Laws of Motion

Point Mass

(1) An object can be considered as a point object if during motion in a given time, it covers distance much greater than its own size.

(2) Object with zero dimension considered as a point mass.

(3) Point mass is a mathematical concept to simplify the problems.

Inertia

(1) Inherent property of all the bodies by virtue of which they cannot change their state of rest or uniform motion along a straight line by their own is called inertia.

(2) Inertia is not a physical quantity, it is only a property of the body which depends on mass of the body.

(3) Inertia has no units and no dimensions

(4) Two bodies of equal mass, one in motion and another is at rest, possess same inertia because it is a factor of mass only and does not depend upon the velocity.

Linear Momentum

(1) Linear momentum of a body is the quantity of motion contained in the body.

(2) It is measured in terms of the force required to stop the body in unit time.

(3) It is also measured as the product of the mass of the body and its velocity *i.e.*, Momentum = mass × velocity.

If a body of mass m is moving with velocity $\vec{v}$ then its linear momentum $\vec{p}$ is given by $\vec{p} = m\vec{v}$

(4) It is a vector quantity and it's direction is the same as the direction of velocity of the body.

(5) Units : *kg-m/sec* [S.I.], *g-cm/sec* [C.G.S.]

(6) Dimension : $[MLT^{-1}]$

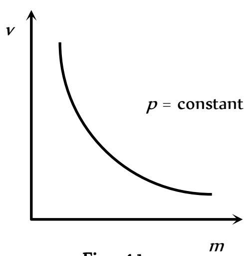


Fig : 4.1

(7) If two objects of different masses have same momentum, the lighter body possesses greater velocity.

$$p = m_1 v_1 = m_2 v_2 = \text{constant} \qquad \therefore \quad \frac{v_1}{v_2} = \frac{m_2}{m_1}$$

i.e. $v \propto \dfrac{1}{m}$

[As p is constant]

(8) For a given body $p \propto v$

(9) For different bodies moving with same velocities $p \propto m$

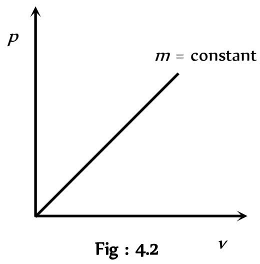


Fig : 4.2

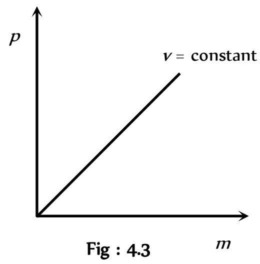


Fig : 4.3

Newton's First Law

A body continue to be in its state of rest or of uniform motion along a straight line, unless it is acted upon by some external force to change the state.

(1) If no net force acts on a body, then the velocity of the body cannot change *i.e.* the body cannot accelerate.

(2) Newton's first law defines inertia and is rightly called the law of inertia. Inertia are of three types :

Inertia of rest, Inertia of motion and Inertia of direction.

(3) **Inertia of rest :** It is the inability of a body to change by itself, its state of rest. This means a body at rest remains at rest and cannot start moving by its own.

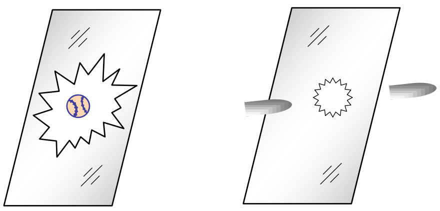
Example : (i) A person who is standing freely in bus, thrown backward, when bus starts suddenly.

When a bus suddenly starts, the force responsible for bringing bus in motion is also transmitted to lower part of body, so this part of the body comes in motion along with the bus. While the upper half of body (say above the waist) receives no force to overcome inertia of rest and so it stays in its original position. Thus there is a relative displacement between the two parts of the body and it appears as if the upper part of the body has been thrown backward.

Note : ❑ (i) If the motion of the bus is slow, the inertia of motion will be transmitted to the body of the person uniformly and so the entire body of the person will come in motion with the bus and the person will not experience any jerk.

(ii) When a horse starts suddenly, the rider tends to fall backward on account of inertia of rest of upper part of the body as explained above.

(iii) A bullet fired on a window pane makes a clean hole through it, while a ball breaks the whole window. The bullet has a speed much greater than the ball. So its time of contact with glass is small. So in case of bullet the motion is transmitted only to a small portion of the glass in that small time. Hence a clear hole is created in the glass window, while in case of ball, the time and the area of contact is large. During this time the motion is transmitted to the entire window, thus creating the cracks in the entire window.



Cracks by the ball   Hole by the bullet

Fig : 4.4

(iv) In the arrangement shown in the figure :

(a) If the string B is pulled with a sudden jerk then it will experience tension while due to inertia of rest of mass M this force will not be transmitted to the string A and so the string B will break.

(b) If the string B is pulled steadily the force applied to it will be transmitted from string B to A through the mass M and as tension in A will be greater than in B by Mg (weight of mass M), the string A will break.

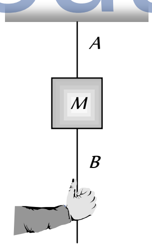


Fig : 4.5

(v) If we place a coin on smooth piece of card board covering a glass and strike the card board piece suddenly with a finger. The cardboard slips away and the coin falls into the glass due to inertia of rest.

(vi) The dust particles in a carpet falls off when it is beaten with a stick. This is because the beating sets the carpet in motion whereas the dust particles tend to remain at rest and hence separate.

(4) **Inertia of motion :** It is the inability of a body to change by itself its state of uniform motion *i.e.,* a body in uniform motion can neither accelerate nor retard by its own.

Example : (i) When a bus or train stops suddenly, a passenger sitting inside tends to fall forward. This is because the lower part of his body comes to rest with the bus or train but the upper part tends to continue its motion due to inertia of motion.

(ii) A person jumping out of a moving train may fall forward.

(iii) An athlete runs a certain distance before taking a long jump. This is because velocity acquired by running is added to velocity of the athlete at the time of jump. Hence he can jump over a longer distance.

(5) **Inertia of direction :** It is the inability of a body to change by itself it's direction of motion.

Example : (i) When a stone tied to one end of a string is whirled and the string breaks suddenly, the stone flies off along the tangent to the circle. This is because the pull in the string was forcing the stone to move in a circle. As soon as the string breaks, the pull vanishes. The stone in a bid to move along the straight line flies off tangentially.

(ii) The rotating wheel of any vehicle throw out mud, if any, tangentially, due to directional inertia.

(iii) When a car goes round a curve suddenly, the person sitting inside is thrown outwards.

Newton's Second Law

(1) The rate of change of linear momentum of a body is directly proportional to the external force applied on the body and this change takes place always in the direction of the applied force.

(2) If a body of mass m, moves with velocity $\vec{v}$ then its linear momentum can be given by $\vec{p} = m\vec{v}$ and if force $\vec{F}$ is applied on a body, then

$$\vec{F} \propto \frac{d\vec{p}}{dt} \Rightarrow F = K\frac{d\vec{p}}{dt}$$

or $\vec{F} = \dfrac{d\vec{p}}{dt}$ (K = 1 in C.G.S. and S.I. units)

or $\vec{F} = \dfrac{d}{dt}(m\vec{v}) = m\dfrac{d\vec{v}}{dt} = m\vec{a}$

(As $\vec{a} = \dfrac{d\vec{v}}{dt}$ = acceleration produced in the body)

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

Force = mass × acceleration

Force

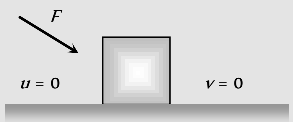
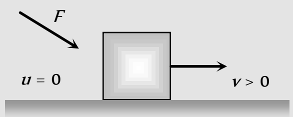
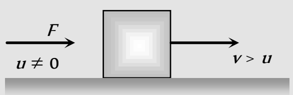
(1) Force is an external effect in the form of a push or pull which

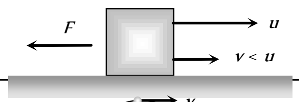
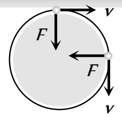
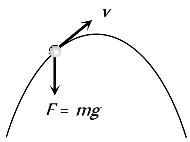
(i) Produces or tries to produce motion in a body at rest.

(ii) Stops or tries to stop a moving body.

(iii) Changes or tries to change the direction of motion of the body.

Table 4.1 : Various condition of force application

	Body remains at rest. Here force is trying to change the state of rest.
	Body starts moving. Here force changes the state of rest.
	In a small interval of time, force increases the magnitude of speed and direction of motion remains same.

	In a small interval of time, force decreases the magnitude of speed and direction of motion remains same.
	In uniform circular motion only direction of velocity changes, speed remains constant. Force is always perpendicular to velocity.
	In non-uniform circular motion, elliptical, parabolic or hyperbolic motion force acts at an angle to the direction of motion. In all these motions. Both magnitude and direction of velocity changes.

(2) Dimension : Force = mass × acceleration

$$[F]=[M][LT^{-2}]=[MLT^{-2}]$$

(3) Units : Absolute units : (i) *Newton* (S.I.) (ii) *Dyne* (C.G.S)

Gravitational units : (i) Kilogram-force (M.K.S.) (ii) Gram-force (C.G.S)

Newton : One Newton is that force which produces an acceleration of $1m/s^2$ in a body of mass 1 *Kilogram*.

$\therefore 1$ *Newton* $=1kg-m/s^2$

Dyne : One dyne is that force which produces an acceleration of $1cm/s^2$ in a body of mass 1 *gram*.

$\therefore$ 1 *Dyne* $=1gm\,cm/\sec^2$

Relation between absolute units of force 1 *Newton* $=10^5$ *Dyne*

Kilogram-force : It is that force which produces an acceleration of $9.8m/s^2$ in a body of mass 1 *kg*.

$\therefore$ 1 *kg-f* = 9.80 *Newton*

Gram-force : It is that force which produces an acceleration of $980cm/s^2$ in a body of mass 1*gm*.

$\therefore$ 1 *gm-f* = 980 *Dyne*

(4) $\vec{F}=m\vec{a}$ formula is valid only if force is changing the state of rest or motion and the mass of the body is constant and finite.

(5) If m is not constant $\vec{F}=\frac{d}{dt}(m\vec{v})=m\frac{d\vec{v}}{dt}+\vec{v}\frac{dm}{dt}$

(6) If force and acceleration have three component along *x*, *y* and *z* axis, then

$$\vec{F}=F_x\hat{i}+F_y\hat{j}+F_z\hat{k} \text{ and } \vec{a}=a_x\hat{i}+a_y\hat{j}+a_z\hat{k}$$

From above it is clear that $F_x=ma_x,\ F_y=ma_y, F_z=ma_z$

(7) No force is required to move a body uniformly along a straight line with constant speed.

$\vec{F}=m\vec{a}$ $\qquad \therefore \vec{F}=0$ (As $\vec{a}=0$)

(8) When force is written without direction then positive force means repulsive while negative force means attractive.

Example : *Positive force* – Force between two similar charges

Negative force – Force between two opposite charges

(9) Out of so many natural forces, for distance 10^{-15} *metre*, nuclear force is strongest while gravitational force weakest. $F_{\text{nuclear}}>F_{\text{electromagnetic}}>F_{\text{gravitational}}$

(10) Ratio of electric force and gravitational force between two electron's $F_e/F_g=10^{43}$ $\quad \therefore F_e>>F_g$

(11) Constant force : If the direction and magnitude of a force is constant. It is said to be a constant force.

(12) Variable or dependent force :

(i) *Time dependent force* : In case of impulse or motion of a charged particle in an alternating electric field force is time dependent.

(ii) *Position dependent force* : Gravitational force between two bodies $\frac{Gm_1m_2}{r^2}$

or Force between two charged particles $=\frac{q_1q_2}{4\pi\varepsilon_0 r^2}$.

(iii) *Velocity dependent force* : Viscous force $(6\pi\eta rv)$

Force on charged particle in a magnetic field $(qvB\sin\theta)$

(13) Central force : If a position dependent force is directed towards or away from a fixed point it is said to be central otherwise non-central.

Example : Motion of Earth around the Sun. Motion of electron in an atom. Scattering of α-particles from a nucleus.

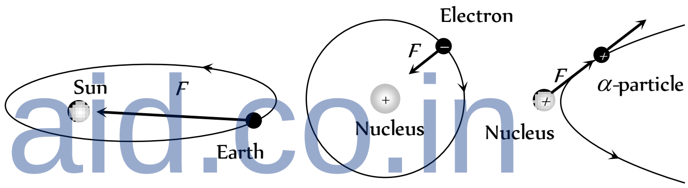


Fig : 4.6

(14) Conservative or non conservative force : If under the action of a force the work done in a round trip is zero or the work is path independent, the force is said to be conservative otherwise non conservative.

Example : Conservative force : Gravitational force, electric force, elastic force.

Non conservative force : Frictional force, viscous force.

(15) Common forces in mechanics :

(i) *Weight* : Weight of an object is the force with which earth attracts it. It is also called the force of gravity or the gravitational force.

(ii) *Reaction or Normal force :* When a body is placed on a rigid surface, the body experiences a force which is perpendicular to the surfaces in contact. Then force is called 'Normal force' or 'Reaction'.

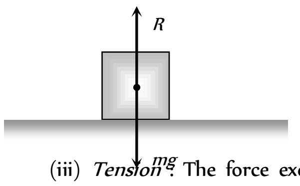


Fig : 4.7

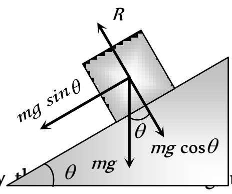


Fig : 4.8

(iii) *Tension* : The force exerted by ... rope or chain against pulling (applied) force is called the tension. The direction of tension is so as to pull the body.

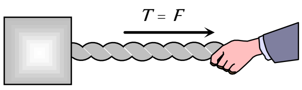


Fig : 4.9

(iv) *Spring force :* Every spring resists any attempt to change its length. This resistive force increases with change in length. Spring force is given by $F = -Kx$; where x is the change in length and K is the spring constant (unit N/m).

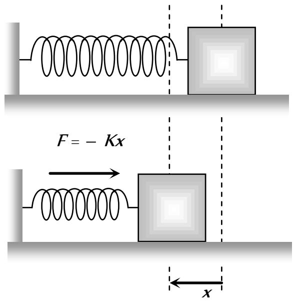


Fig : 4.10

Equilibrium of Concurrent Force

(1) If all the forces working on a body are acting on the same point, then they are said to be concurrent.

(2) A body, under the action of concurrent forces, is said to be in equilibrium, when there is no change in the state of rest or of uniform motion along a straight line.

(3) The necessary condition for the equilibrium of a body under the action of concurrent forces is that the vector sum of all the forces acting on the body must be zero.

(4) Mathematically for equilibrium $\sum \vec{F}_{net} = 0$ or $\sum F_x = 0$; $\sum F_y = 0$; , $\sum F_z = 0$

(5) Three concurrent forces will be in equilibrium, if they can be represented completely by three sides of a triangle taken in order.

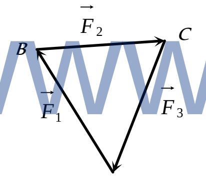


Fig : 4.11

(6) Lami's Theorem : For three concurrent forces in equilibrium

$$\frac{F_1}{\sin\alpha} = \frac{F_2}{\sin\beta} = \frac{F_3}{\sin\gamma}$$

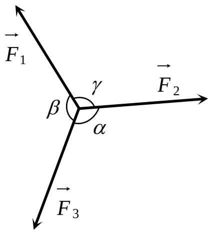


Fig : 4.12

Newton's Third Law

To every action, there is always an equal (in magnitude) and opposite (in direction) reaction.

(1) When a body exerts a force on any other body, the second body also exerts an equal and opposite force on the first.

(2) Forces in nature always occurs in pairs. A single isolated force is not possible.

(3) Any agent, applying a force also experiences a force of equal magnitude but in opposite direction. The force applied by the agent is called '*Action*' and the counter force experienced by it is called '*Reaction*'.

(4) Action and reaction never act on the same body. If it were so, the total force on a body would have always been zero *i.e.* the body will always remain in equilibrium.

(5) If $\vec{F}_{AB}$ = force exerted on body A by body B (Action) and $\vec{F}_{BA}$ = force exerted on body B by body A (Reaction)

Then according to Newton's third law of motion $\vec{F}_{AB} = -\vec{F}_{BA}$

(6) Example : (i) A book lying on a table exerts a force on the table which is equal to the weight of the book. This is the force of action.

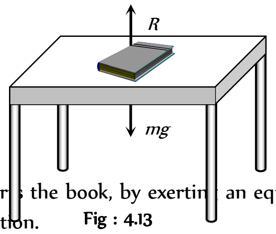


Fig : 4.13

The table supports the book, by exerting an equal force on the book. This is the force of reaction.

As the system is at rest, net force on it is zero. Therefore force of action and reaction must be equal and opposite.

(ii) Swimming is possible due to third law of motion.

(iii) When a gun is fired, the bullet moves forward (action). The gun recoils backward (reaction)

(iv) Rebounding of rubber ball takes place due to third law of motion.

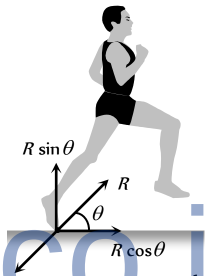


Fig : 4.14

(v) While walking a person presses the ground in the backward direction (action) by his feet. The ground pushes the person in forward direction with an equal force (reaction). The component of reaction in horizontal direction makes the person move forward.

(vi) It is difficult to walk on sand or ice.

(vii) Driving a nail into a wooden block without holding the block is difficult.

Frame of Reference

(1) A frame in which an observer is situated and makes his observations is known as his 'Frame of reference'.

(2) The reference frame is associated with a co-ordinate system and a clock to measure the position and time of events happening in space. We can describe all the physical quantities like position, velocity, acceleration etc. of an object in this coordinate system.

(3) Frame of reference are of two types : (i) Inertial frame of reference (ii) Non-inertial frame of reference.

(i) **Inertial frame of reference :**

(a) A frame of reference which is at rest or which is moving with a uniform velocity along a straight line is called an inertial frame of reference.

(b) In inertial frame of reference Newton's laws of motion holds good.

(c) Inertial frame of reference are also called unaccelerated frame of reference or Newtonian or Galilean frame of reference.

(d) Ideally no inertial frame exist in universe. For practical purpose a frame of reference may be considered as inertial if it's acceleration is negligible with respect to the acceleration of the object to be observed.

(e) To measure the acceleration of a falling apple, earth can be considered as an inertial frame.

(f) To observe the motion of planets, earth can not be considered as an inertial frame but for this purpose the sun may be assumed to be an inertial frame.

Example : The lift at rest, lift moving (up or down) with constant velocity, car moving with constant velocity on a straight road.

(ii) **Non-inertial frame of reference**

(a) Accelerated frame of references are called non-inertial frame of reference.

(b) Newton's laws of motion are not applicable in non-inertial frame of reference.

Example : Car moving in uniform circular motion, lift which is moving upward or downward with some acceleration, plane which is taking off.

Impulse

(1) When a large force works on a body for very small time interval, it is called impulsive force.

An impulsive force does not remain constant, but changes first from zero to maximum and then from maximum to zero. In such case we measure the total effect of force.

(2) Impulse of a force is a measure of total effect of force.

(3) $\vec{I} = \int_{t_1}^{t_2} \vec{F}\,dt$.

(4) Impulse is a vector quantity and its direction is same as that of force.

(5) Dimension : $[MLT^{-1}]$

(6) Units : *Newton-second* or *Kg-m-s*$^{-1}$ (S.I.)

Dyne-second or *gm-cm-S*$^{-1}$ (C.G.S.)

(7) Force-time graph : Impulse is equal to the area under *F-t* curve.

If we plot a graph between force and time, the area under the curve and time axis gives the value of impulse.

I = Area between curve and time axis

$= \frac{1}{2} \times$ Base $\times$ Height

$= \frac{1}{2} F\,t$

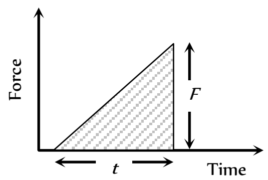


Fig : 4.15

(8) If F_{av} is the average magnitude of the force then

$$I = \int_{t_1}^{t_2} F\,dt = F_{av}\int_{t_1}^{t_2} dt = F_{av}\,\Delta t$$

(9) From Newton's second law

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

or $\int_{t_1}^{t_2} \vec{F}\,dt = \int_{p_1}^{p_2} d\vec{p}$

$\Rightarrow \vec{I} = \vec{p}_2 - \vec{p}_1 = \overrightarrow{\Delta p}$

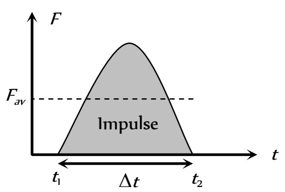


Fig : 4.16

i.e. The impulse of a force is equal to the change in momentum.

This statement is known as *Impulse momentum theorem*.

Examples : Hitting, kicking, catching, jumping, diving, collision *etc.*

In all these cases an impulse acts.

$$I = \int F\,dt = F_{av}.\Delta t = \Delta p = \text{constant}$$

So if time of contact Δt is increased, average force is decreased (or diluted) and vice-versa.

(i) In hitting or kicking a ball we decrease the time of contact so that large force acts on the ball producing greater acceleration.

(ii) In catching a ball a player by drawing his hands backwards increases the time of contact and so, lesser force acts on his hands and his hands are saved from getting hurt.

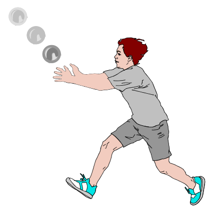


Fig : 4.17

(iii) In jumping on sand (or water) the time of contact is increased due to yielding of sand or water so force is decreased and we are not injured. However if we jump on cemented floor the motion stops in a very short interval of time resulting in a large force due to which we are seriously injured.

(iv) An athlete is advised to come to stop slowly after finishing a fast race, so that time of stop increases and hence force experienced by him decreases.

(v) China wares are wrapped in straw or paper before packing.

Law of Conservation of Linear Momentum

If no external force acts on a system (called isolated) of constant mass, the total momentum of the system remains constant with time.

(1) According to this law for a system of particles $\vec{F} = \frac{d\vec{p}}{dt}$

In the absence of external force $\vec{F} = 0$ then $\vec{p} =$ constant

i.e., $\vec{p} = \vec{p}_1 + \vec{p}_2 + \vec{p}_3 + ... =$ constant.

or $m_1\vec{v}_1 + m_2\vec{v}_2 + m_3\vec{v}_3 + ... =$ constant

This equation shows that in absence of external force for a closed system the linear momentum of individual particles may change but their sum remains unchanged with time.

(2) Law of conservation of linear momentum is independent of frame of reference, though linear momentum depends on frame of reference.

(3) Conservation of linear momentum is equivalent to Newton's third law of motion.

For a system of two particles in absence of external force, by law of conservation of linear momentum.

$\vec{p}_1 + \vec{p}_2 =$ constant.

$\therefore\ m_1\vec{v}_1 + m_2\vec{v}_2 =$ constant.

Differentiating above with respect to time

$$m_1\frac{d\vec{v}_1}{dt} + m_2\frac{d\vec{v}_2}{dt} = 0 \Rightarrow m_1\vec{a}_1 + m_2\vec{a}_2 = 0 \ \Rightarrow\ \vec{F}_1 + \vec{F}_2 = 0$$

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

i.e. for every action there is an equal and opposite reaction which is Newton's third law of motion.

(4) Practical applications of the law of conservation of linear momentum

(i) When a man jumps out of a boat on the shore, the boat is pushed slightly away from the shore.

(ii) A person left on a frictionless surface can get away from it by blowing air out of his mouth or by throwing some object in a direction opposite to the direction in which he wants to move.

(iii) **Recoiling of a gun :** For bullet and gun system, the force exerted by trigger will be internal so the momentum of the system remains unaffected.

Fig : 4.18

Let $m_G =$ mass of gun, $m_B =$ mass of bullet,

$v_G =$ velocity of gun, $v_B =$ velocity of bullet

Initial momentum of system = 0

Final momentum of system $= m_G\vec{v}_G + m_B\vec{v}_B$

By the law of conservation of linear momentum

$$m_G\vec{v}_G + m_B\vec{v}_B = 0$$

So recoil velocity $\vec{v}_G = -\dfrac{m_B}{m_G}\vec{v}_B$

(a) Here negative sign indicates that the velocity of recoil $\vec{v}_G$ is opposite to the velocity of the bullet.

(b) $v_G \propto \dfrac{1}{m_G}$ *i.e.* higher the mass of gun, lesser the velocity of recoil of gun.

(c) While firing the gun must be held tightly to the shoulder, this would save hurting the shoulder because in this condition the body of the shooter and the gun behave as one body. Total mass become large and recoil velocity becomes too small.

$$v_G \propto \frac{1}{m_G + m_{\text{man}}}$$

(iv) **Rocket propulsion :** The initial momentum of the rocket on its launching pad is zero. When it is fired from the launching pad, the exhaust gases rush downward at a high speed and to conserve momentum, the rocket moves upwards.

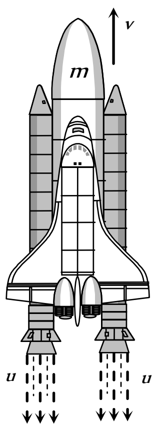


Fig : 4.19

Let $m_0 =$ initial mass of rocket,

$m =$ mass of rocket at any instant 't' (instantaneous mass)

$m_r =$ residual mass of empty container of the rocket

$u =$ velocity of exhaust gases,

$v =$ velocity of rocket at any instant 't' (instantaneous velocity)

$\dfrac{dm}{dt} =$ rate of change of mass of rocket = rate of fuel consumption

= rate of ejection of the fuel.

(a) Thrust on the rocket : $F = -u\dfrac{dm}{dt} - mg$

Here negative sign indicates that direction of thrust is opposite to the direction of escaping gases.

$F = -u\dfrac{dm}{dt}$ (if effect of gravity is neglected)

(b) Acceleration of the rocket : $a = \dfrac{u}{m}\dfrac{dm}{dt} - g$

and if effect of gravity is neglected $a = \dfrac{u}{m}\dfrac{dm}{dt}$

(c) Instantaneous velocity of the rocket :

$$v = u\log_e\left(\frac{m_0}{m}\right) - gt$$

and if effect of gravity is neglected $v = u\log_e\left(\dfrac{m_0}{m}\right)$ $= 2.303u\log_{10}\left(\dfrac{m_0}{m}\right)$

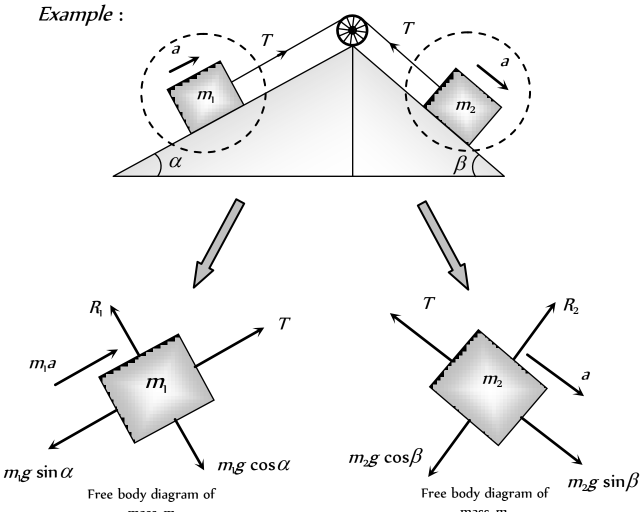
(d) Burnt out speed of the rocket : $v_b = v_{\max} = u\log_e\left(\dfrac{m_0}{m_r}\right)$

The speed attained by the rocket when the complete fuel gets burnt is called burnt out speed of the rocket. It is the maximum speed acquired by the rocket.

Free Body Diagram

In this diagram the object of interest is isolated from its surroundings and the interactions between the object and the surroundings are represented in terms of forces.

Example :

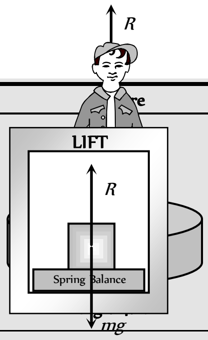
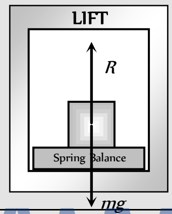
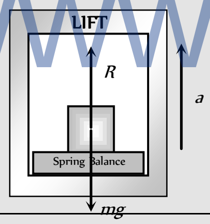
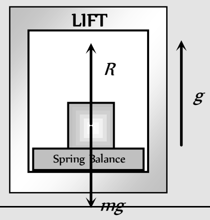
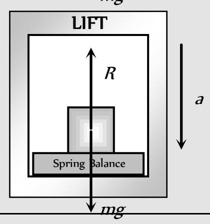
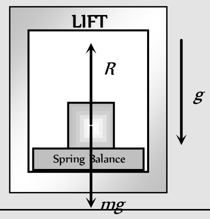
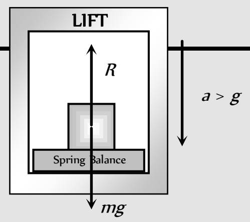


Apparent Weight of a Body in a Lift

When a body of mass m is placed on a weighing machine which is placed in a lift, then actual weight of the body is mg.

This acts on a weighing machine which offers a reaction R given by the reading of weighing machine. This reaction exerted by the surface of contact on the body is the *apparent weight* of the body.

Table 4.2 : Apparent weight in a lift

Condition	Figure	Velocity	Acceleration	Reaction	Conclusion
Lift is at rest		$v = 0$	$a = 0$	$R - mg = 0$ $\therefore\ R = mg$	Apparent weight = Actual weight
Lift moving upward or downward with constant velocity		v = constant	$a = 0$	$R - mg = 0$ $\therefore\ R = mg$	Apparent weight = Actual weight
Lift accelerating upward at the rate of 'a'		v = variable	$a < g$	$R - mg = ma$ $\therefore R = m(g + a)$	Apparent weight > Actual weight
Lift accelerating upward at the rate of 'g'		v = variable	$a = g$	$R - mg = mg$ $R = 2mg$	Apparent weight = 2 Actual weight
Lift accelerating downward at the rate of 'a'		v = variable	$a < g$	$mg - R = ma$ $\therefore\ R = m(g - a)$	Apparent weight < Actual weight
Lift accelerating downward at the rate of 'g'		v = variable	$a = g$	$mg - R = mg$ $R = 0$	Apparent weight = Zero (weightlessness)
Lift accelerating downward at the rate		v = variable	$a > g$	$mg - R = ma$ $R = mg - ma$	Apparent weight negative means the body will rise

of a($>g$)				$R = -\ ve$	from the floor of the lift and stick to the ceiling of the lift.

Acceleration of Block on Horizontal Smooth Surface

(1) **When a pull is horizontal**

$R = mg$

and $F = ma$

$\therefore\ a = F/m$

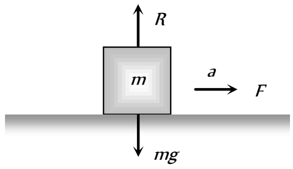


Fig : 4.22

(2) **When a pull is acting at an angle (θ) to the horizontal (upward)**

$R + F\sin\theta = mg$

$\Rightarrow R = mg - F\sin\theta$

and $F\cos\theta = ma$

$\therefore\ a = \dfrac{F\cos\theta}{m}$

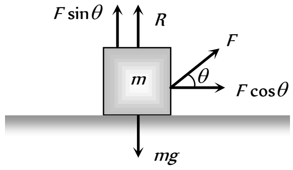


Fig : 4.23

(3) **When a push is acting at an angle (θ) to the horizontal (downward)**

$R = mg + F\sin\theta$

and $F\cos\theta = ma$

$a = \dfrac{F\cos\theta}{m}$

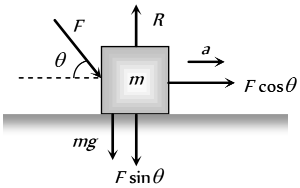


Fig : 4.24

Acceleration of Block on Smooth Inclined Plane

(1) **When inclined plane is at rest**

Normal reaction $R = mg\cos\theta$

Force along a inclined plane

$F = mg\sin\theta$; $ma = mg\ \sin\theta$

$\therefore a = g\sin\theta$

(2) **When a inclined plane given a horizontal acceleration 'b'**

Since the body lies in an accelerating frame, an inertial force (mb) acts on it in the opposite direction.

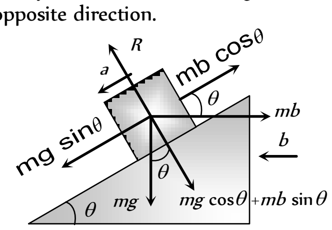


Fig : 4.25

Normal reaction $R = mg\cos\theta + mb\sin\theta$

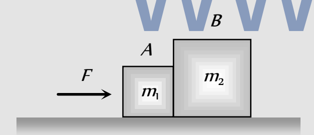
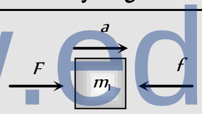
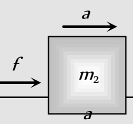
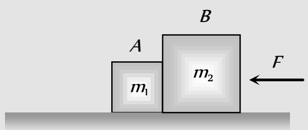
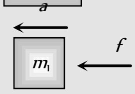
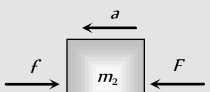
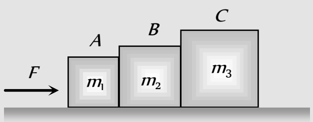
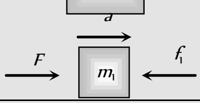
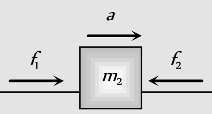
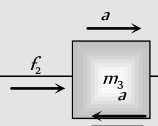
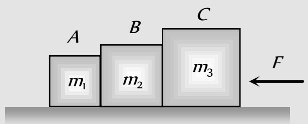
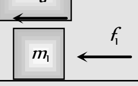
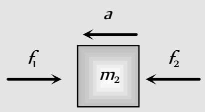
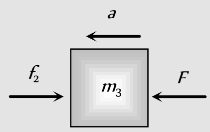
and $ma = mg\ \sin\theta - mb\cos\theta$

$\therefore\quad a = g\sin\theta - b\cos\theta$

Note : ❑ The condition for the body to be at rest relative to the inclined plane : $a = g\sin\theta - b\cos\theta = 0$

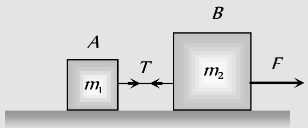
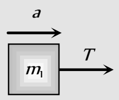
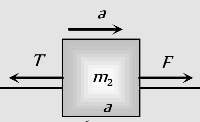
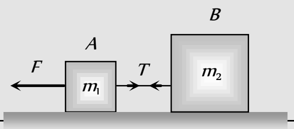
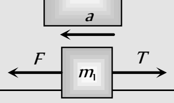
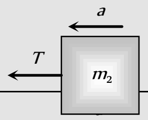
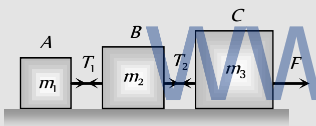
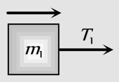
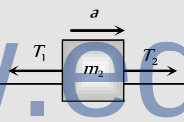
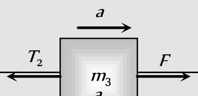
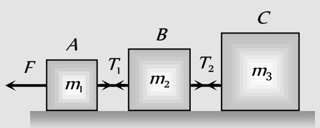
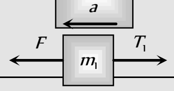
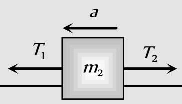
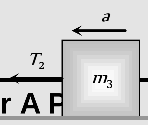
$\therefore\ b = g\tan\theta$

Motion of Blocks In Contact

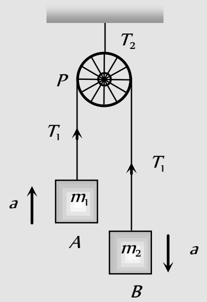
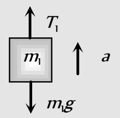
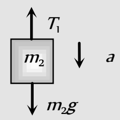
Condition	Free body diagram	Equation	Force and acceleration
		$F - f = m_1 a$	$a = \dfrac{F}{m_1 + m_2}$
		$f = m_2 a$	$f = \dfrac{m_2 F}{m_1 + m_2}$
		$f = m_1 a$	$a = \dfrac{F}{m_1 + m_2}$
		$F - f = m_2 a$	$f = \dfrac{m_1 F}{m_1 + m_2}$
		$F - f_1 = m_1 a$	$a = \dfrac{F}{m_1 + m_2 + m_3}$
		$f_1 - f_2 = m_2 a$	$f_1 = \dfrac{(m_2 + m_3)F}{m_1 + m_2 + m_3}$
		$f_2 = m_3 a$	$f_2 = \dfrac{m_3 F}{m_1 + m_2 + m_3}$
		$f_1 = m_1 a$	$a = \dfrac{F}{m_1 + m_2 + m_3}$
		$f_2 - f_1 = m_2 a$	$f_1 = \dfrac{m_1 F}{m_1 + m_2 + m_3}$
			

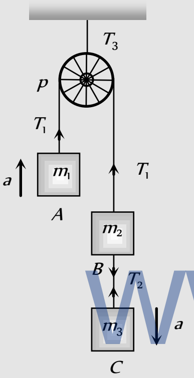
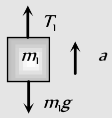
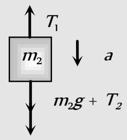
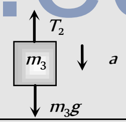
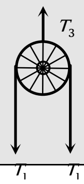
		$F - f_2 = m_3 a$	$f_2 = \dfrac{(m_1 + m_2)F}{m_1 + m_2 + m_3}$

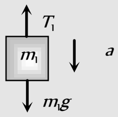
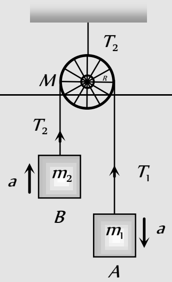
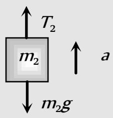
Motion of Blocks Connected by Mass Less String

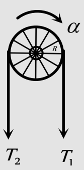
Condition	Free body diagram	Equation	Tension and acceleration
		$T = m_1 a$	$a = \dfrac{F}{m_1 + m_2}$
		$F - T = m_2 a$	$T = \dfrac{m_1 F}{m_1 + m_2}$
		$F - T = m_1 a$	$a = \dfrac{F}{m_1 + m_2}$
		$T = m_2 a$	$T = \dfrac{m_2 F}{m_1 + m_2}$
		$T_1 = m_1 a$	$a = \dfrac{F}{m_1 + m_2 + m_3}$
		$T_2 - T_1 = m_2 a$	$T_1 = \dfrac{m_1 F}{m_1 + m_2 + m_3}$
		$F - T_2 = m_3 a$	$T_2 = \dfrac{(m_1 + m_2)F}{m_1 + m_2 + m_3}$
		$F - T_1 = m_1 a$	$a = \dfrac{F}{m_1 + m_2 + m_3}$
		$T_1 - T_2 = m_2 a$	$T_1 = \dfrac{(m_2 + m_3)F}{m_1 + m_2 + m_3}$
		$T_2 = m_3 a$	$T_2 = \dfrac{m_3 F}{m_1 + m_2 + m_3}$

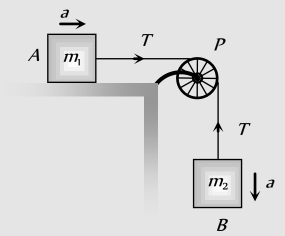
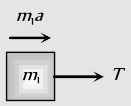
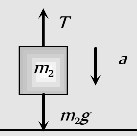
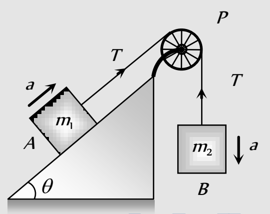
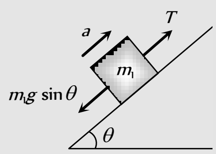
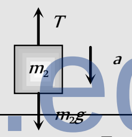
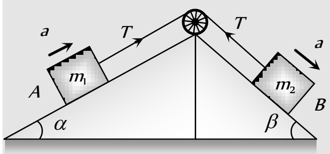
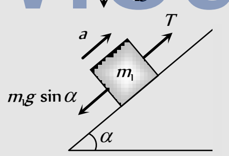
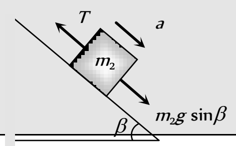
Motion of Connected Block Over A P

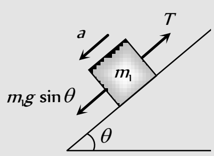
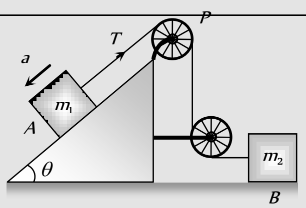
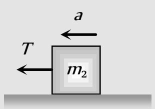
Condition	Free body diagram	Equation	Tension and acceleration
		$m_1 a = T_1 - m_1 g$	$T_1 = \dfrac{2m_1 m_2}{m_1 + m_2} g$
			
			

		$m_2a = m_2g - T_1$	$T_2 = \frac{4m_1m_2}{m_1+m_2}g$
		$T_2 = 2T_1$	$a = \left[\frac{m_2-m_1}{m_1+m_2}\right]g$
		$m_1a = T_1 - m_1g$	$T_1 = \frac{2m_1[m_2+m_3]}{m_1+m_2+m_3}g$
		$m_2a = m_2g + T_2 - T_1$	$T_2 = \frac{2m_1m_3}{m_1+m_2+m_3}g$
		$m_3a = m_3g - T_2$	$T_3 = \frac{4m_1[m_2+m_3]}{m_1+m_2+m_3}g$
		$T_3 = 2T_1$	$a = \frac{[(m_2+m_3)-m_1]g}{m_1+m_2+m_3}$

Condition	Free body diagram	Equation	Tension and acceleration
When pulley have a finite mass M and radius R then tension in two segments of string are different		$m_1a = m_1g - T_1$	$a = \frac{m_1-m_2}{m_1+m_2+\frac{M}{2}}$
		$m_2a = T_2 - m_2g$	$T_1 = \frac{m_1\left[2m_2+\frac{M}{2}\right]}{m_1+m_2+\frac{M}{2}}g$



		Torque $=(T_1-T_2)R = I\alpha$ $(T_1-T_2)R = I\frac{a}{R}$ $(T_1-T_2)R = \frac{1}{2}MR^2\frac{a}{R}$ $T_1 - T_2 = \frac{Ma}{2}$	$T_2 = \frac{m_2\left[2m_1+\frac{M}{2}\right]}{m_1+m_2+\frac{M}{2}}g$
		$T = m_1 a$	$a = \frac{m_2}{m_1+m_2}g$
		$m_2 a = m_2 g - T$	$T = \frac{m_1 m_2}{m_1+m_2}g$
		$m_1 a = T - m_1 g\sin\theta$	$a = \left[\frac{m_2 - m_1\sin\theta}{m_1+m_2}\right]g$
		$m_2 a = m_2 g - T$	$T = \frac{m_1 m_2(1+\sin\theta)}{m_1+m_2}g$
		$T - m_1 g\sin\alpha = m_1 a$	$a = \frac{(m_2\sin\beta - m_1\sin\alpha)}{m_1+m_2}g$
		$m_2 a = m_2 g\sin\beta - T$	$T = \frac{m_1 m_2(\sin\alpha+\sin\beta)}{m_1+m_2}g$

Condition	Free body diagram	Equation	Tension and acceleration
		$m_1 g\sin\theta - T = m_1 a$	$a = \frac{m_1 g\sin\theta}{m_1+m_2}$
			

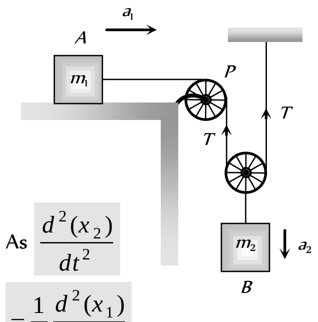
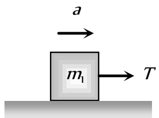
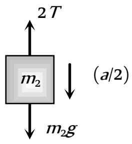
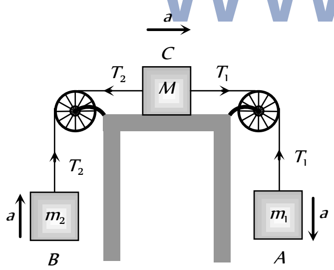
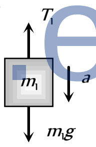
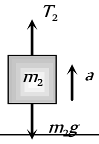
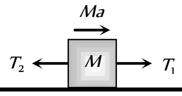
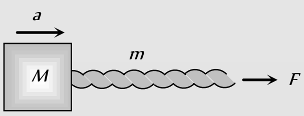
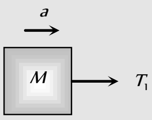
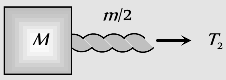
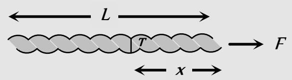
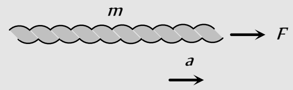
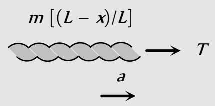
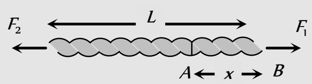
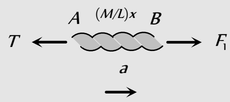
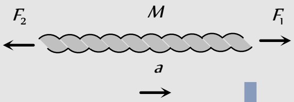
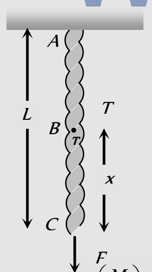
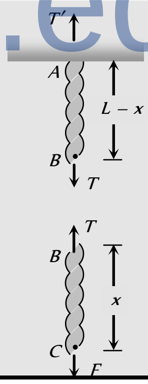
		$T = m_2 a$	$T = \frac{2m_1 m_2}{4m_1 + m_2} g$
 As $\frac{d^2(x_2)}{dt^2} = \frac{1}{2}\frac{d^2(x_1)}{dt^2}$ $\therefore a_2 = \frac{a_1}{2}$ a_1 = acceleration of block A a_2 = acceleration of block B		$T = m_1 a$	$a_1 = a = \frac{2m_2 g}{4m_1 + m_2}$ $a_2 = \frac{m_2 g}{4m_1 + m_2}$ $T = \frac{2m_1 m_2 g}{4m_1 + m_2}$
		$m_2 \frac{a}{2} = m_2 g - 2T$	
		$m_1 a = m_1 g - T_1$	$a = \frac{(m_1 - m_2)}{[m_1 + m_2 + M]} g$
		$m_2 a = T_2 - m_2 g$	$T_1 = \frac{m_1(2m_2 + M)}{[m_1 + m_2 + M]} g$
		$T_1 - T_2 = Ma$	$T_2 = \frac{m_2(2m_2 + M)}{[m_1 + m_2 + M]} g$

Table 4.3 : Motion of massive string

Condition	Free body diagram	Equation	Tension and acceleration
	 T_1 = force applied by the string on the block	$F = (M + m)a$ $T_1 = Ma$	$a = \frac{F}{M + m}$ $T_1 = M\frac{F}{(M+m)}$
			

	T_2 = Tension at mid point of the rope	$T_2 = \left(M + \frac{m}{2}\right)a$	$T_2 = \frac{(2M+m)}{2(M+m)}F$
		$F = ma$	$a = F/m$
m = Mass of string T = Tension in string at a distance x from the end where the force is applied		$T = m\left(\frac{L-x}{L}\right)a$	$T = \left(\frac{L-x}{L}\right)F$
		$F_1 - T = \frac{Mxa}{L}$	$a = \frac{F_1 - F_2}{M}$
M = Mass of uniform string L = Length of string		$F_1 - F_2 = Ma$	$T = F_1\left(1 - \frac{x}{L}\right) + F_2\left(\frac{x}{L}\right)$
 Mass of segment $BC = \left(\frac{M}{L}\right)x$		$T' = \frac{M}{L}(L-x)g + T$ $T = F + \frac{M}{L}xg$	$T' = F + Mg$ $T = F + \frac{M}{L}xg$

Spring Balance and Physical Balance

(1) **Spring balance :** When its upper end is fixed with rigid support and body of mass m hung from its lower end. Spring is stretched and the weight of the body can be measured by the reading of spring balance $R = W = mg$

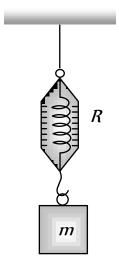


Fig : 4.26

The mechanism of weighing machine is same as that of spring balance.

Effect of frame of reference : In inertial frame of reference the reading of spring balance shows the actual weight of the body but in non-inertial frame of reference reading of spring balance increases or decreases in accordance with the direction of acceleration

(2) **Physical balance :** In physical balance actually we compare the mass of body in both the pans. Here we does not calculate the absolute weight of the body.

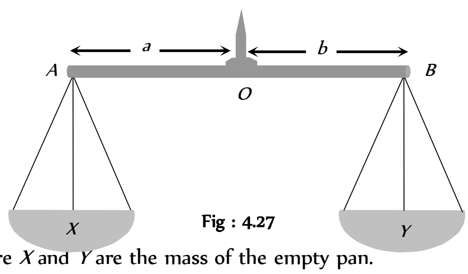


Fig : 4.27

Here X and Y are the mass of the empty pan.

(i) Perfect physical balance :

Weight of the pan should be equal *i.e.* $X = Y$

and the needle must in middle of the beam *i.e.* $a = b$.

Effect of frame of reference : If the physical balance is perfect then there will be no effect of frame of reference (either inertial or non-inertial) on the measurement. It is always errorless.

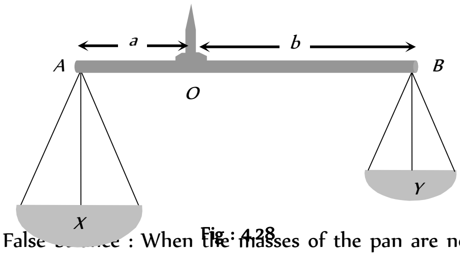


Fig : 4.28

(ii) False balance : When the masses of the pan are not equal then balance shows the error in measurement. False balance may be of two types

(a) If the beam of physical balance is horizontal (when the pans are empty) but the arms are not equal

$X > Y$ and $a < b$

For rotational equilibrium about point '*O*'

$Xa = Yb$ ...(i)

In this physical balance if a body of weight W is placed in pan X then to balance it we have to put a weight W_1 in pan *Y*.

For rotational equilibrium about point '*O*'

$(X + W)a = (Y + W_1)b$ ...(ii)

Now if the pans are changed then to balance the body we have to put a weight W_2 in pan *X*.

For rotational equilibrium about point '*O*'

$(X + W_2)a = (Y + W)b$ ...(iii)

From (i), (ii) and (iii)

True weight $W = \sqrt{W_1 W_2}$

(b) If the beam of physical balance is not horizontal (when the pans are empty) and the arms are equal

i.e. $X > Y$ and $a = b$

In this physical balance if a body of weight W is placed in X Pan then to balance it.

We have to put a weight W_1 in Y Pan

For equilibrium $X + W = Y + W_1$ ...(i)

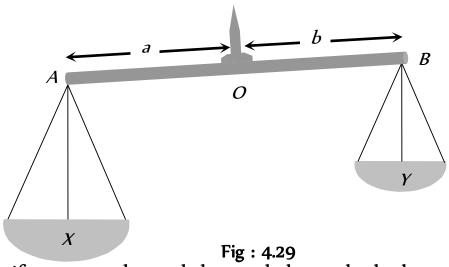


Fig : 4.29

Now if pans are changed then to balance the body we have to put a weight W_2 in X Pan.

For equilibrium $X + W_2 = Y + W$ ...(ii)

From (i) and (ii)

True weight $W = \dfrac{W_1 + W_2}{2}$

Modification of Newton's Laws of motion

According to Newton, time and space are absolute. The velocity of observer has no effect on it. But, according to special theory of relativity Newton's laws are true, as long as we are dealing with velocities which are small compare to velocity of light. Hence the time and space measured by two observers in relative motion are not same. Some conclusions drawn by the special theory of relativity about mass, time and distance which are as follows :

(1) Let the length of a rod at rest with respect to an observer is L_0. If the rod moves with velocity v w.r.t. observer and its length is *L*, then

$L = L_0\sqrt{1 - v^2 / c^2}$

where, c is the velocity of light.

Now, as v increases L decreases, hence the length will appear shrinking.

(2) Let a clock reads T_0 for an observer at rest. If the clock moves with velocity v and clock reads T with respect to observer, then

$$T = \frac{T_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Hence, the clock in motion will appear slow.

(3) Let the mass of a body is m_0 at rest with respect to an observer. Now, the body moves with velocity v with respect to observer and its mass is *m*, then $m = \dfrac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$

m_0 is called the rest mass.

Hence, the mass increases with the increases of velocity.

Note : ❑ If $v << c$, *i.e.*, velocity of the body is very small *w.r.t.* velocity of light, then $m = m_0$. *i.e.*, in the practice there will be no change in the mass.

❑ If v is comparable to c, then $m > m_0$ *i.e.*, mass will increase.

❑ If $v = c$, then $m = \dfrac{m_0}{\sqrt{1 - \frac{v^2}{v^2}}}$ or $m = \dfrac{m_0}{0} = \infty$. Hence, the mass becomes infinite, which is not possible, thus the speed cannot be equal to the velocity of light.

❑ The velocity of particles can be accelerated up to a certain limit. Even in cyclotron the speed of charged particles cannot be increased beyond a certain limit.

Tips & Tricks

✍ Inertia is proportional to mass of the body.

✍ Force cause acceleration.

✍ In the absence of the force, a body moves along a straight line path.

✍ A system or a body is said to be in equilibrium, when the net force acting on it is zero.

✍ If a number of forces $\vec{F}_1, \vec{F}_2, \vec{F}_3, ...$ act on the body, then it is in equilibrium when $\vec{F}_1 + \vec{F}_2 + \vec{F}_3 + ... = \vec{0}$

- A body in equilibrium cannot change the direction of motion.
- Four types of forces exist in nature. They are – gravitation (F_g), electromagnetic (F_{em}), weak force (F_w) and nuclear force (F_n).

$(F_g):(F_w):(F_{em}):(F_n)$: : 1 : 10^{25} : 10^{36} : 10^{38}

- If a body moves along a curved path, then it is certainly acted upon by a force.
- A single isolated force cannot exist.
- Forces in nature always occur in pairs.
- Newton's first law of the motion defines the force.
- Absolute units of force remains the same throughout the universe while gravitational units of force varies from place to place as they depend upon the value of 'g'.
- Newton's second law of motion gives the measure of force i.e. $F = ma$.
- Force is a vector quantity.
- Absolute units of force are dyne in CGS system and newton (N) in *SI*.
- 1 $N = 10^5$ *dyne.*
- Gravitational units of force are *gf* (or *gwt*) in *CGS* system and *kgf* (or *kgwt*) in *SI*.
- 1 *gf* = 980 *dyne* and 1 *kgf* = 9.8 *N*
- The beam balance compares masses.
- Acceleration of a horse-cart system is

$$a = \frac{H - F}{M + m}$$

where H = Horizontal component of reaction; F = force of friction; M = mass of horse; m = mass of cart.

- The weight of the body measured by the spring balance in a lift is equal to the apparent weight.
- Apparent weight of a freely falling body = ZERO, (state of weightlessness).
- If the person climbs up along the rope with acceleration *a*, then tension in the rope will be $m(g+a)$
- If the person climbs down along the rope with acceleration, then tension in the rope will be $m(g - a)$
- When the person climbs up or down with uniform speed, tension in the string will be *mg*.
- A body starting from rest moves along a smooth inclined plane of length *l*, height *h* and having angle of inclination θ.

(i) Its acceleration down the plane is $g \sin\theta$.

(ii) Its velocity at the bottom of the inclined plane will be $\sqrt{2gh} = \sqrt{2gl\sin\theta}$.

(iii) Time taken to reach the bottom will be

$$t = \sqrt{\frac{2l}{g\sin\theta}} = \frac{1}{\sin\theta}\sqrt{\frac{2h}{g}}$$

(iv) If the angle of inclination is changed keeping the height constant then

$$\frac{t_1}{t_2} = \frac{\sin\theta_2}{\sin\theta_1}$$

- For an isolated system (on which no external force acts), the total momentum remains conserved (Law of conservation of momentum).
- The change in momentum of a body depends on the magnitude and direction of the applied force and the period of time over which it is applied *i.e.* it depends on its impulse.
- Guns recoil when fired, because of the law of conservation of momentum. The positive momentum gained by the bullet is equal to negative recoil momentum of the gun and so the total momentum before and after the firing of the gun is zero.
- Recoil velocity of the gun is $\vec{V} = \frac{-m}{M}\vec{v}$
- where m = mass of bullet, M = mass of gun and $\vec{v}$ = muzzle velocity of bullet.
- The rocket pushes itself forwards by pushing the jet of exhaust gases backwards.
- Upthrust on the rocket = $u \times \frac{dm}{dt}$.

where u = velocity of escaping gases relative to rocket and $\frac{dm}{dt}$ = rate of consumption of fuel.

- Initial thrust on rocket = $m(g + a)$, where a is the acceleration of the rocket.
- Upward acceleration of rocket = $\frac{u}{m} \times \frac{dm}{dt}$.
- Impulse, $\vec{I} = \vec{F} \times \Delta t =$ change in momentum
- Unit of impulse is *N-s.*
- Action and reaction forces never act on the same body. They act on different bodies. If they act on the same body, the resultant force on the body will be zero i.e., the body will be in equilibrium.
- Action and reaction forces are equal in magnitude but opposite in direction.
- Action and reaction forces act along the line joining the centres of two bodies.
- Newton's third law is applicable whether the bodies are at rest or in motion.
- The non-inertial character of the earth is evident from the fact that a falling object does not fall straight down but slightly deflects to the

east.

Ordinary Thinking

Objective Questions

First law of motion

1. A rider on horse back falls when horse starts running all of a sudden because [MP PMT 1982]
   (a) Rider is taken back
   (b) Rider is suddenly afraid of falling
   (c) Inertia of rest keeps the upper part of body at rest whereas lower part of the body moves forward with the horse
   (d) None of the above
2. When a train stops suddenly, passengers in the running train feel an instant jerk in the forward direction because [MP PMT 1982]
   (a) The back of seat suddenly pushes the passengers forward
   (b) Inertia of rest stops the train and takes the body forward
   (c) Upper part of the body continues to be in the state of motion whereas the lower part of the body in contact with seat remains at rest
   (d) Nothing can be said due to insufficient data
3. Inertia is that property of a body by virtue of which the body is [MGIMS Wardha 1982]
   (a) Unable to change by itself the state of rest
   (b) Unable to change by itself the state of uniform motion
   (c) Unable to change by itself the direction of motion
   (d) Unable to change by itself the state of rest and of uniform linear motion
4. A man getting down a running bus falls forward because [CPMT 1981]
   (a) Due to inertia of rest, road is left behind and man reaches forward
   (b) Due to inertia of motion upper part of body continues to be in motion in forward direction while feet come to rest as soon as they touch the road
   (c) He leans forward as a matter of habit
   (d) Of the combined effect of all the three factors stated in (*a*), (*b*) and (*c*)
5. A boy sitting on the topmost berth in the compartment of a train which is just going to stop on a railway station, drops an apple aiming at the open hand of his brother sitting vertically below his hands at a distance of about 2 *meter*. The apple will fall [CPMT 1986]
   (a) Precisely on the hand of his brother
   (b) Slightly away from the hand of his brother in the direction of motion of the train
   (c) Slightly away from the hand of his brother in the direction opposite to the direction of motion of the train
   (d) None of the above

6. Newton's first law of motion describes the following [MP PMT 1996]

(a) Energy (b) Work

(c) Inertia (d) Moment of inertia

7. A person sitting in an open car moving at constant velocity throws a ball vertically up into air. The ball falls [EAMCET (Med.) 1995; MH CET 2003;BCECE 2004]

(a) Outside the car

(b) In the car ahead of the person

(c) In the car to the side of the person

(d) Exactly in the hand which threw it up

8. A bird weighs 2 *kg* and is inside a closed cage of 1 *kg*. If it starts flying, then what is the weight of the bird and cage assembly

(a) 1.5 *kg* (b) 2.5 *kg*

(c) 3 *kg* (d) 4 *kg*

9. A particle is moving with a constant speed along a straight line path. A force is not required to [AFMC 2001]

(a) Increase its speed

(b) Decrease the momentum

(c) Change the direction

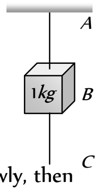
(d) Keep it moving with uniform velocity

10. When a bus suddenly takes a turn, the passengers are thrown outwards because of [AFMC 1999; CPMT 2000, 2001]

(a) Inertia of motion (b) Acceleration of motion

(c) Speed of motion (d) Both (b) and (c)

11. A mass of 1 *kg* is suspended by a string *A*. Another string *C* is connected to its lower end (see figure). If a sudden jerk is given to C, then



(a) The portion *AB* of the string will break

(b) The portion *BC* of the string will break

(c) None of the strings will break

(d) The mass will start rotating

12. In the above Question, if the string *C* is stretched slowly, then

(a) The portion *AB* of the string will break

(b) The portion *BC* of the string will break

(c) None of the strings will break

(d) None of the above

Second Law of Motion

1. If a bullet of mass 5 *gm* moving with velocity 100 *m /sec*, penetrates the wooden block upto 6 *cm*. Then the average force imposed by the bullet on the block is [MP PMT 2003]

(a) 8300 *N* (b) 417 *N*

(c) 830 *N* (d) Zero

2. Newton's second law gives the measure of [CPMT 1982]

(a) Acceleration (b) Force

(c) Momentum (d) Angular momentum

3. A force of 100 dynes acts on mass of 5 *gm* for 10 *sec*. The velocity produced is [MNR 1987]

(a) 2 *cm/sec* (b) 20 *cm/sec*

(c) 200 *cm/sec* (d) 2000 *cm/sec*

4. An object will continue moving uniformly until [CPMT 1975]

(a) The resultant force acting on it begins to decrease

(b) The resultant force on it is zero

(c) The resultant force is at right angle to its rotation

(d) The resultant force on it is increased continuously

5. A diwali rocket is ejecting 0.05 *kg* of gases per second at a velocity of 400 *m/sec*. The accelerating force on the rocket is [NCERT 1979; DPMT 2001; MP PMT 2004]

(a) 20 *dynes* (b) 20 *N*

(c) 22 *dynes* (d) 1000 *N*

6. A body of mass 2 *kg* moving on a horizontal surface with an initial velocity of 4 *m/sec* comes to rest after 2 sec. If one wants to keep this body moving on the same surface with a velocity of 4 *m/sec*, the force required is [NCERT 1977] [AFMC 1997]

(a) 8 *N* (b) 4 *N*

(c) Zero (d) 2 *N*

7. 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 [NCERT 1977]

(a) 2 *kg* (b) $(4 \times g) kg$

(c) $(2 \times g) kg$ (d) Zero

8. In the above problem, if the lift moves up with a constant velocity of 2 *m/sec*, the reading on the balance will be [NCERT 1977]

(a) 2 *kg* (b) 4 *kg*

(c) Zero (d) 1 *kg*

9. In the above problem if the lift moves up with an acceleration equal to the acceleration due to gravity, the reading on the spring balance will be [NCERT 1977]

(a) 2 *kg* (b) $(2 \times g) kg$

(c) $(4 \times g) kg$ (d) 4 *kg*

10. A coin is dropped in a lift. It takes time t_1 to reach the floor when lift is stationary. It takes time t_2 when lift is moving up with constant acceleration. Then

(a) $t_1 > t_2$ (b) $t_2 > t_1$

(c) $t_1 = t_2$ (d) $t_1 >> t_2$

11. If the tension in the cable of 1000 *kg* elevator is 1000 *kg* weight, the elevator [NCERT 1971]

(a) Is accelerating upwards

(b) Is accelerating downwards

(c) May be at rest or accelerating

(d) May be at rest or in uniform motion

12. A man weighing 80 kg is standing in a trolley weighing 320 *kg*. The trolley is resting on frictionless horizontal rails. If the man starts walking on the trolley with a speed of 1 *m / s*, then after 4 *sec* his displacement relative to the ground will be

(a) 5 *m* (b) 4.8 *m*

(c) 3.2 *m* (d) 3.0 *m*

13. In doubling the mass and acceleration of the mass, the force acting on the mass with respect to the previous value

(a) Decreases to half (b) Remains unchanged

(c) Increases two times (d) Increases four times

14. A force of 5 N acts on a body of weight 9.8 N. What is the acceleration produced in $m/\sec^2$ [NCERT 1990]

(a) 49.00 (b) 5.00

(c) 1.46 (d) 0.51

15. A body of mass 40 *gm* is moving with a constant velocity of 2 *cm/sec* on a horizontal frictionless table. The force on the table is

(a) 39200 *dyne* (b) 160 *dyne*

(c) 80 *dyne* (d) Zero *dyne*

16. When 1 N force acts on 1 *kg* body that is able to move freely, the body receives [CPMT 1971]

(a) A speed of 1 *m/sec*

(b) An acceleration of $1\,m/\sec^2$

(c) An acceleration of $980\,cm/\sec^2$

(d) An acceleration of $1\,cm/\sec^2$

17. An object with a mass 10 *kg* moves at a constant velocity of 10 *m/sec*. A constant force then acts for 4 second on the object and gives it a speed of 2 *m/sec* in opposite direction. The acceleration produced in it, is [CPMT 1971]

(a) $3\,m/\sec^2$ (b) $-3\,m/\sec^2$

(c) $0.3\,m/\sec^2$ (d) $-0.3\,m/\sec^2$

18. In the above question, the force acting on the object is [CPMT 1971]

(a) 30 N (b) – 30 N

(c) 3 N (d) – 3 N

19. In the above question, the impulse acting on the object is [CPMT 1971]

(a) $120\ newton \times \sec$ (b) $-120\ newton\sec$

(c) $30\ newton \times \sec$ (d) $-30\ newton \times \sec$

20. A machine gun is mounted on a 2000 *kg* car on a horizontal frictionless surface. At some instant the gun fires bullets of mass 10 *gm* with a velocity of 500 *m/sec* with respect to the car. The number of bullets fired per second is ten. The average thrust on the system is [CPMT 1971]

(a) 550 N (b) 50 N

(c) 250 N (d) 250 *dyne*

21. In the above question, the acceleration of the car will be [CPMT 1971]

(a) $0.25\,m/\sec^2$ (b) $2.5\,m/\sec^2$

(c) $5.0\,m/\sec^2$ (d) $0.025\,m/\sec^2$

22. A person is standing in an elevator. In which situation he finds his weight less than actual when [AIIMS 2005]

(a) The elevator moves upward with constant acceleration

(b) The elevator moves downward with constant acceleration.

(c) The elevator moves upward with uniform velocity

(d) The elevator moves downward with uniform velocity

23. 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) 5 *m/s* (b) 10 *m/s*

(c) 3 *m/s* (d) 15 *m/s*

24. A block of metal weighing 2 *kg* is resting on a frictionless plane. It is struck by a jet releasing water at a rate of 1 *kg/sec* and at a speed of 5 *m/sec*. The initial acceleration of the block will be [NCERT 1978]

(a) $2.5\,m/\sec^2$ (b) $5.0\,m/\sec^2$

(c) $10\,m/\sec^2$ (d) None of the above

25. Gravels are dropped on a conveyor belt at the rate of 0.5 *kg/sec*. The extra force required in *newtons* to keep the belt moving at 2 *m/sec* is [EAMCET 1988]

(a) 1 (b) 2

(c) 4 (d) 0.5

26. A parachutist of weight '*w*' strikes the ground with his legs fixed and comes to rest with an upward acceleration of magnitude 3 *g*. Force exerted on him by ground during landing is

(a) *w* (b) 2*w*

(c) 3*w* (d) 4*w*

27. At a place where the acceleration due to gravity is $10\,m\,\sec^{-2}$ a force of 5 *kg-wt* acts on a body of mass 10 *kg* initially at rest. The velocity of the body after 4 *second* is [EAMCET 1981]

(a) $5\,m\,\sec^{-1}$ (b) $10\,m\,\sec^{-1}$

(c) $20\,m\,\sec^{-1}$ (d) $50\,m\,\sec^{-1}$

28. In a rocket of mass 1000 *kg* fuel is consumed at a rate of 40 *kg/s*. The velocity of the gases ejected from the rocket is $5\times10^4\,m/s$. The thrust on the rocket is [MP PMT 1994]

(a) $2\times10^3\,N$ (b) $5\times10^4\,N$

(c) $2\times10^6\,N$ (d) $2\times10^9\,N$

29. A man is standing on a weighing machine placed in a lift. When stationary his weight is recorded as 40 *kg*. If the lift is accelerated upwards with an acceleration of $2\,m/s^2$, then the weight recorded in the machine will be $(g = 10\,m/s^2)$ [MP PMT 1994]

(a) 32 *kg* (b) 40 *kg*

(c) 42 *kg* (d) 48 *kg*

30. A body of mass 4 *kg* weighs 4.8 *kg* when suspended in a moving lift. The acceleration of the lift is [Manipal MEE 1995]

(a) $9.80\,ms^{-2}$ downwards (b) $9.80\,ms^{-2}$ upwards

(c) $1.96\,ms^{-2}$ downwards (d) $1.96\,ms^{-2}$ upwards

31. An elevator weighing 6000 *kg* is pulled upward by a cable with an acceleration of $5\,ms^{-2}$. Taking g to be $10\,ms^{-2}$, then the tension in the cable is [Manipal MEE 1995]

(a) 6000 N (b) 9000 N

(c) 60000 N (d) 90000 N

32. A ball of mass 0.2 *kg* moves with a velocity of 20 *m/sec* and it stops in 0.1 *sec*; then the force on the ball is [BHU 1995]

(a) 40 *N* (b) 20 *N*
(c) 4 *N* (d) 2 *N*

33. A vehicle of 100 *kg* is moving with a velocity of 5 *m/sec*. To stop it in $\frac{1}{10}$ sec, the required force in opposite direction is [MP PET 1995]

(a) 5000 *N* (b) 500 *N*
(c) 50 *N* (d) 1000 *N*

34. A boy having a mass equal to 40 *kilograms* is standing in an elevator. The force felt by the feet of the boy will be greatest when the elevator

$(g = 9.8\, metres/\sec^2)$ [MP PMT 1995; BVP 2003]

(a) Stands still
(b) Moves downward at a constant velocity of 4 *metres/sec*
(c) Accelerates downward with an acceleration equal to $4\, metres/\sec^2$
(d) Accelerates upward with an acceleration equal to $4\, metres/\sec^2$

35. A rocket has an initial mass of $20 \times 10^3\, kg$. If it is to blast off with an initial acceleration of $4\, ms^{-2}$, the initial thrust needed is $(g \cong 10\, ms^{-2})$ [Kurukshetra CEE 1996]

(a) $6 \times 10^4\, N$ (b) $28 \times 10^4\, N$
(c) $20 \times 10^4\, N$ (d) $12 \times 10^4\, N$

36. The ratio of the weight of a man in a stationary lift and when it is moving downward with uniform acceleration '*a*' is 3 : 2. The value of '*a*' is (*g*-Acceleration due to gravity of the earth)

(a) $\frac{3}{2}g$ (b) $\frac{g}{3}$
(c) $\frac{2}{3}g$ (d) *g*

37. The mass of a lift is 500 *kg*. When it ascends with an acceleration of $2\, m/s^2$, the tension in the cable will be $[g = 10\, m/s^2]$

(a) 6000 *N* (b) 5000 *N*
(c) 4000 *N* (d) 50 *N*

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

(a) 0.7 *kg/s* (b) 1.4 *kg/s*
(c) 0.07 *kg/s* (d) 10.7 *kg/s*

39. In an elevator moving vertically up with an acceleration *g*, the force exerted on the floor by a passenger of mass *M* is [CPMT 1999]

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

40. A mass 1 *kg* is suspended by a thread. It is

(i) lifted up with an acceleration $4.9\, m/s^2$

(ii) lowered with an acceleration $4.9\, m/s^2$.

The ratio of the tensions is [CBSE PMT 1998]

(a) 3 : 1 (b) 1 : 3
(c) 1 : 2 (d) 2 : 1

41. A 5000 *kg* rocket is set for vertical firing. The exhaust speed is $800\, ms^{-1}$. To give an initial upward acceleration of $20\, ms^{-2}$, the amount of gas ejected per second to supply the needed thrust will be $(g = 10\, ms^{-2})$ [CBSE PMT 1998]

(a) $127.5\, kg\, s^{-1}$ (b) $187.5\, kg\, s^{-1}$
(c) $185.5\, kg\, s^{-1}$ (d) $137.5\, kg\, s^{-1}$

42. If a person with a spring balance and a body hanging from it goes up and up in an aeroplane, then the reading of the weight of the body as indicated by the spring balance will [AIIMS 1998; JIPMER 2000]

(a) Go on increasing
(b) Go on decreasing
(c) First increase and then decrease
(d) Remain the same

43. The time period of a simple pendulum measured inside a stationary lift is found to be *T*. If the lift starts accelerating upwards with an acceleration *g*/3, the time period is [EAMCET 1994; CMEET Bihar 1995; RPMT 2000]

(a) $T\sqrt{3}$ (b) $T\sqrt{3}/2$
(c) $T/\sqrt{3}$ (d) $T/3$

44. A cork is submerged in water by a spring attached to the bottom of a pail. [MP PET 1997] When the pail is kept in a elevator moving with an acceleration downwards, the spring length [EAMCET (Engg.) 1995]

(a) Increases (b) Decreases
(c) Remains unchanged (d) Data insufficient

45. Two trolleys of mass *m* and 3*m* are connected by a spring. They were compressed and [MP PMT 1999, 2000] released once, they move off in opposite direction and comes to rest after covering distances S_1 and S_2 respectively. Assuming the coefficient of friction to be uniform, the ratio of distances $S_1 : S_2$ is [EAMCET (Engg.) 1995]

(a) 1 : 9 (b) 1 : 3
(c) 3 : 1 (d) 9 : 1

46. A boy of 50 *kg* is in a lift moving down with an acceleration $9.8\, ms^{-2}$. The apparent weight of the body is $(g = 9.8\, ms^{-2})$ [EAMCET (Med KCET 2000]

(a) $50 \times 9.8\, N$ (b) Zero
(c) 50 *N* (d) $\frac{50}{9.8}N$

47. A body is imparted motion from rest to move in a straight line. If it is then obstructed by an opposite force, then [NTSE 1995]

(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

48. A mass of 10 *gm* is suspended by a string and the entire system is falling with a uniform acceleration of $400\,cm/\sec^2$. The tension in the string will be $(g = 980\,cm/\sec^2)$

(a) 5,800 *dyne* (b) 9,800 *dyne*

(c) 11,800 *dyne* (d) 13,800 *dyne*

49. A second's pendulum is mounted in a rocket. Its period of oscillation decreases when the rocket [CBSE PMT 1994]

(a) Comes down with uniform acceleration

(b) Moves round the earth in a geostationary orbit

(c) Moves up with a uniform velocity

(d) Moves up with uniform acceleration

50. Two balls of masses m_1 and m_2 are separated from each other by a powder charge placed between them. The whole system is at rest on the ground. Suddenly the powder charge explodes and masses are pushed apart. The mass m_1 travels a distance s_1 and stops. If the coefficients of friction between the balls and ground are same, the mass m_2 stops after travelling the distance

(a) $s_2 = \frac{m_1}{m_2}s_1$ (b) $s_2 = \frac{m_2}{m_1}s_1$

(c) $s_2 = \frac{m_1^2}{m_2^2}s_1$ (d) $s_2 = \frac{m_2^2}{m_1^2}s_1$

51. A force vector applied on a mass is represented as $\vec{F} = 6\hat{i} - 8\hat{j} + 10\hat{k}$ and accelerates with $1\,m/s^2$. What will be the mass of the body [CBSE PMT 1996]

(a) $10\sqrt{2}\,kg$ (b) $2\sqrt{10}\,kg$

(c) 10 *kg* (d) 20 *kg*

52. A cart of mass *M* is tied by one end of a massless rope of length 10 *m*. The other end of the rope is in the hands of a man of mass *M*. The entire system is on a smooth horizontal surface. The man is at *x* = 0 and the cart at *x* = 10 *m*. If the man pulls the cart by the rope, the man and the cart will meet at the point

(a) $x = 0$ (b) $x = 5\,m$

(c) $x = 10\,m$ (d) They will never meet

53. A cricket ball of mass 250 *g* collides with a bat with velocity 10 *m/s* and returns with the same velocity within 0.01 second. The force acted on bat is [CPMT 1997]

(a) 25 *N* (b) 50 *N*

(c) 250 *N* (d) 500 *N*

54. A pendulum bob of mass 50 *gm* is suspended from the ceiling of an elevator. The tension in the string if the elevator goes up with uniform velocity is approximately [AMU (Med.) 1999]

(a) 0.30 *N* (b) 0.40 *N*

(c) 0.42 *N* (d) 0.50 *N*

55. A train is moving with velocity 20 *m/sec.* on this dust is falling at the rate of 50 *kg/minute.* The extra force required to move this train with constant velocity will be [RPET 1999]

(a) 16.66 *N* (b) 1000 *N*

(c) 166.6 *N* (d) 1200 *N*

56. The average force necessary to stop a bullet of mass 20 *g* moving with a speed of 250 *m/s*, as it penetrates into the wood for a distance of 12 *cm* is [SCRA 1994] [CBSE PMT 2000; DPMT 2003]

(a) $2.2\times10^3\,N$ (b) $3.2\times10^3\,N$

(c) $4.2\times10^3\,N$ (d) $5.2\times10^3\,N$

57. The average resisting force that must act on a 5 *kg* mass to reduce its speed from 65 *cm/s* to 15 *cm/s* in 0.2*s* is [RPET 2000]

(a) 12.5 *N* (b) 25 *N*

(c) 50 *N* (d) 100 *N*

58. A mass is hanging on a spring balance which is kept in a lift. The lift ascends. The spring balance will show in its reading [DCE 2000]

(a) Increase

(b) Decrease

(c) No change

(d) Change depending upon velocity [BHU 1994]

59. An army vehicle of mass 1000 *kg* is moving with a velocity of 10 *m/s* and is acted upon by a forward force of 1000 *N* due to the engine and a retarding force of 500 *N* due to friction. What will be its velocity after 10 *s* [Pb. PMT 2000]

(a) 5 *m/s* (b) 10 *m/s*

(c) 15 *m/s* (d) 20 *m/s*

60. 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 [Pb. PMT 2000]

(a) 8 *N* (b) 4 *N*

(c) 2 *N* (d) 1 *N*

61. The apparent weight of the body, when it is travelling upwards with an acceleration of $2m/s^2$ and mass is 10 *kg*, will be

(a) 198 *N* (b) 164 *N*

(c) 140 *N* (d) 118 *N*

62. A man measures time period of a pendulum (T) in stationary lift. If the lift moves upward with acceleration $\frac{g}{4}$, then new time period will be [CBSE PMT 1997] [BHU 2001]

(a) $\frac{2T}{\sqrt{5}}$ (b) $\frac{\sqrt{5}T}{2}$

(c) $\frac{\sqrt{5}}{2T}$ (d) $\frac{2}{\sqrt{5}T}$

63. A 30 *gm* bullet initially travelling at 120 *m/s* penetrates 12 *cm* into a wooden block. The average resistance exerted by the wooden block is [AFMC 1999; CPMT 2001]

(a) 2850*N* (b) 2200 *N*

(c) 2000*N* (d) 1800 *N*

64. A force of 10 Newton acts on a body of mass 20 *kg* for 10 seconds. Change in its momentum is [MP PET 2002]

(a) 5 $kg\,m/s$ (b) $100 kg\,m/s$

(c) $200 kg\,m/s$ (d) 1000 $kg\,m/s$

65. A body of mass 1.0 *kg* is falling with an acceleration of 10 m/sec^2. Its apparent weight will be $(g = 10 m/\sec^2)$

[MP PET 2002]

(a) $1.0\,kg\,wt$ (b) $2.0\,kg\,wt$

(c) $0.5\,kg\,wt$ (d) Zero

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

(a) 0.3 *N* (b) 30 *N*

(c) 300 *N* (d) 3000 *N*

67. If rope of lift breaks suddenly, the tension exerted by the surface of lift [AFMC 2002]

(a = acceleration of lift)

(a) mg (b) $m(g+a)$

(c) $m(g-a)$ (d) 0

68. A boy whose mass is 50 *kg* stands on a spring balance inside a lift. The lift starts to ascent with an acceleration of $2 ms^{-2}$. The reading of the machine or balance $(g = 10 ms^{-2})$ is

[Kerala PET 2002]

(a) $50\,kg$ (b) Zero

(c) $49\,kg$ (d) $60\,kg$

69. A rocket is ejecting $50 g$ of gases per sec at a speed of $500 m/s$. The accelerating force on the rocket will be

[Pb. PMT 2002]

(a) $125\,N$ (b) $25\,N$

(c) $5\,N$ (d) Zero

70. A block of mass $5\,kg$ is moving horizontally at a speed of 1.5 *m/s.* A perpendicular force of 5*N* acts on it for 4 sec. What will be the distance of the block from the point where the force started acting

(a) 10 *m* (b) 8 *m*

(c) 6 *m* (d) 2 *m*

71. A lift of mass 1000 *kg* is moving with an acceleration of 1 m/s^2 in upward direction. Tension developed in the string, which is connected to the lift, is [CBSE PMT 2002]

(a) 9,800 *N* (b) 10,000 *N*

(c) 10,800 *N* (d) 11,000 *N*

72. A lift accelerated downward with acceleration '*a*'. A man in the lift throws a ball upward with acceleration $a_0 (a_0 < a)$. Then acceleration of ball observed by observer, which is on earth, is

(a) $(a + a_0)$ upward (b) $(a - a_0)$ upward

(c) $(a + a_0)$ downward (d) $(a - a_0)$ downward

73. 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 [AIEEE 2002]

(a) g, g (b) $g-a, g-a$

(c) $g-a, g$ (d) a, g

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

(a) 400 *N* (b) 800 *N*

(c) 1200 *N* (d) Zero

75. A monkey of mass 20 *kg* 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 $(g = 10 m/s^2)$ [Kerala PET 2005]

(a) $10\,m/s^2$ (b) $25\,m/s^2$

(c) $2.5\,m/s^2$ (d) $5\,m/s^2$

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

(a) $R_0 > R_u > R_d$ (b) $R_u > R_0 > R_d$

(c) $R_d > R_0 > R_u$ (d) $R_u > R_d > R_0$

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

(a) $1.75 \times 10^5\,N$ (b) $3.5 \times 10^5\,N$

(c) $7.0 \times 10^5\,N$ (d) $14.0 \times 10^5\,N$

78. 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

(a) 49 *N* (b) 24 *N*

(c) 74 [Pb. PMT 2002] (d) 15 *N*

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

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

(c) $\cos^{-1}(a/g)$ (d) $\cos^{-1}(g/a)$

80. Mass of a person sitting in a lift is 50 *kg*. If lift is coming down with a constant acceleration of 10 m/sec^2. Then the reading of spring balance will be $(g = 10 m/sec^2)$

[AIEEE 2002] [RPET 2003; Kerala PMT 2005]

(a) 0 (b) 1000 *N*

(c) 100 *N* (d) 10 *N*

81. A body of mass 2 *kg* has an initial velocity of 3 *meters* per second along *OE* and it is subjected to a force of 4 *N* in a direction perpendicular to *OE*. The distance of the body from *O* after 4 seconds will be [CPMT 1976]

(a) 12 *m* (b) 20 *m*

(c) 8 *m* (d) 48 *m*

82. A block of mass *m* is placed on a smooth wedge of inclination θ. The whole system is accelerated horizontally so that the block does not slip on the wedge. The force exerted by the wedge on the block (*g* is acceleration due to gravity) will be

(a) $mg\cos\theta$ (b) $mg\sin\theta$

(c) mg (d) $mg/\cos\theta$

83. 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

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

[AIEEE 2004]

(a) 20 *m* (b) 40 *m*

(c) 60 *m* (d) 80 *m*

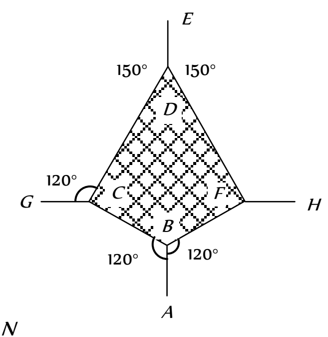
85. A man of weight 75 *kg* is standing in an elevator which is moving with an acceleration of $5\,m/s^2$ in upward direction the apparent weight of the man will be $(g = 10\ m/s^2)$

[Pb. PMT 2004]

(a) 1425 *N* (b) 1375 *N*

(c) 1250 *N* (d) 1125 *N*

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



(a) 10 *N*, 11 *N*

(b) 10 *N*, 6 *N*

(c) 10 *N*, 10 *N*

(d) Can't calculate due to insufficient data

87. 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*

88. The spring balance inside a lift suspends an object. As the lift begins to ascent, the reading indicated by the spring balance will

(a) Increase [CBSE PMT 2004]

(b) Decrease

(c) Remain unchanged

(d) Depend on the speed of ascend

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

(a) 0.8 *T* (b) 0.25 *T*

(c) 2 *T* (d) 4 *T*

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

(a) 1480 *N* (b) 1280 *N*

(c) 1380 *N* (d) None of these

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

(a) $2000\ cm/sec$ (b) $200\ cm/sec$

(c) $20\ cm/sec$ (d) $2\ cm/sec$

92. When the speed of a moving body is doubled

[UPSEAT 2004]

(a) Its acceleration is doubled

(b) Its momentum is doubled

(c) Its kinetic energy is doubled

(d) Its potential energy is doubled

93. 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

94. A thief stole a box full of valuable articles of weight *W* and while carrying it on his back, he jumped down a wall of height '*h*' from the ground. Before he reached the ground he experienced a load of

(a) 2*W* (b) *W*

(c) *W*/2 (d) Zero

95. *N* bullets each of mass *m kg* are fired with a velocity $v\ ms^{-1}$ at the rate of *n* bullets per second upon a wall. The reaction offered by the wall to the bullets is given by

(a) *nmv* (b) $\dfrac{Nmv}{n}$

(c) $n\dfrac{Nm}{v}$ (d) $n\dfrac{Nv}{m}$

96. If a body of mass m is carried by a lift moving with an upward acceleration a, then the forces acting on the body are (i) the reaction R on the floor of the lift upwards (ii) the weight mg of the body acting vertically downwards. The equation of motion will be given by[MNR 1998]

(a) $R = mg - ma$ (b) $R = mg + ma$

(c) $R = ma - mg$ (d) $R = mg \times ma$

97. With what minimum acceleration can a fireman slides down a rope while breaking strength of the rope is $\frac{2}{3}$ of his weight

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

(c) $\frac{1}{3}g$ (d) Zero

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

[BCECE 2005]

(a) $\frac{2mv}{t}$ (b) $\frac{mv}{t}$

(c) mvt (d) $\frac{mv}{2t}$

99. The velocity of a body at time $t = 0$ is $10\sqrt{2}$ m/s in the north-east direction and it is moving with an acceleration of 2 m/s directed towards the south. The magnitude and direction of the velocity of the body after 5 sec will be

[AMU (Engg.) 1999]

(a) 10 m/s, towards east

(b) 10 m/s, towards north

(c) 10 m/s, towards south

(d) 10 m/s, towards north-east

100. A body of mass 5 kg starts from the origin with an initial velocity $\vec{u} = 30\hat{i} + 40\hat{j}\, ms^{-1}$. If a constant force $\vec{F} = -(\hat{i} + 5\hat{j})N$ acts on the body, the time in which the y-component of the velocity becomes zero is

[EAMCET (Med.) 2000]

(a) 5 *seconds* (b) 20 *seconds*

(c) 40 *seconds* (d) 80 *seconds*

101. A body of mass $8kg$ is moved by a force $F = 3x\, N$, where x is the distance covered. Initial position is $x = 2m$ and the final position is $x = 10$ m. The initial speed is $0.0 m/s$. The final speed is [Orissa JEE 2002]

(a) 6 m/s (b) 12 m/s

(c) 18 m/s (d) 14 m/s

102. 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) Proportional to t^2

(b) A constant

(c) Proportional to t

(d) Inversely proportional to t

103. A ball of mass 0.5 kg moving with a velocity of 2 m/sec strikes a wall normally and bounces back with the same speed. If the time of contact between the ball and the wall is one millisecond, the average force exerted by the wall on the ball is

(a) 2000 N (b) 1000 N

(c) 5000 N (d) 125 N

[CPMT 1979]

104. A particle moves in the xy-plane under the action of a force F such that the components of its linear momentum p at any time t are $p_x = 2\cos t$, $p_y = 2\sin t$. The angle between F and p at time t is

[MP PET 1996; UPSEAT 2000]

(a) 90° (b) 0°

(c) 180° (d) 30°

105. n small balls each of mass m impinge elastically each second on a surface with velocity u. The force experienced by the surface will be

RPET 2001; BHU 2001; MP PMT 2003]

(a) mnu (b) 2 mnu

(c) 4 mnu (d) $\frac{1}{2}mnu$

106. A ball of mass 400 gm is dropped from a height of 5m. A boy on the ground hits the ball vertically upwards with a bat with an average force of 100 *newton* so that it attains a vertical height of 20 m. The time for which the ball remains in contact with the bat is $[g = 10\, m/s^2]$ [MP PMT 1999]

(a) 0.12s (b) 0.08 s

(c) 0.04 s (d) 12 s

107. The time in which a force of 2 N produces a change of momentum of $0.4\, kg - ms^{-1}$ in the body is

[CMEET Bihar 1995]

(a) 0.2 s (b) 0.02 s

(c) 0.5 s (d) 0.05 s

108. A gun of mass $10kg$ fires 4 bullets per second. The mass of each bullet is 20 g and the velocity of the bullet when it leaves the gun is $300\, ms^{-1}$. The force required to hold the gun while firing is

[EAMCET (Med.) 2000]

(a) 6 N (b) 8 N

(c) 24 N (d) 240 N

109. A gardner waters the plants by a pipe of diameter 1mm. The water comes out at the rate or 10 cm/sec. The reactionary force exerted on the hand of the gardner is

[KCET 2000]

(a) Zero (b) $1.27 \times 10^{-2} N$

(c) $1.27 \times 10^{-4} N$ (d) $0.127 N$

110. A solid disc of mass M is just held in air horizontally by throwing 40 stones per sec vertically upwards to strike the disc each with a velocity 6 ms^{-1}. If the mass of each stone is $0.05kg$ what is the mass of the disc $(g = 10ms^{-2})$ [MP PMT 1993]

[Kerala (Engg.) 2001]

(a) $1.2 kg$ (b) $0.5 kg$

(c) $20 kg$ (d) $3 kg$

111. A ladder rests against a frictionless vertical wall, with its upper end $6m$ above the ground and the lower end $4m$ away from the wall. The weight of the ladder is 500 *N* and its C. G. at 1/3rd distance from the lower end. Wall's reaction will be, (in *Newton*)

(a) 111 (b) 333

(c) 222 (d) 129

112. A satellite in force-free space sweeps stationary interplanetary dust at a rate $dM/dt = \alpha v$ where M is the mass, v is the velocity of the satellite and α is a constant. What is the deacceleration of the satellite [CBSE PMT 1994]

(a) $-2\alpha v^2/M$ (b) $-\alpha v^2/M$

(c) $+\alpha v^2/M$ (d) $-\alpha v^2$

113. 10,000 small balls, each weighing 1 *gm*, strike one square *cm* of area per second with a velocity 100 *m/s* in a normal direction and rebound with the same velocity. The value of pressure on the surface will be [MP PMT 1994]

(a) $2 \times 10^3\ N/m^2$ (b) $2 \times 10^5\ N/m^2$

(c) $10^7\ N/m^2$ (d) $2 \times 10^7\ N/m^2$

Third Law of Motion

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

(a) First law of motion

(b) Second law of motion

(c) Third law of motion

(d) Newton's law of gravitation

2. When we jump out of a boat standing in water it moves

(a) Forward (b) Backward

(c) Sideways (d) None of the above

3. You are on a frictionless horizontal plane. How can you get off if no horizontal force is exerted by pushing against the surface

(a) By jumping

(b) By spitting or sneezing

(c) By rolling your body on the surface

(d) By running on the plane

4. On a stationary sail-boat, air is blown at the sails from a fan attached to the boat. The boat will

(a) Remain stationary

(b) Spin around

(c) Move in a direction opposite to that in which air is blown

(d) Move in the direction in which the air is blown

5. A man is at rest in the middle of a pond on perfectly smooth ice. He can get himself to the shore by making use of Newton's

(a) First law (b) Second law

(c) Third law (d) All the laws

6. A cannon after firing recoils due to [EAMCET 1980]

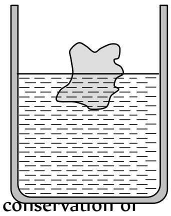
(a) Conservation of energy

(b) Backward thrust of gases produced

(c) Newton's third law of motion

(d) Newton's first law of motion

7. A body floats in a liquid contained in a beaker. If the whole system as shown in figure falls freely under gravity, then the upthrust on the body due to liquid is [Manipal MEE 1995]



(a) Zero[AMU (Med.) 2000]

(b) Equal to the weight of liquid displaced

(c) Equal to the weight of the body in air

(d) None of these

8. Newton's third law of motion leads to the law of conservation of

(a) Angular momentum (b) Energy

(c) Mass (d) Momentum

9. A man is carrying a block of a certain substance (of density 1000 kgm^{-3}) weighing 1 *kg* in his left hand and a bucket filled with water and weighing 10 *kg* in his right hand. He drops the block into the bucket. How much load does he carry in his right hand now

(a) 9 *kg* (b) 10 *kg*

(c) 11 *kg* (d) 12 *kg*

10. A man is standing on a balance and his weight is measured. If he takes a step in the left side, then weight [AFMC 1996]

(a) Will decrease

(b) Will increase

(c) Remains same

(d) First decreases then increases

11. A man is standing at a spring platform. Reading of spring balance is 60 *kg wt*. If man jumps outside platform, then reading of spring balance

[AFMC 1996; AIIMS 2000; Pb. PET 2000]

(a) First increases then decreases to zero

(b) Decreases

(c) Increases

(d) Remains same

12. A cold soft drink is kept on the balance. When the cap is open, then the weight [AFMC 1996]

(a) Increases

(b) Decreases

(c) First increases then decreases

(d) Remains same

13. Action and reaction forces act on

(a) The same body (b) The different bodies

(c) The horizontal surface (d) Nothing can be said

14. A bird is sitting in a large closed cage which is placed on a spring balance. It records a weight of 25 *N*. The bird (mass m = 0.5 *kg*) flies upward in the cage with an acceleration of $2m/s^2$. The spring balance will now record a weight of

[MP PMT 1999]

(a) 24 *N* (b) 25 *N*

(c) 26[CPMT 1981] (d) 27 *N*

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

[AIEEE 2003]

(a) Both the scales read *M*/2 *kg* each

(b) Both the scales read *M kg* each

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

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

16. A machine gun fires 20 bullets per second into a target. Each bullet weighs 150 *gms* and has a speed of 800 *m/sec*. Find the force necessary to hold the gun in position

[EAMCET 1994]

(a) 800 *N* (b) 1000 *N*

(c) 1200 *N* (d) 2400 *N*

17. The tension in the spring is [AMU (Engg.) 2001]

(a) Zero (b) 2.5 *N*

(c) 5 *N* (d) 10 *N*

18. A book is lying on the table. What is the angle between the action of the book on the table and the reaction of the table on the book

(a) 0° (b) 30°

(c) 45° (d) 180°

19. When a horse pulls a wagon, the force that causes the horse to move forward is the force [Pb. PET 2004]

(a) The ground exerts on it (b) It exerts on the ground

(c) The wagon exerts on it (d) It exerts on the wagon

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

(a) As the force exerted is small

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

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

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

21. A man is standing at the centre of frictionless pond of ice. How can he get himself to the shore [J&K CET 2005]

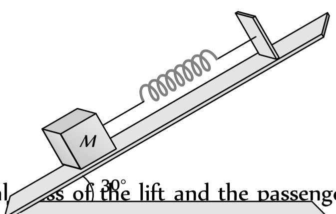
(a) By throwing his shirt in vertically upward direction

(b) By spitting horizontally

(c) He will wait for the ice to melt in pond

(d) Unable to get at the shore

22. A body of mass 5*kg* is suspended by a spring balance on an inclined plane as shown in figure. The spring balance measure



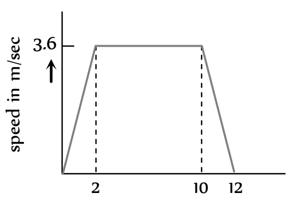
(a) 50 *N*

(b) 25 *N*

(c) 500 *N*

(d) 10 *N*

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



(a) 17400 *N*

(b) 14700 *N*

(c) 12000 *N*

(d) Zero

24. In the above ques., the height to which the lift takes the passenger is

(a) 3.6 *meters* (b) 8 *meters*

(c) 1.8 *meters* (d) 36 *meters*

Conservation of Linear Momentum and Impulse

1. A jet plane flies in the air because [NCERT 1971]

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

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

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

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

2. A player caught a cricket ball of mass 150 *gm* moving at a rate of 20 *m/s*. If the catching process be completed in 0.1 *s*, then the force of the blow exerted by the ball on the hands of the player is[AFMC 1993; CBSE PMT [Kerala PMT 2005]

(a) 0.3 *N* (b) 30 *N*

(c) 300 *N* (d) 3000 *N*

3. A rocket has a mass of 100 *kg*. 90% of this is fuel. It ejects fuel vapours at the rate of 1 *kg/sec* with a velocity of 500 *m/sec* relative to the rocket. It is supposed that the rocket is outside the gravitational field. The initial upthrust on the rocket when it just starts moving upwards is [NCERT 1978]

(a) Zero (b) 500 *N*

(c) 1000 *N* (d) 2000 *N*

4. In which of the following cases forces may not be required to keep the [AIIMS 1983]

(a) Particle going in a circle

(b) Particle going along a straight line

(c) The momentum of the particle constant

(d) Acceleration of the particle constant

5. A wagon weighing 1000 *kg* is moving with a velocity 50*km/h* on smooth horizontal rails. A mass of 250 *kg* is dropped into it. The velocity with which it moves now is

[MP PMT 1994]

(a) 2.5 *km/hour* (b) 20 *km/hour*

(c) 40 *km/hour* (d) 50 *km/hour*

6. If a force of 250 *N* act on body, the momentum acquired is 125 *kg-m/s*. What is the period for which force acts on the body

(a) 0.5 *sec* (b) 0.2 *sec*

(c) 0.4 *sec* (d) 0.25 *sec*

7. A 100 *g* iron ball having velocity 10 *m/s* collides with a wall at an angle 30° and rebounds with the same angle. If the period of contact between the ball and wall is 0.1 *second*, then the force experienced by the wall is [CPMT 1997]

(a) 10 *N* (b) 100 *N*

(c) 1.0 *N* (d) 0.1 *N*

8. A ball of mass 150*g* starts moving with an acceleration of $20 m/s^2$. When hit by a force, which acts on it for 0.1 sec. The impulsive force is [AFMC 1999; Pb. PMT 2003]

(a) 0.5 *N-s* (b) 0.1 *N-s*
(c) 0.3 *N-s* (d) 1.2 *N-s*

9. A body, whose momentum is constant, must have constant [AIIMS 2000]

(a) Force (b) Velocity
(c) Acceleration (d) All of these

10. The motion of a rocket is based on the principle of conservation of

(a) Mass (b) Kinetic energy
(c) Linear momentum (d) Angular momentum

11. A rope of length 5*m* is kept on frictionless surface and a force of 5*N* is applied to one of its end. Find tension in the rope at 1*m* from this end [RPET 2000]

(a) 1 *N* (b) 3 *N*
(c) 4 *N* (d) 5 *N*

12. An aircraft is moving with a velocity of $300 ms^{-1}$. If all the forces acting on it are balanced, then [Kerala PMT 2004]

(a) It still moves with the same velocity
(b) It will be just floating at the same point in space
(c) It will fall down instantaneously
(d) It will lose its velocity gradually
(e) It will explode

13. A rocket of mass 1000 *kg* exhausts gases at a rate of 4 *kg/sec* with a velocity 3000 *m/s*. The thrust developed on the rocket is

(a) 12000 *N* (b) 120 *N*
(c) 800 *N* (d) 200 *N*

14. The momentum is most closely related to [DCE 2001]

(a) Force (b) Impulse
(c) Power (d) K.E.

15. Rocket engines lift a rocket from the earth surface because hot gas with high velocity [AIIMS 1998; JIPMER 2001, 02]

(a) Push against the earth
(b) Push against the air
(c) React against the rocket and push it up
(d) Heat up the air which lifts the rocket

16. A man fires a bullet of mass 200 *g* at a speed of 5 *m/s*. The gun is of one *kg* mass. by what velocity the gun rebounds backwards[CBSE PMT 1996; JIPMER 2000]

(a) 0.1 *m/s* (b) 10 *m/s*
(c) 1 *m/s* (d) 0.01 *m/s*

17. A bullet of mass 5 *g* is shot from a gun of mass 5 *kg*. The muzzle velocity of the bullet is 500 *m/s*. The recoil velocity of the gun is

(a) 0.5 *m/s* (b) 0.25 *m/s*
(c) 1 *m/s* (d) Data is insufficient

18. A force of 50 *dynes* is acted on a body of mass 5 *g* which is at rest for an interval of 3 seconds, then impulse is [AFMC 1998]

(a) 0.15×10^{-3} *Ns* (b) 0.98×10^{-3} *Ns*
(c) 1.5×10^{-3} *Ns* (d) 2.5×10^{-3} *Ns*

19. A body of mass *M* at rest explodes into three pieces, two of which of mass *M*/4 each are thrown off in perpendicular directions with velocities of 3 *m/s* and 4 *m/s* respectively. The third piece will be thrown off with a velocity of [CPMT 1990]

(a) 1.5 *m/s* (b) 2.0 *m/s*
(c) 2.5 *m/s* (d) 3.0 *m/s*

20. The momentum of a system is conserved [CPMT 1982]

(a) Always
(b) Never
(c) In the absence of an external force on the system
(d) None of the above [AFMC 2000]

21. A body of mass 0.25 *kg* is projected with muzzle velocity $100 ms^{-1}$ from a tank of mass 100 *kg*. What is the recoil velocity of the tank

(a) $5 ms^{-1}$ (b) $25 ms^{-1}$
(c) $0.5 ms^{-1}$ (d) $0.25 ms^{-1}$

22. A bullet is fired from a gun. The force on the bullet is given by $F = 600 - 2 \times 10^5 t$, where *F* is in *newtons* and *t* in seconds. The force on the bullet becomes zero as soon as it leaves the barrel. What is the average impulse imparted to the bullet

(a) 9 *Ns* (b) Zero
(c) 0.9 *Ns* (d) 1.8 *Ns*

23. A bullet of mass 0.1 *kg* is fired with a speed of 100 *m/sec*, the mass of gun is 50 *kg*. The velocity of recoil is [AFMC 1995; JIPMER 2000; Pb.PMT 2002]

(a) 0.2 *m/sec* (b) 0.1 *m/sec*
(c) 0.5 *m/sec* (d) 0.05 *m/sec* [Orissa JEE 2005]

24. A bullet mass 10 *gm* is fired from a gun of mass 1*kg*. If the recoil velocity is 5 m/s, the velocity of the muzzle is [Orissa JEE 2002]

(a) 0.05 *m/s* (b) 5 *m/s*
(c) 50 *m/s* (d) 500 *m/s*

25. A rocket can go vertically upwards in earth's atmosphere because

(a) It is lighter than air
(b) Of gravitational pull of the sun
(c) It has a fan which displaces more air per unit time than the weight of the rocket
(d) Of the force exerted on the rocket by gases ejected by it

26. At a certain instant of time the mass of a rocket going up vertically is 100 kg. If it is ejecting 5 kg of gas per second at a speed of 400 m/s, the acceleration of the rocket would be (taking $g = 10 m/s^2$)

(a) $20 m/s^2$ (b) $10 m/s^2$
(c) $2 m/s^2$ (d) $1 m/s^2$ [DCE 2004]

27. A jet engine works on the principle of [CPMT 1973; MP PMT 1996]

(a) Conservation of mass
(b) Conservation of energy
(c) Conservation of linear momentum
(d) Conservation of angular momentum

Equilibrium of Forces

1. The weight of an aeroplane flying in the air is balanced by [NCERT 1974]

(a) Vertical component of the thrust created by air currents striking the lower surface of the wings

(b) Force due to reaction of gases ejected by the revolving propeller

(c) Upthrust of the air which will be equal to the weight of the air having the same volume as the plane

(d) Force due to the pressure difference between the upper and lower surfaces of the wings created by different air speeds on the surfaces

2. When a body is stationary [NCERT 1978]

(a) There is no force acting on it

(b) The force acting on it is not in contact with it

(c) The combination of forces acting on it balances each other

(d) The body is in vacuum

3. Two forces of magnitude F have a resultant of the same magnitude F. The angle between the two forces is [CBSE PMT 1990]

(a) 45° (b) 120°

(c) 150° (d) 60°

4. Two forces with equal magnitudes F act on a body and the magnitude of the resultant force is $F/3$. The angle between the two forces is [MP PMT 1999]

(a) $\cos^{-1}\left(-\frac{17}{18}\right)$ (b) $\cos^{-1}\left(-\frac{1}{3}\right)$

(c) $\cos^{-1}\left(\frac{2}{3}\right)$ (d) $\cos^{-1}\left(\frac{8}{9}\right)$

5. An object is subjected to a force in the north-east direction. To balance this force, a second force should be applied in the direction

(a) North-East (b) South

(c) South-West (d) West

6. The resultant force of 5 N and 10 N can not be [RPET 2000]

(a) 12 N (b) 8 N

(c) 4 N (d) 5 N

7. The resultant of two forces $3P$ and $2P$ is R. If the first force is doubled then the resultant is also doubled. The angle between the two forces is [KCET 2001]

(a) 60^o (b) 120^o

(c) 70^o (d) 180^o

8. The resultant of two forces, one double the other in magnitude, is perpendicular to the smaller of the two forces. The angle between the two forces is [KCET 2002]

(a) 60^0 (b) 120^0

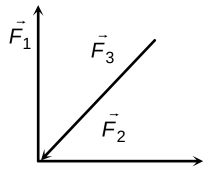
(c) 150^0 (d) 90^0

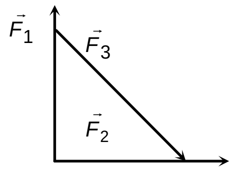
9. Two forces are such that the sum of their magnitudes is 18 N and their resultant is perpendicular to the smaller force and magnitude of resultant is 12 N. Then the magnitudes of the forces are

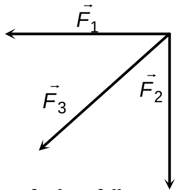
(a) 12 N, 6 N (b) 13 N, 5N

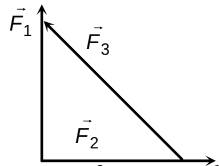
(c) 10 N, 8 N (d) 16 N, 2 N

10. Which of the four arrangements in the figure correctly shows the vector addition of two forces $\vec{F_1}$ and $\vec{F_2}$ to yield the third force $\vec{F_3}$ [Orissa JEE 2003]

(a)


(b)


(c)


(d)


11. Which of the following sets of concurrent forces may be in equilibrium [KCET 2003]

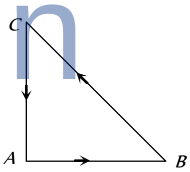
(a) $F_1 = 3N,\ F_2 = 5N,\ F_3 = 9N$

(b) $F_1 = 3N,\ F_2 = 5N,\ F_3 = 1N$

(c) $F_1 = 3N, F_2 = 5N, F_3 = 15N$

(d) $F_1 = 3N,\ F_2 = 5N,\ F_3 = 6N$

12. Three forces starts acting simultaneously on a particle moving with velocity $\vec v$. These forces are represented in magnitude and direction by the three sides of a triangle ABC (as shown). The particle will now move with velocity [AIEEE 2003]



(a) $\vec v$ remaining unchanged

(b) Less than $\vec v$ [KCET 1994]

(c) Greater than $\vec v$

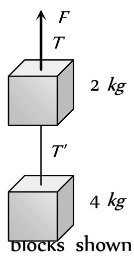
(d) $\vec v$ in the direction of the largest force BC

13. Which of the following groups of forces could be in equibrium

(a) 3 N, 4 N, 5 N (b) 4N, 5 N, 10 N

(c) 30N, 40 N, 80 N (d) 1N, 3 N, 5 N

14. Two blocks are connected by a string as shown in the diagram. The upper block is hung by another string. A force F applied on the upper string produces an acceleration of $2m/s^2$ in the upward direction in both the blocks. If T and T' be the tensions in the two parts of the string, then [AMU (Engg.) 2000]



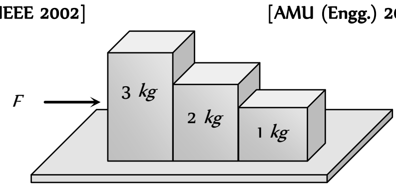
(a) $T = 70.8N$ and $T' = 47.2N$

(b) $T = 58.8N$ and $T' = 47.2N$

(c) $T = 70.8N$ and $T' = 58.8N$

(d) $T = 70.8N$ and $T' = 0$

15. Consider the following statements about the blocks shown in the diagram that are being pushed by a constant force on a frictionless table [AIEEE 2002] [AMU (Engg.) 2001]



A. All blocks move with the same acceleration

B. The net force on each block is the same Which of these statements are/is correct

(a) A only (b) B only

(c) Both A and B (d) Neither A nor B

16. If two forces of 5 N each are acting along X and Y axes, then the magnitude and direction of resultant is [DCE 2004]

(a) $5\sqrt{2}, \pi/3$ (b) $5\sqrt{2}, \pi/4$

(c) $-5\sqrt{2}, \pi/3$ (d) $-5\sqrt{2}, \pi/4$

17. Which of the following is the correct order of forces [AIEEE 2002]

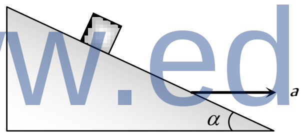
(a) Weak < gravitational forces < strong forces (nuclear) < electrostatic

(b) Gravitational < weak < (electrostatic) < strong force

(c) Gravitational < electrostatic < weak < strong force

(d) Weak < gravitational < electrostatic < strong forces

18. 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

(b) $g\tan\alpha$

(c) $g/\tan\alpha$

(d) g cosec α

Motion of Connected Bodies

1. A block of mass M is pulled along a horizontal frictionless surface by a rope of mass m. If a force P is applied at the free end of the rope, the force exerted by the rope on the block will be [CBSE PMT 1993; CPMT 1972, 75, 82; MP PMT 1996; AIEEE 2003]

(a) P (b) $\frac{Pm}{M+m}$

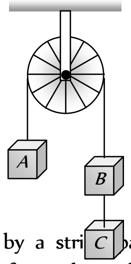
(c) $\frac{PM}{M+m}$ (d) $\frac{Pm}{M-m}$

2. A rope of length L is pulled by a constant force F. What is the tension in the rope at a distance x from the end where the force is applied [MP PET 1996, 97, 2000]

(a) $\frac{FL}{x}$ (b) $\frac{F(L-x)}{L}$

(c) $\frac{FL}{L-x}$ (d) $\frac{Fx}{L-x}$

3. Three equal weights A, B and C of mass 2 kg each are hanging on a string passing over a fixed frictionless pulley as shown in the figure The tension in the string connecting weights B and C is[MP PET 1985; SCRA 1996]



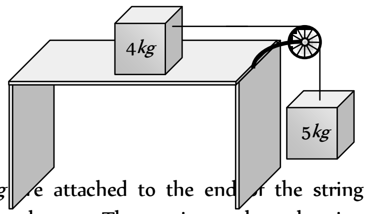
(a) Zero

(b) 13 N

(c) 3.3 N

(d) 19.6 N

4. Two masses of 4 kg and 5 kg are connected by a string passing through a frictionless pulley and are kept on a frictionless table as shown in the figure. The acceleration of 5 kg mass is



(a) $49\,m/s^2$

(b) $5.44\,m/s^2$

(c) $19.5\,m/s^2$

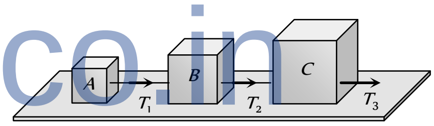
(d) $2.72\,m/s^2$

5. Two masses 2 kg and 3 kg are attached to the end of the string passed over a pulley fixed at the top. The tension and acceleration are

(a) $\frac{7g}{8};\frac{g}{8}$ (b) $\frac{21g}{8};\frac{g}{8}$

(c) $\frac{21g}{8};\frac{g}{5}$ (d) $\frac{12g}{5};\frac{g}{5}$

6. Three blocks A, B and C weighing 1, 8 and 27 kg respectively are connected as shown in the figure with an inextensible string and are moving on a smooth surface. T_3 is equal to 36 N. Then T_2 is



(a) 18 N

(b) 9 N

(c) 3.375 N

(d) 1.25 N

7. 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 $(g = 9.8\,m/s^2)$ [MP PET 1994; CBSE PMT 2001]

(a) $4.9\,m/s^2$ (b) $2.45\,m/s^2$

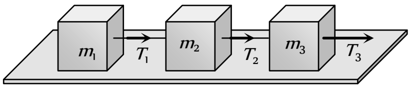
(c) $1.4\,m/s^2$ (d) $9.5\,m/s^2$

8. Three solids of masses m_1, m_2 and m_3 are connected with weightless string in succession and are placed on a frictionless table. If the mass m_3 is dragged with a force T, the tension in the string between m_2 and m_3 is [MP PET 1995]

(a) $\frac{m_2}{m_1+m_2+m_3}T$ (b) $\frac{m_3}{m_1+m_2+m_3}T$

(c) $\frac{m_1+m_2}{m_1+m_2+m_3}T$ (d) $\frac{m_2+m_3}{m_1+m_2+m_3}T$

9. Three blocks of masses m_1, m_2 and m_3 are connected by massless strings as shown on a frictionless table. They are pulled with a force $T_3 = 40\,N$. If $m_1 = 10\,kg, m_2 = 6\,kg$ and $m_3 = 4\,kg$, the tension T_2 will be [MP PMT/PET 1998]



(a) 20 N (b) 40 N

(c) 10 N (d) 32 N

10. A block of mass m_1 rests on a horizontal table. A string tied to the block is passed on a frictionless pulley fixed at the end of the table and to the other end of string is hung another block of mass m_2. The acceleration of the system is

[EAMCET (Med.) 1995; DPMT 2000]

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

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

11. A 2 kg block is lying on a smooth table which is connected by a body of mass 1 kg by a string which passes through a pulley. The 1 kg mass is hanging vertically. The acceleration of block and tension in the string will be [RPMT 1997]

(a) $3.27\, m/s^2, 6.54\, N$ (b) $4.38\, m/s^2, 6.54\, N$

(c) $3.27\, m/s^2, 9.86\, N$ (d) $4.38\, m/s^2, 9.86\, N$

12. A light string passes over a frictionless pulley. To one of its ends a mass of 6 kg is attached. To its other end a mass of 10 kg is attached. The tension in the thread will be

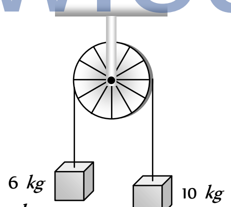
[RPET 1996; JIPMER 2001, 02]

(a) 24.5 N

(b) 2.45 N

(c) 79 N

(d) 73.5 N



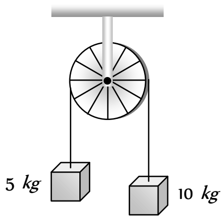
13. USS 150) Two masses of $5 kg$ and $10 kg$ are connected to a pulley as shown. What will be the acceleration of the system (g = acceleration due to gravity) [CBSE PMT 2000]

(a) g

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

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

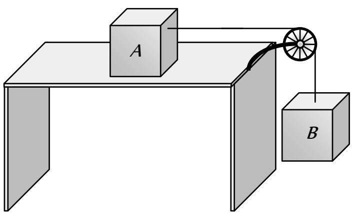
(d) $\frac{g}{4}$



14. A block A of mass 7 kg is placed on a frictionless table. A thread tied to it passes over a frictionless pulley and carries a body B of mass 3 kg at the other end. The acceleration of the system is (given $g = 10\, ms^{-2}$) [Kerala (Engg.) 2000]

(a) $100\, ms^{-2}$

(b) $3 ms^{-2}$



(c) $10 ms^{-2}$

(d) $30 ms^{-2}$

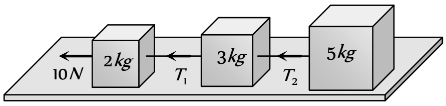
15. Three blocks of masses 2 kg, 3 kg and 5 kg are connected to each other with light string and are then placed on a frictionless surface as shown in the figure. The system is pulled by a force $F = 10 N$, then tension T_1 = [Orissa JEE 2002]

(a) 1N

(b) 5 N

(c) 8 N

(d) 10 N



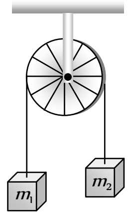
16. Two masses m_1 and m_2 are attached to a string which passes over a frictionless smooth pulley. When $m_1 = 10 kg$, $m_2 = 6 kg$, the acceleration of masses is [Orissa JEE 2002]

(a) 20 m/s^2

(b) $5 m/s^2$

(c) 2.5 m/s^2

(d) $10 m/s^2$



17. A body of weight $2 kg$ is suspended as shown in the figure. The tension T_1 in the horizontal string (in $kg\ wt$) is

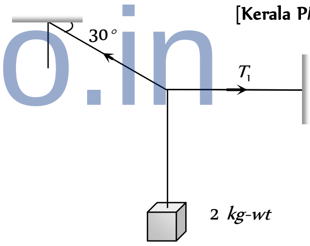
[Kerala PMT 2002]

(a) $2/\sqrt{3}$

(b) $\sqrt{3}/2$

(c) $2\sqrt{3}$

(d) 2



18. One end of a 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 monkey of $60 kg$ move down on the rope

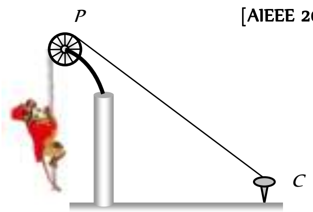
[AIEEE 2002]

(a) 16

(b) 6

(c) 4

(d) 8



19. 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

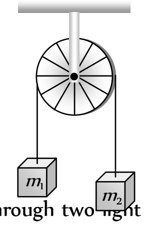
20. Two masses $m_1 = 5\,kg$ and $m_2 = 4.8\,kg$ tied to a string are hanging over a light frictionless pulley. What is the acceleration of the masses when they are free to move $(g = 9.8\ m/s^2)$

(a) $0.2\ m/s^2$

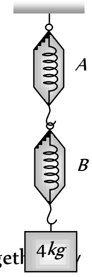
(b) $9.8\ m/s^2$

(c) $5\ m/s^2$

(d) $4.8\ m/s^2$



21. A block of mass 4 *kg* is suspended through two light spring balances *A* and *B*. Then *A* and *B* will read respectively [AIIMS 1995]



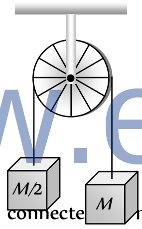
(a) 4 *kg* and zero *kg*

(b) Zero *kg* and 4 *kg*

(c) 4 *kg* and 4 *kg*

(d) 2 *kg* and 2 *kg*

22. Two masses *M* and *M*/2 are joint together by means of a light inextensible string passes over a frictionless pulley as shown in figure. When bigger mass is released the small one will ascend with an acceleration of [Kerala PET 2005]



(a) *g*/3

(b) 3*g*/2

(c) *g*/2

(d) *g*

23. Two masses m_1 and m_2 $(m_1 > m_2)$ are connected by a massless flexible and inextensible string passed over massless and frictionless pulley. The acceleration of centre of mass is

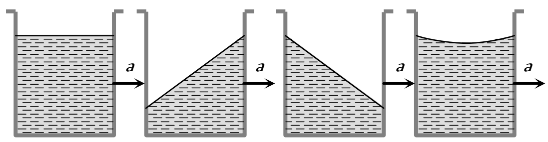
(a) $\left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2 g$ (b) $\frac{m_1 - m_2}{m_1 + m_2} g$

(c) $\frac{m_1 + m_2}{m_1 - m_2} g$ (d) Zero

Critical Thinking

Objective Questions

1. A vessel containing water is given a constant acceleration *a* towards the right, along a straight horizontal path. Which of the following diagram represents the surface of the liquid [IIT 1981]



(A) (B) (C) (D)

(a) A (b) B

(c) C (d) D

2. A closed compartment containing gas is moving with some acceleration in horizontal direction. Neglect effect of gravity. Then the pressure in the compartment is [IIT-JEE 1999]

[AIEEE 2004]

(a) Same everywhere (b) Lower in front side

(c) Lower in rear side (d) Lower in upper side

3. A ship of mass $3 \times 10^7\ kg$ initially at rest is pulled by a force of $5 \times 10^4\ N$ through a distance of 3 *m*. Assume that the resistance due to water is negligible, the speed of the ship is [IIT 1980; MP PMT 2000]

(a) 1.5 *m*/*s* (b) 60 *m*/*s*

(c) 0.1 *m*/*s* (d) 5 *m*/*s*

4. 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 [MP PET 1994]

(a) $m\left(1 - \frac{a}{g}\right)$ (b) $m\left(1 + \frac{a}{g}\right)$

(c) m (d) Zero

5. Three weights *W*, 2*W* and 3*W* are connected to identical springs suspended from a rigid horizontal rod. The assembly of the rod and the weights fall freely. The positions of the weights from the rod are such that [Roorkee 1999]

(a) 3*W* will be farthest

(b) *W* will be farthest

(c) All will be at the same distance

(d) 2*W* will be farthest

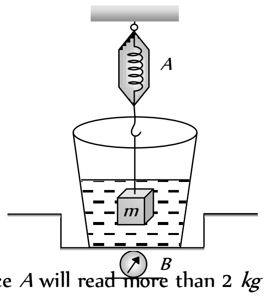
6. When forces F_1, F_2, F_3 are acting on a particle of mass *m* such that F_2 and F_3 are mutually perpendicular, then the particle remains stationary. If the force F_1 is now removed then the acceleration of the particle is [AIEEE 2002]

[J&K CET 2005]

(a) F_1/m (b) F_2F_3/mF_1

(c) $(F_2 - F_3)/m$ (d) F_2/m

7. The spring balance *A* reads 2 *kg* with a block *m* suspended from it. A balance *B* reads 5 *kg* when a beaker filled with liquid is put on the pan of the balance. The two balances are now so arranged that the hanging mass is inside the liquid as shown in figure. In this situation



(a) The balance *A* will read more than 2 *kg*

(b) The balance *B* will read more than 5 *kg*

(c) The balance *A* will read less than 2 *kg* and *B* will read more than 5 *kg*

(d) The balances *A* and *B* will read 2 *kg* and 5 *kg* respectively

8. A rocket is propelled by a gas which is initially at a temperature of 4000 *K*. The temperature of the gas falls to 1000 *K* as it leaves the exhaust nozzle. The gas which will acquire the largest momentum while leaving the nozzle, is

[SCRA 1994]

(a) Hydrogen (b) Helium

(c) Nitrogen (d) Argon

9. Consider the following statement: When jumping from some height, you should bend your knees as you come to rest, instead of keeping your legs stiff. Which of the following relations can be useful in explaining the statement

[AMU (Engg.) 2001]

(a) $\Delta \overrightarrow{P_1} = -\Delta \overrightarrow{P_2}$

(b) $\Delta E = -\Delta(PE + KE) = 0$

(c) $\vec{F}\Delta t = m\Delta \vec{v}$

(d) $\Delta \vec{x} \propto \Delta \vec{F}$

Where symbols have their usual meaning

10. A false balance has equal arms. An object weigh X when placed in one pan and Y when placed in other pan, then the weight W of the object is equal to [AFMC 1994]

(a) $\sqrt{XY}$

(b) $\frac{X+Y}{2}$

(c) $\frac{X^2+Y^2}{2}$

(d) $\frac{2}{\sqrt{X^2+Y^2}}$

11. The vector sum of two forces is perpendicular to their vector differences. In that case, the force [CBSE PMT 2003]

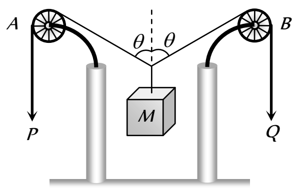
(a) Are equal to each other in magnitude

(b) Are not equal to each other in magnitude

(c) Cannot be predicted

(d) Are equal to each other

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



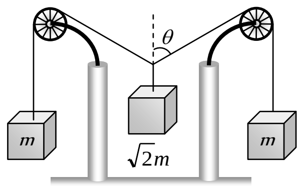
(a) $2U\cos\theta$

(b) $U\cos\theta$

(c) $\frac{2U}{\cos\theta}$

(d) $\frac{U}{\cos\theta}$

13. The pulleys and strings shown in the figure are smooth and of negligible mass. For the system to remain in equilibrium, the angle θ should be [IIT-JEE 2001]



(a) 0^o

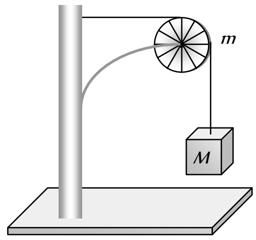
(b) 30^o

(c) 45^o

(d) 60^o

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

[IIT-JEE 2001]



(a) $\sqrt{2}Mg$

(b) $\sqrt{2}mg$

(c) $\sqrt{(M+m)^2+m^2}\,g$

(d) $\sqrt{(M+m)^2+M^2}\,g$

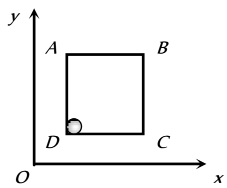
15. A pulley fixed to the ceilling carries a string with blocks of mass m and 3 m attached to its ends. The masses of string and pulley are negligible. When the system is released, its centre of mass moves with what acceleration

[UPSEAT 2002]

(a) 0 (b) $g/4$

(c) $g/2$ (d) $-g/2$

16. A solid sphere of mass 2 kg is resting inside a cube as shown in the figure. The cube is moving with a velocity $v = (5t\hat{i} + 2t\hat{j})m/s$. Here t is the time in second. All surface are smooth. The sphere is at rest with respect to the cube. What is the total force exerted by the sphere on the cube. (Take g = 10 m/s)



(a) $\sqrt{29}N$ (b) 29 N

(c) 26 N (d) $\sqrt{89}$ N

17. A stick of 1 m is moving with velocity of $2.7 \times 10^8 ms^{-1}$. What is the apparent length of the stick $(c = 3 \times 10^8 ms^{-1})$ [IIT 1982]

[BHU 1995]

(a) 10 m (b) 0.22 m

(c) 0.44 m (d) 2.4 m

18. One day on a spacecraft corresponds to 2 days on the earth. The speed of the spacecraft relative to the earth is

[CBSE PMT 1993]

(a) $1.5 \times 10^8 ms^{-1}$ (b) $2.1 \times 10^8 ms^{-1}$

(c) $2.6 \times 10^8 ms^{-1}$ (d) $5.2 \times 10^8 ms^{-1}$

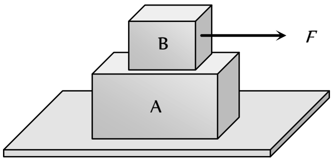
19. A flat plate moves normally with a speed v_1 towards a horizontal jet of water of uniform area of cross-section. The jet discharges water at the rate of volume V per second at a speed of v_2. The density of water is ρ. Assume that water splashes along the surface of the plate at right angles to the original motion. The magnitude of the force acting on the plate due to the jet of water is

(a) $\rho V v_1$ (b) $\rho V(v_1 + v_2)$

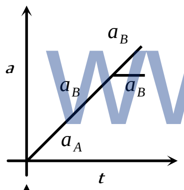
(c) $\frac{\rho V}{v_1 + v_2} v_1^2$ (d) $\rho\left[\frac{V}{v_2}\right](v_1 + v_2)^2$

GQ Graphical Questions

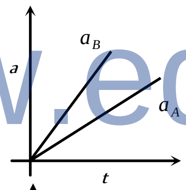
1. A block B is placed on block A. The mass of block B is less than the mass of block A. Friction exists between the blocks, whereas the ground on which the block A is placed is taken to be smooth. A horizontal force F, increasing linearly with time begins to act on B. The acceleration a_A and a_B of blocks A and B respectively are plotted against t. The correctly plotted graph is



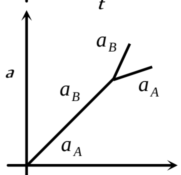
(a)



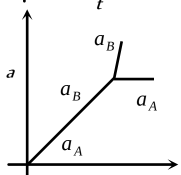
(b)



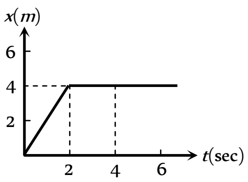
(c)



(d)



2. In the figure given below, the position-time graph of a particle of mass 0.1 Kg is shown. The impulse at $t = 2\,\text{sec}$ is



(a) 0.2 $kg\ m\ sec^{-1}$

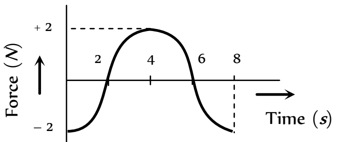
(b) $-0.2 kg\ m\ sec^{-1}$

(c) $0.1 kg\ m\ sec^{-1}$

(d) $-0.4 kg\ m\ sec^{-1}$

3. The force-time $(F - t)$ curve of a particle executing linear motion is as shown in the figure. The momentum acquired by the particle in time interval from zero to 8 *second* will be

[CPMT 1989]



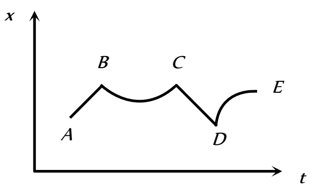
(a) – 2 *N-s*

(b) + 4 *N-s*

(c) 6 *N-s*

(d) Zero

4. Figure shows the displacement of a particle going along the X-axis as a function of time. The force acting on the particle is zero in the region



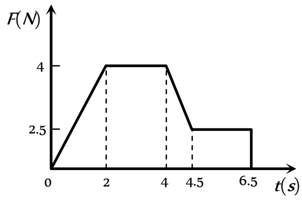
(a) AB

(b) BC

(c) CD

(d) DE

5. A body of 2 kg has an initial speed $5ms$. A force acts on it for some time in the direction of motion. The force time graph is shown in figure. The final speed of the body. [IIT 1995]



(a) $9.25\,ms^{-1}$

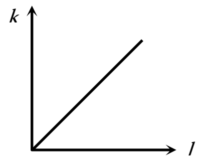
(b) $5\,ms^{-1}$

(c) 14.25 ms

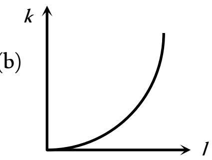
(d) 4.25 ms

6. Which of the following graph depicts spring constant k versus length l of the spring correctly

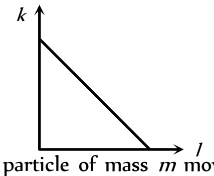
(a)



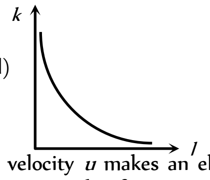
(b)



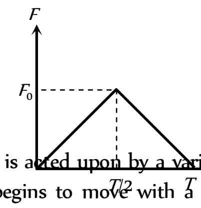
(c)



(d)



7. A particle of mass m moving with velocity u makes an elastic one dimensional collision with a stationary particle of mass m. They are in contact for a very short time T. Their force of interaction increases from zero to F linearly in time $T/2$, and decreases linearly to zero in further time $T/2$. The magnitude of F is



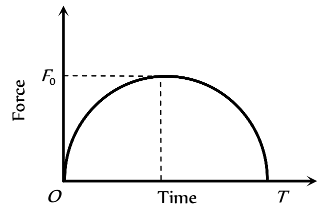
(a) mu / T

(b) $2mu / T$

(c) $mu / 2T$

(d) None of these

8. A particle of mass m, initially at rest, is acted upon by a variable force F for a brief interval of time T. It begins to move with a velocity u after the force stops acting. F is shown in the graph as a function of time. The curve is a semicircle. [AIIMS 2005]



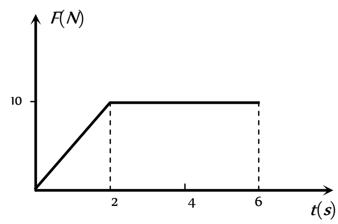
(a) $u = \frac{\pi F_0^2}{2m}$

(b) $u = \frac{\pi T^2}{8m}$

(c) $u = \frac{\pi F_0 T}{4m}$

(d) $u = \frac{F_0 T}{2m}$

9. A body of mass 3kg is acted on by a force which varies as shown in the graph below. The momentum acquired is given by



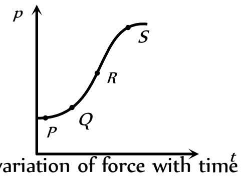
(a) Zero

(b) 5 *N-s*

(c) 30 *N-s*

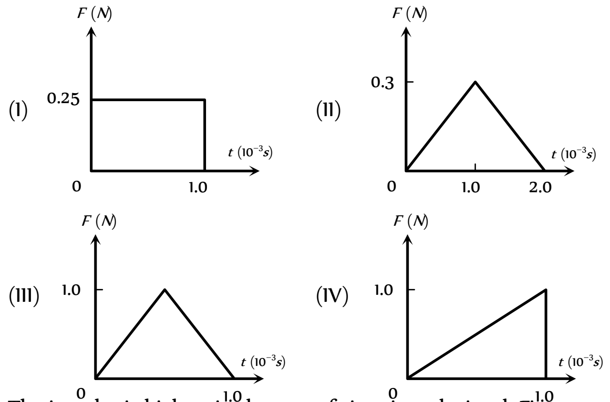
(d) 50 *N-s*

10. The variation of momentum with time of one of the body in a two body collision is shown in fig. The instantaneous force is maximum corresponding to point



(a) *P*
(b) *Q*
(c) *R*
(d) *S*

11. Figures I, II, III and IV depict variation of force with time



The impulse is highest in the case of situations depicted. Figure

(a) I and II
(b) III and I
(c) III and IV
(d) IV only

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.
(c) If assertion is true but reason is false.
(d) If the assertion and reason both are false.
(e) If assertion is false but reason is true.

1. Assertion : Inertia is the property by virtue of which the body is unable to change by itself the state of rest only.
Reason : The bodies do not change their state unless acted upon by an unbalanced external force.

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

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

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

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

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

7. Assertion : No force is required by the body to remain in any state.
Reason : In uniform linear motion, acceleration has a finite value.

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

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

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

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

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

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

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

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

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

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

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

19. Assertion : The acceleration produced by a force in the motion of a body depends only upon its mass.

Reason : Larger is the mass of the body, lesser will be the acceleration produced.

20. Assertion : Linear momentum of a body changes even when it is moving uniformly in a circle.

Reason : In uniform circular motion velocity remain constant.

21. Assertion : Newton's third law of motion is applicable only when bodies are in motion.

Reason : Newton's third law applies to all types of forces, *e.g.* gravitational, electric or magnetic forces etc.

22. Assertion : A reference frame attached to earth is an inertial frame of reference.

Reason : The reference frame which has zero acceleration is called a non inertial frame of reference.

23. Assertion : A table cloth can be pulled from a table without dislodging the dishes.

Reason : To every action there is an equal and opposite reaction.

24. Assertion : A body subjected to three concurrent forces cannot be in equilibrium.

Reason : If large number of concurrent forces acting on the same point, then the point will be in equilibrium, if sum of all the forces is equal to zero.

25. Assertion : Impulse and momentum have different dimensions.

Reason : From Newton's second law of motion, impulse is equal to change in momentum.

Answers

First Law of Motion

1	c	2	c	3	d	4	b	5	b
6	c	7	d	8	c	9	d	10	a
11	b	12	a						

Second Law of Motion

1	b	2	b	3	c	4	b	5	b
6	b	7	d	8	a	9	d	10	a
11	d	12	c	13	d	14	b	15	a
16	b	17	b	18	b	19	b	20	b
21	d	22	b	23	b	24	a	25	a
26	d	27	c	28	c	29	d	30	d
31	d	32	a	33	a	34	d	35	b
36	b	37	a	38	a	39	d	40	a
41	b	42	c	43	b	44	b	45	d
46	b	47	b	48	a	49	d	50	c
51	a	52	b	53	d	54	d	55	a
56	d	57	a	58	d	59	c	60	b
61	d	62	a	63	d	64	b	65	d
66	b	67	d	68	d	69	b	70	a
71	c	72	d	73	c	74	c	75	c
76	b	77	c	78	b	79	a	80	a
81	b	82	d	83	d	84	d	85	d
86	c	87	d	88	a	89	c	90	b
91	b	92	b	93	a	94	d	95	a
96	b	97	c	98	a	99	a	100	c
101	a	102	c	103	a	104	a	105	b
106	a	107	a	108	c	109	d	110	a
111	a	112	c	113	d				

Third Law of Motion

1	c	2	b	3	b	4	a	5	c
6	c	7	a	8	d	9	c	10	c
11	a	12	c	13	b	14	b	15	b
16	d	17	c	18	d	19	a	20	d
21	b	22	b	23	c	24	d		

Conservation of Linear Momentum Impulse

1	b	2	b	3	b	4	c	5	c
6	a	7	a	8	c	9	b	10	c
11	c	12	a	13	a	14	b	15	c
16	c	17	a	18	c	19	c	20	c
21	d	22	c	23	a	24	d	25	d
26	b	27	c						

Equilibrium of Forces

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

Motion of Connected Bodies

1	c	2	b	3	b	4	b	5	d
6	b	7	c	8	c	9	d	10	a
11	a	12	d	13	c	14	b	15	c
16	c	17	c	18	c	19	b	20	a
21	c	22	a	23	a				

Critical Thinking Questions

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

Graphical Questions

1	d	2	b	3	d	4	ac	5	c
6	d	7	b	8	c	9	d	10	c
11	c								

Assertion & Reason

1	e	2	c	3	a	4	b	5	c
6	a	7	c	8	a	9	d	10	c
11	c	12	b	13	d	14	a	15	c
16	e	17	a	18	a	19	b	20	c
21	e	22	d	23	b	24	e	25	e

AS Answers and Solutions

First Law of Motion

1. (c)
2. (c)
3. (d)
4. (b)
5. (b) Horizontal velocity of apple will remain same but due to retardation of train, velocity of train and hence velocity of boy *w.r.t.* ground decreases, so apple falls away from the hand of boy in the direction of motion of the train.
6. (c) Newton's first law of motion defines the inertia of body. It states that every body has a tendency to remain in its state (either rest or motion) due to its inertia.
7. (d) Horizontal velocity of ball and person are same so both will cover equal horizontal distance in a given interval of time and after following the parabolic path the ball falls exactly in the hand which threw it up.
8. (c) When the bird flies, it pushes air down to balance its weight. So the weight of the bird and closed cage assembly remains unchanged.
9. (d) Particle will move with uniform velocity due to inertia.
10. (a)
11. (b) When a sudden jerk is given to C, an impulsive tension exceeding the breaking tension develops in C first, which breaks before this impulse can reach A as a wave through block.
12. (a) When the spring C is stretched slowly, the tension in A is greater than that of C, because of the weight mg and the former reaches breaking point earlier.

Second Law of Motion

1. (b) $u = 100\ m/s,\ v = 0,\ s = 0.06\ m$

$$\text{Retardation } = a = \frac{u^2}{2s} = \frac{(100)^2}{2 \times 0.06} = \frac{1 \times 10^6}{12}$$

$$\therefore \text{ Force } = ma = \frac{5 \times 10^{-3} \times 1 \times 10^6}{12} = \frac{5000}{12} = 417\ N$$

2. (b) $\vec{F} = m\vec{a}$
3. (c) Acceleration $a = \dfrac{F}{m} = \dfrac{100}{5} = 20\ cm/s^2$

Now $v = at = 20 \times 10 = 200\ cm/s$

4. (b)
5. (b) $F = u\left(\dfrac{dm}{dt}\right) = 400 \times 0.05 = 20\ N$
6. (b) $u = 4\ m/s,\ v = 0,\ t = 2\ \text{sec}$

$v = u + at \Rightarrow 0 = 4 + 2a \Rightarrow a = -2\ m/s^2$

$\therefore$ Retarding force $= ma = 2 \times 2 = 4\ N$

This force opposes the motion. If the same amount of force is applied in forward direction, then the body will move with constant velocity.

7. (d) Reading on the spring balance $= m(g-a)$

and since $a = g$ $\therefore$ Force = 0

8. (a) The lift is not accelerated, hence the reading of the balance will be equal to the true weight.

$R = mg = 2g$ *Newton* or 2 *kg*

9. (d) When lift moves upward then reading of the spring balance, $R = m(g+a) = 2(g+g) = 4g\ N = 4\ kg$ [As $a = g$]

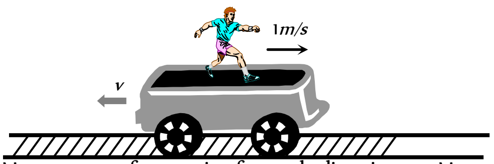
10. (a) For stationary lift $t_1 = \sqrt{\frac{2h}{g}}$

and when the lift is moving up with constant acceleration

$t_2 = \sqrt{\frac{2h}{g+a}}$ $\therefore$ $t_1 > t_2$

11. (d) Since $T = mg$, it implies that elevator may be at rest or in uniform motion.

12. (c) If the man starts walking on the trolley in the forward direction then whole system will move in backward direction with same momentum.



Momentum of man in forward direction = Momentum of system (man + trolley) in backward direction

$\Rightarrow 80 \times 1 = (80 + 320) \times v \Rightarrow v = 0.2\ m/s$

So the velocity of man *w.r.t.* ground $1.0 - 0.2 = 0.8\ m/s$

$\therefore$ Displacement of man *w.r.t.* ground $= 0.8 \times 4 = 3.2\ m$

13. (d) Force = Mass × Acceleration. If mass and acceleration both are doubled then force will become four times.

14. (b) As weight = 9.8 N $\therefore$ Mass = 1 *kg*

Acceleration $= \frac{\text{Force}}{\text{Mass}} = \frac{5}{1} = 5\ m/s^2$

15. (a) Force on the table $= mg = 40 \times 980 = 39200$ *dyne*

16. (b) $a = \frac{F}{m} = \frac{1\ N}{1\ kg} = 1\ m/s^2$

17. (b) $\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{t} = \frac{(-2)-(+10)}{4} = \frac{-12}{4} = -3\ m/s^2$

18. (b) $F = ma = 10 \times (-3) = -30\ N$

19. (b) Impulse = Force × Time $= -30 \times 4 = -120$ *N-s*

20. (b) u = velocity of bullet

$\frac{dm}{dt}$ = Mass thrown per second by the machine gun

= Mass of bullet × Number of bullet fired per second

$= 10\ g \times 10\ bullet/\sec = 100\ g/\sec = 0.1\ kg/\sec$

$\therefore$ Thrust $= \frac{udm}{dt} = 500 \times 0.1 = 50\ N$

21. (d) Acceleration of the car $= \frac{\text{Thrust on the car}}{\text{Mass of the car}}$

$= \frac{50}{2000} = \frac{1}{40} = 0.025\ m/s^2$

22. (b)

23. (b) Force on particle at 20 *cm* away $F = kx$

$F = 15 \times 0.2 = 3\ N$ $[\text{Ask} = 15\ N/m]$

$\therefore$ Acceleration $= \frac{\text{Force}}{\text{Mass}} = \frac{3}{0.3} = 10\ m/s^2$

24. (a) Force on the block $F = u\left(\frac{dm}{dt}\right) = 5 \times 1 = 5\ N$

$\therefore$ Acceleration of block $a = \frac{F}{m} = \frac{5}{2} = 2.5\ m/s^2$

25. (a) Opposing force $F = u\left(\frac{dm}{dt}\right) = 2 \times 0.5 = 1\ N$

So same amount of force is required to keep the belt moving at 2 *m/s*

26. (d) Resultant force is $w + 3w = 4w$

27. (c) Acceleration $= \frac{\text{Force}}{\text{Mass}} = \frac{50\ N}{10\ kg} = 5\ m/s^2$

From $v = u + at = 0 + 5 \times 4 = 20\ m/s$

28. (c) Thrust $F = u\left(\frac{dm}{dt}\right) = 5 \times 10^4 \times 40 = 2 \times 10^6\ N$

29. (d) In stationary lift man weighs 40 *kg i.e.* 400 *N*.

When lift accelerates upward it's apparent weight $= m(g+a) = 40(10+2) = 480\ N$ *i.e.* 48 *kg*

For the clarity of concepts in this problem *kg-wt* can be used in place of *kg*.

30. (d) As the apparent weight increase therefore we can say that acceleration of the lift is in upward direction.

$R = m(g+a) \Rightarrow 4.8\ g = 4(g+a)$

$\Rightarrow a = 0.2g = 1.96\ m/s^2$

31. (d) $T = m(g+a) = 6000(10+5) = 90000\ N$

32. (a) $F = ma = \frac{m\Delta v}{\Delta t} = \frac{0.2 \times 20}{0.1} = 40\ N$

33. (a) $F = m\left(\frac{dv}{dt}\right) = \frac{100 \times 5}{0.1} = 5000\ N$

34. (d)

35. (b) $F = m(g+a) = 20 \times 10^3 \times (10+4) = 28 \times 10^4\ N$

36. (b) $\frac{mg}{m(g-a)} = \frac{3}{2} \Rightarrow a = g/3$

37. (a) $T = m(g+a) = 500(10+2) = 6000\ N$

38. (a) $F = u\left(\frac{dm}{dt}\right) \Rightarrow \frac{dm}{dt} = \frac{F}{u} = \frac{210}{300} = 0.7\ kg/s$

39. (d) $R = m(g+a) = m(g+g) = 2mg$

40. (a) $T_1 = m(g+a) = 1 \times \left(g + \frac{g}{2}\right) = \frac{3g}{2}$

$T_2 = m(g-a) = 1\times\left(g-\frac{g}{2}\right) = \frac{g}{2} \quad \therefore \quad \frac{T_1}{T_2} = \frac{3}{1}$

41. (b) $F = \frac{udm}{dt} = m(g+a)$

$\Rightarrow \frac{dm}{dt} = \frac{m(g+a)}{u} = \frac{5000\times(10+20)}{800} = 187.5\ kg/s$

42. (c) Initially due to upward acceleration apparent weight of the body increases but then it decreases due to decrease in gravity.

43. (b) $T = 2\pi\sqrt{\frac{l}{g}}$ and $T' = 2\pi\sqrt{\frac{l}{4g/3}}$

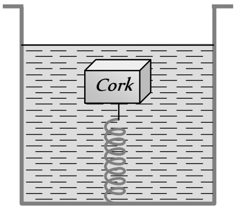
$[As\ g' = g + a = g + \frac{g}{3} = \frac{4g}{3}]$

$\therefore T' = \frac{\sqrt{3}}{2}T$

44. (b) Density of cork = d, Density of water = ρ

Resultant upward force on cork $= V(\rho - d)g$

This causes elongation in the spring. When the lift moves down with acceleration a, the resultant upward force on cork $= V(\rho-d)(g-a)$ which is less than the previous value. So the elongation decreases.



45. (d) When trolley are released then they posses same linear momentum but in opposite direction. Kinetic energy acquired by any trolley will dissipate against friction.

$\therefore \mu mg\,s = \frac{p^2}{2m} \Rightarrow s \propto \frac{1}{m^2}$ [As P and μ are constants]

$\Rightarrow \frac{s_1}{s_2} = \left(\frac{m_2}{m_1}\right)^2 = \left(\frac{3}{1}\right)^2 = \frac{9}{1}$

46. (b) Apparent weight $= m(g-a) = 50(9.8-9.8) = 0$

47. (b) Opposite force causes retardation.

48. (a) $T = m(g-a) = 10(980-400) = 5800$ dyne

49. (d) $T = 2\pi\sqrt{\frac{l}{g}}$. T will decrease, If g increases.

It is possible when rocket moves up with uniform acceleration.

50. (c) We know that in the given condition $s \propto \frac{1}{m^2}$

$\therefore \frac{s_2}{s_1} = \left(\frac{m_1}{m_2}\right)^2 \Rightarrow s_2 = \left(\frac{m_1}{m_2}\right)^2 \times s_1$

51. (a) $m = \frac{F}{a} = \frac{\sqrt{6^2+8^2+10^2}}{1} = \sqrt{200} = 10\sqrt{2}\,kg$

52. (b) In the absence of external force, position of centre of mass remain same therefore they will meet at their centre of mass.

53. (d) Force $= m\left(\frac{dv}{dt}\right) = \frac{0.25\times[(10)-(-10)]}{0.01} = 25\times 20 = 500\ N$

54. (d) $T = mg = 50\times10^{-3}\times10 = 0.5\ N$

55. (a) $F = u\left(\frac{dm}{dt}\right) = 20\times\frac{50}{60} = 16.66\ N$

56. (d) $u = 250\,m/s,\ v = 0,\ s = 0.12\,metre$

$F = ma = m\left(\frac{u^2-v^2}{2s}\right) = \frac{20\times10^{-3}\times(250)^2}{2\times0.12}$

$\therefore \quad F = 5.2\times10^3\ N$

57. (a) $F = m\left(\frac{v-u}{t}\right) = \frac{5(65-15)\times10^{-2}}{0.2} = 12.5\ N$

58. (d)

59. (c) $v = u + \frac{F}{m}t = 10 + \left(\frac{1000-500}{1000}\right)\times10 = 15\,m/s$

60. (b) $F = ma = \frac{m(u-v)}{t} = \frac{2\times(8-0)}{4} = 4\,N$

61. (d) $R = m(g+a) = 10\times(9.8+2) = 118\ N$

62. (a) $T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow \frac{T'}{T} = \sqrt{\frac{g}{g'}} = \sqrt{\frac{g}{g+\frac{g}{4}}} = \sqrt{\frac{4}{5}} = \frac{2}{\sqrt{5}}$

63. (d) $F = \frac{m(u^2-v^2)}{2S} = \frac{30\times10^{-3}\times(120)^2}{2\times12\times10^{-2}} = 1800\ N$

64. (b) $dp = F\times dt = 10\times10 = 100\ kg\ m/s$

65. (d) $R = m(g-a) = m(10-10) =$ zero

66. (b) Force exerted by the ball

$\Rightarrow F = m\left(\frac{dv}{dt}\right) = 0.15\times\frac{20}{0.1} = 30\ N$

67. (d) If rope of lift breaks suddenly, acceleration becomes equal to g so that tension, $T = m(g-g) = 0$

68. (d) $R = m(g+a) = 50\times(10+2) = 600\ N = 60\,kg\,wt$

69. (b) $F = u\left(\frac{dm}{dt}\right) = 500\times50\times10^{-3} = 25\ N$

70. (a) $S_{Horizontal} = ut = 1.5\times4 = 6\,m$

$S_{Vertical} = \frac{1}{2}at^2 = \frac{1}{2}\frac{F}{m}t^2 = \frac{1}{2}\times1\times16 = 8\,m$

$S_{Net} = \sqrt{6^2+8^2} = 10\,m$

71. (c) $T = m(g+a) = 1000(9.8+1) = 10800\ N$

72. (d) The effective acceleration of ball observed by observer on earth $= (a - a)$

As $a_0 < a$, hence net acceleration is in downward direction.

73. (c) Due to relative motion, acceleration of ball observed by observer in lift $= (g - a)$ and for man on earth the acceleration remains g.

74. (c) For accelerated upward motion

$R = m(g+a) = 80(10+5) = 1200\ N$

75. (c) Tension the string $= m(g+a) =$ Breaking force

$\Rightarrow 20(g+a) = 25\times g \Rightarrow a = g/4 = 2.5\ m/s^2$

76. (b) Rate of flow will be more when lift will move in upward direction with some acceleration because the net downward pull will be more and vice-versa.

$F_{\text{upward}} = m(g+a)$ and $F_{\text{downward}} = m(g-a)$

77. (c) Initial thrust must be

$m[g+a] = 3.5\times10^4(10+10) = 7\times10^5\,N$

78. (b) When the lift is stationary $W = mg$

$\Rightarrow 49 = m\times9.8 \Rightarrow m = 5\,kg$.

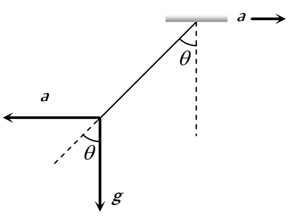
When the lift is moving downward with an acceleration $R = m(9.8-a) = 5[9.8-5] = 24\,N$

79. (a) When car moves towards right with acceleration a then due to pseudo force the plumb line will tilt in backward direction making an angle θ with vertical.

From the figure,

$\tan\theta = a/g$

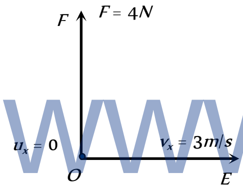
$\therefore\ \theta = \tan^{-1}(a/g)$



80. (a) $R = m(g-a) = 0$

81. (b) Displacement of body in 4 *sec* along *OE*

$s_x = v_x t = 3\times4 = 12\,m$



Force along *OF* (perpendicular to *OE*) = 4 *N*

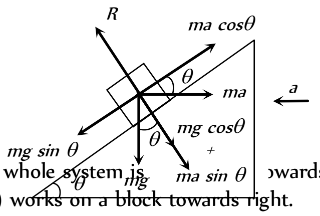
$\therefore\ a_y = \dfrac{F}{m} = \dfrac{4}{2} = 2\,m/s^2$

Displacement of body in 4 *sec* along *OF*

$\Rightarrow s_y = u_y t + \dfrac{1}{2}a_y t^2 = \dfrac{1}{2}\times2\times(4)^2 = 16\,m$ [As $u_y = 0$]

$\therefore$ Net displacement $s = \sqrt{s_x^2+s_y^2} = \sqrt{(12)^2+(16)^2} = 20\,m$

82. (d)



When the whole system is ...owards left then pseudo force (*ma*) works on a block towards right.

For the condition of equilibrium

$mg\sin\theta = ma\cos\theta \Rightarrow a = \dfrac{g\sin\theta}{\cos\theta}$

$\therefore$ Force exerted by the wedge on the block

$R = mg\cos\theta + ma\sin\theta$

$R = mg\cos\theta + m\left(\dfrac{g\sin\theta}{\cos\theta}\right)\sin\theta = \dfrac{mg(\cos^2\theta+\sin^2\theta)}{\cos\theta}$

$R = \dfrac{mg}{\cos\theta}$

83. (d) u = velocity of bullet

$\dfrac{dm}{dt}$ = Mass fired per second by the gun

$\dfrac{dm}{dt}$ = Mass of bullet (m) × Bullets fired per sec (N)

Maximum force that man can exert $F = u\left(\dfrac{dm}{dt}\right)$

$\therefore\ F = u\times m_B\times N$

$\Rightarrow N = \dfrac{F}{m_B\times u} = \dfrac{144}{40\times10^{-3}\times1200} = 3$

84. (d) The stopping distance, $S\propto u^2$ $(\because v^2 = u^2-2as)$

$\Rightarrow \dfrac{S_2}{S_1} = \left(\dfrac{u_2}{u_1}\right)^2 = \left(\dfrac{120}{60}\right)^2 = 4$

$\Rightarrow S_2 = 4\times S_1 = 4\times20 = 80\,m$

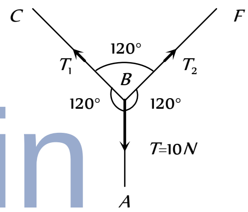
85. (d) The apparent weight,

$R = m(g+a) = 75(10+5) = 1125\,N$

86. (c) By drawing the free body diagram of point B

Let the tension in the section BC and BF are T_1 and T_2 respectively.

From Lami's theorem



$\dfrac{T_1}{\sin120°} = \dfrac{T_2}{\sin120°} = \dfrac{T}{\sin120°}$

$\Rightarrow T = T_1 = T_2 = 10\,N$.

87. (d) $F = \dfrac{dp}{dt} \equiv \dfrac{d}{dt}(a+bt^2) = 2bt \ \therefore\ F\propto t$

88. (a) When the lift moves upwards, the apparent weight,

$= m(g+a)$. Hence reading of spring balance increases.

89. (c) When lift is at rest, $T = 2\pi\sqrt{l/g}$

If acceleration becomes $g/4$ then

$T' = 2\pi\sqrt{\dfrac{l}{g/4}} = 2\pi\sqrt{\dfrac{4l}{g}} = 2\times T$

90. (b) The apparent weight of man,

$R = m(g+a) = 80(10+6) = 1280\,N$

91. (b) $v = u+at = 0+\left(\dfrac{F}{m}\right)t = \left(\dfrac{100}{5}\right)\times10 = 200\,cm/\text{sec}$

92. (b)

93. (a) $\Delta p = p_i - p_f = mv-(-mv) = 2mv$

94. (d) In the condition of free fall apparent weight becomes zero.

95. (a) Total mass of bullets = *Nm*, time $t = \dfrac{N}{n}$

Momentum of the bullets striking the wall = *Nmv*

Rate of change of momentum (Force) = $\dfrac{Nmv}{t}$ = *nmv*.

96. (b)

97. (c) If man slides down with some acceleration then its apparent weight decreases. For critical condition rope can bear only 2/3 of his weight. If a is the minimum acceleration then,

Tension in the rope $= m(g-a) =$ Breaking strength

$$\Rightarrow m(g-a) = \frac{2}{3}mg \Rightarrow a = g - \frac{2g}{3} = \frac{g}{3}$$

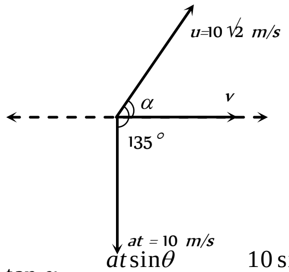
98. (a) For exerted by ball on wall

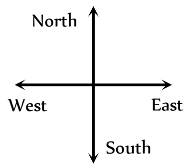
= rate of change in momentum of ball

$$= \frac{mv-(-mv)}{t} = \frac{2mv}{t}$$

99. (a) $\vec{v} = \vec{u} + \vec{a}t \therefore v = \sqrt{u^2 + a^2t^2 + 2u\,at\cos\theta}$

$$v = \sqrt{200 + 100 + 2\times 10\sqrt{2}\times 10\times\cos 135} = 10\,m/s$$





$$\tan\alpha = \frac{at\sin\theta}{u + at\cos\theta} = \frac{10\sin 135}{10\sqrt{2} + 10\cos 135} = 1 \therefore \alpha = 45°$$

i.e. resultant velocity is 10 m/s towards East.

100. (c) $u_y = 40\,m/s$, $F_y = -5N$, $m = 5kg$.

So $a_y = \frac{F_y}{m} = -1\,m/s^2$ (As $v = u + at$)

$\therefore v_y = 40 - 1\times t = 0 \Rightarrow t = 40$ sec.

101. (a) Increment in kinetic energy = work done

$$\Rightarrow \frac{1}{2}m(v^2 - u^2) = \int_{x_1}^{x_2} F.dx = \int_2^{10}(3x)\,dx$$

$$\Rightarrow \frac{1}{2}mv^2 = \frac{3}{2}[x^2]_2^{10} = \frac{3}{2}[100-4]$$

$$\Rightarrow \frac{1}{2}\times 8\times v^2 = \frac{3}{2}\times 96 \Rightarrow v = 6m/s$$

102. (c) $\vec{F} = \frac{d\vec{p}}{dt} = \frac{d}{dt}(a + bt^2) = 2bt$ *i.e.* $F \propto t$

103. (a) $F_{av} = \frac{\Delta p}{\Delta t} = \frac{mv-(-mv)}{\Delta t} = \frac{2mv}{\Delta t} = \frac{2\times 0.5\times 2}{10^{-3}} = 2000\ N$

104. (a) Given that $\vec{p} = p_x\hat{i} + p_y\hat{j} = 2\cos t\,\hat{i} + 2\sin t\,\hat{j}$

$$\therefore \vec{F} = \frac{d\vec{p}}{dt} = -2\sin t\,\hat{i} + 2\cos t\,\hat{j}$$

Now, $\vec{F}.\vec{p} = 0$ *i.e.* angle between $\vec{F}$ and $\vec{p}$ is 90°.

105. (b) $\vec{F} = \frac{d\vec{p}}{dt} =$ Rate of change of momentum

As balls collide elastically hence, rate of change of momentum of ball = $n[mu - (mu)] = 2mnu$

i.e. $F = 2mnu$

106. (a) Velocity by which the ball hits the bat

$v_1 = \sqrt{2gh_1} = \sqrt{2\times 10\times 5}$ or $\vec{v_1} = +10\,m/s = 10\,m/s$

velocity of rebound

$v_2 = \sqrt{2gh_2} = \sqrt{2\times 10\times 20} = 20\,m/s$ or $\vec{v_2} = -20\,m/s$

$$F = m\frac{dv}{dt} = \frac{m(\vec{v_2} - \vec{v_1})}{dt} = \frac{0.4(-20-10)}{dt} = 100\,N$$

by solving $dt = 0.12$ sec

107. (a) $\vec{F} = \frac{\Delta\vec{p}}{\Delta t} \Rightarrow \Delta t = \frac{|\Delta\vec{p}|}{|\vec{F}|} = \frac{0.4}{2} = 0.2\ s$

108. (c) Rate of change of momentum of the bullet in forward direction = Force required to hold the gun.

$F = nmv = 4\times 20\times 10^{-3}\times 300 = 24\ N$

109. (d) Rate of flow of water $\frac{V}{t} = \frac{10\,cm^3}{\text{sec}} = 10\times 10^{-6}\,\frac{m^3}{\text{sec}}$

Density of water $\rho = \frac{10^3 kg}{m^3}$

Cross-sectional area of pipe $A = \pi(0.5\times 10^{-3})^2$

$$\text{Force} = m\frac{dv}{dt} = \frac{mv}{t} = \frac{V\rho v}{t} = \frac{\rho V}{t}\times\frac{V}{At} = \left(\frac{V}{t}\right)^2\frac{\rho}{A}$$

$$\left(\because v = \frac{V}{At}\right)$$

By substituting the value in the above formula we get

$F = 0.127\,N$

110. (a) Weight of the disc will be balanced by the force applied by the bullet on the disc in vertically upward direction.

$F = nmv = 40\times 0.05\times 6 = Mg$

$$\Rightarrow M = \frac{40\times 0.05\times 6}{10} = 1.2\,kg$$

111. (a)

112. (c) $F = \frac{dp}{dt} = v\left(\frac{dM}{dt}\right) = \alpha v^2 \therefore a = \frac{F}{M} = \frac{\alpha v^2}{M}$

113. (d) $P = \frac{F}{A} = \frac{n[mv-(-mv)]}{A} = \frac{2mnv}{A}$

$$= \frac{2\times 10^{-3}\times 10^4\times 10^2}{10^{-4}} = 2\times 10^7\,N/m^2$$

Third Law of Motion

1. (c) Swimming is a result of pushing water in the opposite direction of the motion.

2. (b) Because for every action there is an equal and opposite reaction takes place.

3. (b)

4. (a) The force exerted by the air of fan on the boat is internal and for motion external force is required.

5. (c)

6. (c)

7. (a) Up thrust on the body $= v\sigma g$. For freely falling body effective g becomes zero. So up thrust becomes zero

8. (d)

9. (c) Total weight in right hand = 10 + 1 = 1 kg

10. (c)

11. (a) For jumping he presses the spring platform, so the reading of spring balance increases first and finally it becomes zero.

12. (c) Gas will come out with sufficient speed in forward direction, so reaction of this forward force will change the reading of the spring balance.

13. (b)

14. (b) Since the cage is closed and we can treat bird, cage and the air as a closed (isolated) system. In this condition the force applied by the bird on cage is an internal force, due to this the reading of spring balance will not change.

15. (b) As the spring balance are massless therefore both the scales read M kg each.

16. (d) $F = mnv = 150 \times 10^{-3} \times 20 \times 800 = 2400\ N$.

17. (c) 5N force will not produce any tension in spring without support of other 5N force. So here the tension in the spring will be 5N only.

18. (d) Since action and reaction acts in opposite direction on same line, hence angle between them is 180°.

19. (a)

20. (d) As by an internal force momentum of the system can not be changed.

21. (b)

22. (b) Since downward force along the inclined plane

$= mg\sin\theta = 5 \times 10 \times \sin 30° = 25N$

23. (c) At 11th second lift is moving upward with acceleration

$$a = \frac{0-3.6}{2} = -1.8 m/s^2$$

Tension in rope, $T = m(g-a)$

$= 1500(9.8 - 1.8) = 12000N$

24. (d) Distance travelled by the lift

$=$ Area under velocity time graph

$$= \left(\frac{1}{2} \times 2 \times 3.6\right) + (8 \times 3.6) + \left(\frac{1}{2} \times 2 \times 3.6\right) = 36m$$

Conservation of Linear Momentum and Impulse

1. (b)

2. (b) Force exerted by the ball on hands of the player

$$= \frac{mdv}{dt} = \frac{0.15 \times 20}{0.1} = 30\ N$$

3. (b) $F = u\left(\frac{dm}{dt}\right) = 500 \times 1 = 500\ N$

4. (c) If momentum remains constant then force will be zero because $F = \frac{dP}{dt}$

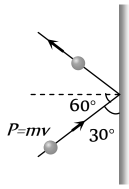
5. (c) According to principle of conservation of linear momentum $1000 \times 50 = 1250 \times v \Rightarrow v = 40\, km/hr$

6. (a) Change in momentum = Impulse

$$\Rightarrow \Delta p = F \times \Delta t \Rightarrow \Delta t = \frac{\Delta p}{F} = \frac{125}{250} = 0.5 \text{ sec}$$

7. (a) During collision of ball with the wall horizontal momentum changes (vertical momentum remains constant)

$$\therefore F = \frac{\text{Change in horizontal momentum}}{\text{Time of contact}}$$



$$= \frac{2P\cos\theta}{0.1} = \frac{2mv\cos\theta}{0.1}$$

$$= \frac{2 \times 0.1 \times 10 \times \cos 60°}{0.1} = 10\ N$$

8. (c) Impulse = Force × time = $m\ a\ t$

$= 0.15 \times 20 \times 0.1 = 0.3\ N\text{-}s$

9. (b) For a given mass $P \propto v$. If the momentum is constant then it's velocity must have constant.

10. (c)

11. (c) $T = \frac{F(L-x)}{L} = \frac{5(5-1)}{5} = 4\,N$

12. (a)

13. (a) $F = u\left(\frac{dm}{dt}\right) = 3000 \times 4 = 12000\ N$

14. (b)

15. (c) It works on the principle of conservation of momentum.

16. (c) $v_G = \frac{m_B v_B}{m_G} = \frac{0.2 \times 5}{1} = 1\, m/s$

17. (a) By the conservation of linear momentum $m_B v_B = m_a v_a$

$$\Rightarrow v_G = \frac{m_B \times v_B}{m_G} = \frac{5 \times 10^{-3} \times 500}{5} = 0.5\, m/s$$

18. (c) Impulse, $I = F \times \Delta t = 50 \times 10^{-5} \times 3 = 1.5 \times 10^{-3}\ N\text{-}s$

19. (c) Momentum of one piece $= \frac{M}{4} \times 3$

Momentum of the other piece $= \frac{M}{4} \times 4$

$\therefore$ Resultant momentum $= \sqrt{\frac{9M^2}{16} + M^2} = \frac{5M}{4}$

The third piece should also have the same momentum. Let its velocity be v, then

$$\frac{5M}{4} = \frac{M}{2} \times v \text{ or } v = \frac{5}{2} = 2.5\, m/sec$$

20. (c)

21. (d) Using law of conservation of momentum, we get

$100 \times v = 0.25 \times 100 \Rightarrow v = 0.25\, m/s$

22. (c) $F = 600 - 2 \times 10^5 t = 0 \Rightarrow t = 3 \times 10^{-3}$ sec

Impulse $I = \int_0^t F\,dt = \int_0^{3\times10^{-3}} (600 - 2 \times 10^3 t)dt$

$= [600t - 10^5 t^2]_0^{3\times10^{-3}} = 0.9\ N \times \text{sec}$

23. (a) According to principle of conservation of linear momentum, $m_G v_G = m_B v_B$

$$\Rightarrow v_G = \frac{m_B v_B}{m_G} = \frac{0.1 \times 10^2}{50} = 0.2 m/s$$

24. (d) $m_G v_G = m_B v_B \Rightarrow v_B = \dfrac{m_G v_G}{m_B} = \dfrac{1\times 5}{10\times 10^{-3}} = 500 m/s$

25. (d)

26. (b) The acceleration of a rocket is given by

$$a = \frac{v}{m}\left(\frac{\Delta m}{\Delta t}\right) - g = \frac{400}{100}\left(\frac{5}{1}\right) - 10$$

$$= (20-10) = 10\ m/s^2$$

27. (c)

Equilibrium of Forces

1. (d) Application of Bernoulli's theorem.

2. (c)

3. (b) $F = \sqrt{(F)^2 + (F)^2 + 2F.F\cos\theta} \Rightarrow \theta = 120°$

4. (a) $F_{net}^2 = F_1^2 + F_2^2 + 2F_1F_2\cos\theta$

$$\Rightarrow \left(\frac{F}{3}\right)^2 = F^2 + F^2 + 2F^2\cos\theta \Rightarrow \cos\theta = \left(-\frac{17}{18}\right)$$

5. (c) Direction of second force should be at 180°.

6. (c) $F_{max} = 5 + 10 = 15N$ and $F_{min} = 10 - 5 = 5N$

Range of resultant $5 \le F \le 15$

7. (b) $R^2 = (3P)^2 + (2P)^2 + 2\times 3P \times 2P \times \cos\theta$ ...(i)

$(2R)^2 = (6P)^2 + (2P)^2 + 2\times 6P \times 2P \times \cos\theta$ ...(ii)

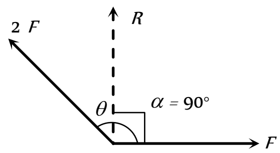
by solving (i) and (ii), $\cos\theta = -1/2 \Rightarrow \theta = 120°$

8. (b) $\tan\alpha = \dfrac{2F\sin\theta}{F + 2F\cos\theta} = \infty$ (as α = 90°)

$\Rightarrow F + 2F\cos\theta = 0$

$\Rightarrow \cos\theta = -\dfrac{1}{2}$

$\theta = 120°$



9. (b) $A + B = 18$ ...(i)

$12 = \sqrt{A^2 + B^2 + 2AB\cos\theta}$ ...(ii)

$\tan\alpha = \dfrac{B\sin\theta}{A + B\cos\theta} = \tan 90° \Rightarrow \cos\theta = -\dfrac{A}{B}$ ...(iii)

By solving (i), (ii) and (iii), $A = 13N$ and $B = 5N$

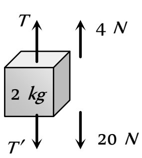
10. (c)

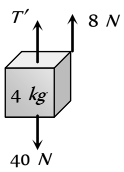
11. (d) Range of resultant of F_1 and F_2 varies between (3+5)=8*N* and $(5-3) = 2N$. It means for some value of angle (θ), resultant 6 can be obtained. So, the resultant of 3*N*, 5*N* and 6*N* may be zero and the forces may be in equilibrium.

12. (a) Net force on the particle is zero so the $\vec{v}$ remains unchanged.

13. (a) For equilibrium of forces, the resultant of two (smaller) forces should be equal and opposite to third one.

14. (a) FBD of mass 2 *kg* FBD of mass 4*kg*





$T - T' - 20 = 4$ ....(i) $T' - 40 = 8$ ...(ii)

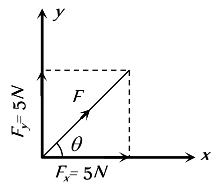
By solving (i) and (ii) $T' = 47.23\ N$ and $T = 70.8\ N$

15. (a)

16. (b) $|\vec{F}| = \sqrt{5^2 + 5^2} = 5\sqrt{2}\ N$.

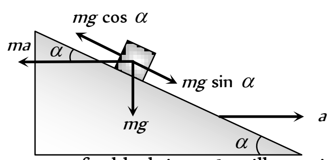
and $\tan\theta = \dfrac{5}{5} = 1$

$\Rightarrow \theta = \pi/4$.



17. (b)

18. (b)

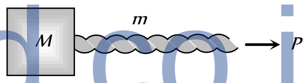


Let the mass of a block is *m*. It will remains stationary if forces acting on it are in equilibrium *i.e*, $ma\cos\alpha = mg\sin\alpha \Rightarrow a = g\tan\alpha$

Here ma = Pseudo force on block, mg = Weight.

Motion of Connected Bodies

1. (c)



Acceleration of the system $= \dfrac{P}{m+M}$

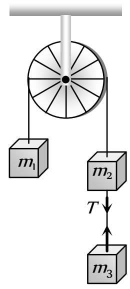
The force exerted by rope on the mass $= \dfrac{MP}{m+M}$

2. (b)

3. (b) Tension between m_2 and m_3 is given by

$$T = \frac{2m_1m_3}{m_1 + m_2 + m_3} \times g$$

$$= \frac{2\times 2\times 2}{2+2+2} \times 9.8 = 13\ N$$



4. (b) $a = \dfrac{m_2}{m_1 + m_2} \times g = \dfrac{5}{4+5} \times 9.8 = \dfrac{49}{9} = 5.44\ m/s^2$

5. (d) $T = \dfrac{2m_1m_2}{m_1 + m_2} g = \dfrac{2\times 2\times 3}{2+3} g = \dfrac{12}{5} g$

$$a = \left(\frac{m_2 - m_1}{m_1 + m_2}\right) g = \left(\frac{3-2}{3+2}\right) g = \frac{g}{5}$$

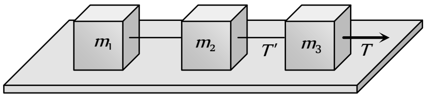
6. (b) $T_2 = (m_A + m_B) \times \dfrac{T_3}{m_A + m_B + m_C}$

$$T_2 = (1+8)\times\frac{36}{(1+8+27)} = 9\ N$$

7. (c) Acceleration $= \frac{(m_2 - m_1)}{(m_2+m_1)}g$

$$= \frac{4-3}{4+3}\times 9.8 = \frac{9.8}{7} = 1.4\, m/\sec^2$$

8. (c)



$$T' = (m_1+m_2)\times\frac{T}{m_1+m_2+m_3}$$

9. (d) $T_2 = (m_1+m_2)\times\frac{T_3}{m_1+m_2+m_3} = \frac{(10+6)\times 40}{20} = 32\ N$

10. (a)

11. (a) Acceleration $= \frac{m_2}{m_1+m_2}\times g \ = \frac{1}{2+1}\times 9.8 = 3.27\ m/s^2$

and $T = m_1 a = 2\times 3.27 = 6.54\ N$

12. (d) $T = \frac{2m_1m_2}{m_1+m_2}g = \frac{2\times 10\times 6}{10+6}\times 9.8 = 73.5N$

13. (c) $a = \frac{m_2-m_1}{m_1+m_2}g = \frac{10-5}{10+5}g = \frac{g}{3}$

14. (b) $a = \frac{m_2}{m_1+m_2}g = \frac{3}{7+3}10 = 3\,m/s^2$

15. (c) $T_1 = \left(\frac{m_2+m_3}{m_1+m_2+m_3}\right)g = \frac{3+5}{2+3+5}\times 10 = 8N$

16. (c) $a = \left(\frac{m_2-m_1}{m_1+m_2}\right)g = \left(\frac{10-6}{10+6}\right)\times 10 = 2.5\,m/s^2$

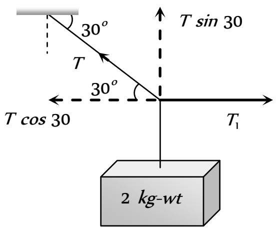
17. (c) $T\sin 30 = 2kg\ wt$

$\Rightarrow T = 4\ kg\ wt$

$T_1 = T\cos 30°$

$= 4\cos 30°$

$= 2\sqrt{3}$



18. (c) If monkey move downward with acceleration a then its apparent weight decreases. In that condition

Tension in string $= m(g-a)$

This should not be exceed over breaking strength of the rope *i.e.* $360 \ge m(g-a) \Rightarrow 360 \ge 60(10-a)$

$\Rightarrow a \ge 4\ m/s^2$

19. (b) $a = \left(\frac{m_1-m_2}{m_1+m_2}\right)g \Rightarrow \frac{g}{8} = \left(\frac{m_1-m_2}{m_1+m_2}\right)g \Rightarrow \frac{m_1}{m_2} = \frac{9}{7}$

20. (a) $a = \left[\frac{m_1-m_2}{m_1+m_2}\right]g = \left[\frac{5-4.8}{5+4.8}\right]\times 9.8 = 0.2\ m/s^2$

21. (c) As the spring balances are massless therefore the reading of both balance should be equal.

22. (a) $a = \left(\frac{m_2-m_1}{m_1+m_2}\right)g = \left(\frac{m-m/2}{m+m/2}\right)g = \frac{g}{3}$

23. (a) Acceleration of each mass $= a = \left(\frac{m_1-m_2}{m_1+m_2}\right)g$

Now acceleration of centre of mass of the system

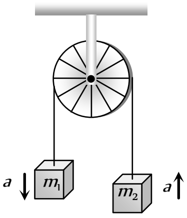
$$A_{cm} = \frac{m_1\vec{a_1} + m_1\vec{a_2}}{m_1+m_2}$$

As both masses move with same acceleration but in opposite direction so $\vec{a_1} = -\vec{a_2} = a$ (let)

$$\therefore\ A_{cm} = \frac{m_1a - m_2a}{m_1+m_2}$$

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

$$= \left(\frac{m_1-m_2}{m_1+m_2}\right)^2\times g$$



Critical Thinking Questions

1. (c) Due to acceleration in forward direction, vessel is an accelerated frame therefore a Pseudo force will be exerted in backward direction. Therefore water will be displaced in backward direction.

2. (b) The pressure on the rear side would be more due to fictitious force (acting in the opposite direction of acceleration) on the rear face. Consequently the pressure in the front side would be lowered.

3. (c) $v^2 = 2as = 2\left(\frac{F}{m}\right)s \qquad [As\ u = 0]$

$$\Rightarrow v^2 = 2\left(\frac{5\times 10^4}{3\times 10^7}\right)\times 3 = \frac{1}{100}$$

$$\Rightarrow v = 0.1\ m/s$$

4. (c) Mass measured by physical balance remains unaffected due to variation in acceleration due to gravity.

5. (c) For W, $2W$, $3W$ apparent weight will be zero because the system is falling freely. So the distances of the weight from the rod will be same.

6. (a) For equilibrium of system, $F_1 = \sqrt{F_2^2+F_3^2}$ As $\theta = 90°$

In the absence of force F_1, Acceleration $= \frac{\text{Net force}}{\text{Mass}}$

$$= \frac{\sqrt{F_2^2+F_3^2}}{m} = \frac{F_1}{m}$$

7. (b,c) Force of upthrust will be there on mass m shown in figure, so A weighs less than 2 kg. Balance will show sum of load of beaker and reaction of upthrust so it reads more than 5 kg.

8. (d) Heavier gas will acquire largest momentum *i.e.* Argon.

9. (c) $\vec{F}\Delta t = m\Delta\vec{v} \Rightarrow F = \frac{m\Delta\vec{v}}{t}$

By doing so time of change in momentum increases and impulsive force on knees decreases.

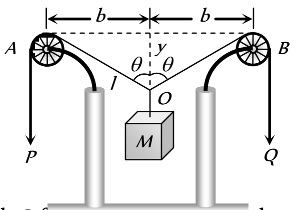
10. (b) When false balance has equal arms then, $W = \frac{X+Y}{2}$

11. (a) Let two vectors be $\vec{A}$ and $\vec{B}$ then $(\vec{A}+\vec{B}).(\vec{A}-\vec{B}) = 0$

$\vec{A}.\vec{A} - \vec{B}.\vec{B} + \vec{B}.\vec{A} - \vec{B}.\vec{B} = 0$

$A^2 - B^2 = 0 \Rightarrow A^2 = B^2 \therefore A = B$

12. (d)



As P and Q fall down, the length l decreases at the rate of U m/s.

From the figure, $l^2 = b^2 + y^2$

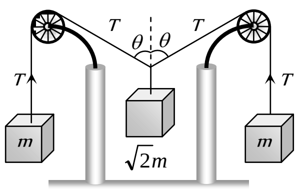
Differentiating with respect to time

$$2l \times \frac{dl}{dt} = 2b \times \frac{db}{dt} + 2y \times \frac{dy}{dt} \left(\text{As} \frac{db}{dt} = 0, \frac{dl}{dt} = U\right)$$

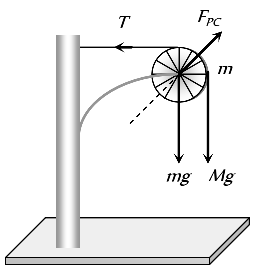
$$\Rightarrow \frac{dy}{dt} = \left(\frac{l}{y}\right) \times \frac{dl}{dt} \Rightarrow \frac{dy}{dt} = \left(\frac{1}{\cos\theta}\right) \times U = \frac{U}{\cos\theta}$$

13. (c) From the figure for the equilibrium of the system

$$2T\cos\theta = \sqrt{2}mg \Rightarrow \cos\theta = \frac{1}{\sqrt{2}} \Rightarrow \theta = 45°$$



14. (d) Force on the pulley by the clamp



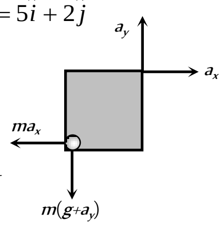
$F_{pc} = \sqrt{T^2 + [(M+m)g]^2}$

$F_{pc} = \sqrt{(Mg)^2 + [(M+m)g]^2}$

$F_{pc} = \sqrt{M^2 + (M+m)^2}\, g$

15. (b) $a_{cm} = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2 g = \left(\frac{3m - m}{3m + m}\right)^2 g = \frac{g}{4}$

16. (c) As $\vec{v} = 5t\hat{i} + 2t\hat{j} \therefore \vec{a} = a_x\hat{i} + a_y\hat{j} = 5\hat{i} + 2\hat{j}$



$\vec{F} = ma_x\hat{i} + m(g + a_y)\hat{j}$

$\therefore |\vec{F}| = m\sqrt{a_x^2 + (g + a_y)^2} = 26\ N$

17. (c) $l = l_0\sqrt{1 - \frac{v^2}{c^2}} = 1\sqrt{1 - \left(\frac{2.7\times10^8}{3\times10^8}\right)^2} \Rightarrow l = 0.44\ m$

18. (c) $T = \frac{T_0}{[1 - (v^2/c^2)]^{1/2}}$

By substituting $T_0 = 1$ day and $T = 2$ days we get

$v = 2.6\times10^8\ ms^{-1}$

19. (d) Force acting on plate, $F = \frac{dp}{dt} = v\left(\frac{dm}{dt}\right)$

Mass of water reaching the plate per $sec = \frac{dm}{dt}$

$= Av\rho = A(v_1 + v_2)\rho = \frac{V}{v_2}(v_1 + v_2)\rho$

($v = v_1 + v_2 =$ velocity of water coming out of jet *w.r.t.* plate)

($A =$ Area of cross section of jet $= \frac{V}{v_2}$)

$\therefore F = \frac{dm}{dt}v = \frac{V}{v_2}(v_1 + v_2)\rho \times (v_1 + v_2) = \rho\left[\frac{V}{v_2}\right](v_1 + v_2)^2$

Graphical Questions

1. (d) If the applied force is less than limiting friction between block A and B, then whole system move with common acceleration

i.e. $a_A = a_B = \frac{F}{m_A + m_B}$

But the applied force increases with time, so when it becomes more than limiting friction between A and B, block B starts moving under the effect of net force $F - F_k$

Where F_k = Kinetic friction between block A and B

$\therefore$ Acceleration of block B, $a_B = \frac{F - F_k}{m_B}$

As F is increasing with time so a_B will increase with time

Kinetic friction is the cause of motion of block A

$\therefore$ Acceleration of block A, $a_A = \frac{F_k}{m_A}$

It is clear that $a_B > a_A$. *i.e.* graph (d) correctly represents the variation in acceleration with time for block A and B.

2. (b) Velocity between $t = 0$ and $t = 2\sec$

$\Rightarrow v_i = \frac{dx}{dt} = \frac{4}{2} = 2\ m/s$

Velocity at $t = 2\,\sec$, $v_f = 0$

Impulse = Change in momentum $= m(v_f - v_i)$

$= 0.1(0-2) = -0.2\ kg\ m\ \sec^{-1}$

3. (d) Momentum acquired by the particle is numerically equal to area enclosed between the *F-t* curve and time axis. For the given diagram area in upper half is positive and in lower half is negative (and equal to upper half), so net area is zero. Hence the momentum acquired by the particle will be zero.

4. (a,c) In region *AB* and *CD*, slope of the graph is constant *i.e.* velocity is constant. It means no force acting on the particle in this region.

5. (c) Impulse = Change in momentum $= m(v_2 - v_1)$ ...(i)

Again impulse = Area between the graph and time axis

$$= \frac{1}{2} \times 2 \times 4 + 2 \times 4 + \frac{1}{2}(4 + 2.5) \times 0.5 + 2 \times 2.5$$

$$= 4 + 8 + 1.625 + 5 = 18.625 \quad ...(ii)$$

From (i) and (ii), $m(v_2 - v_1) = 18.625$

$$\Rightarrow v_2 = \frac{18.625}{m} + v_1 = \frac{18.625}{2} + 5 = 14.25\ m/s$$

6. (d) $K = \frac{F}{x}$ and increment in length is proportional the original length *i.e.* $x \propto l \ \therefore\ K \propto \frac{1}{l}$

It means graph between *K* and *l* should be hyperbolic in nature.

7. (b) In elastic one dimensional collision particle rebounds with same speed in opposite direction

i.e. change in momentum $= 2mu$

But Impulse $= F \times T =$ Change in momentum

$$\Rightarrow F_0 \times T = 2mu \Rightarrow F_0 = \frac{2mu}{T}$$

8. (c) Initially particle was at rest. By the application of force its momentum increases.

Final momentum of the particle = Area of F - t graph

$\Rightarrow mu =$ Area of semi circle

$$mu = \frac{\pi r^2}{2} = \frac{\pi r_1 r_2}{2} = \frac{\pi (F_0)(T/2)}{2} \Rightarrow u = \frac{\pi F_0 T}{4m}$$

9. (d) momentum acquired = Area of force-time graph

$$= \frac{1}{2} \times (2) \times (10) + 4 \times 10 = 10 + 40 = 50\ N\text{-}S$$

10. (c) $F = \frac{dp}{dt}$, so the force is maximum when slope of graph is maximum

11. (c) Impulse = Area between force and time graph and it is maximum for graph (III) and (IV)

Assertion and Reason

1. (e) Inertia is the property by virtue of which the body is unable to change by itself not only the state of rest, but also the state of motion.

2. (c) According to Newton's second law

Acceleration = $\frac{\text{Force}}{\text{Mass}}$ *i.e.* if net external force on the body is zero then acceleration will be zero

3. (a) According to second law $F = \frac{dp}{dt} = ma$.

If we know the values of *m* and *a*, the force acting on the body can be calculated and hence second law gives that how much force is applied on the body.

4. (b) When a body is moving in a circle, its speed remains same but velocity changes due to change in the direction of motion of body. According to first law of motion, force is required to change the state of a body. As in circular motion the direction of velocity of body is changing so the acceleration cannot be zero. But for a uniform motion acceleration is zero (for rectilinear motion).

5. (c) According to definition of momentum

$P = mv$ if P = constant then mv = constant or $v \propto \frac{1}{m}$.

As velocity is inversely proportional to mass, therefore lighter body possess greater velocity.

6. (a) The wings of the aeroplane pushes the external air backward and the aeroplane move forward by reaction of pushed air. At low altitudes. density of air is high and so the aeroplane gets sufficient force to move forward.

7. (c) Force is required to change the state of the body. In uniform motion body moves with constant speed so acceleration should be zero.

8. (a) According to Newton's second law of motion $a = \frac{F}{m}$ *i.e.* magnitude of the acceleration produced by a given force is inversely proportional to the mass of the body. Higher is the mass of the body, lesser will be the acceleration produced *i.e.* mass of the body is a measure of the opposition offered by the body to change a state, when the force is applied *i.e.* mass of a body is the measure of its inertia.

9. (d) $F = \frac{dp}{dt}$ = Slope of momentum-time graph

i.e. Rate of change of momentum = Slope of momentum- time graph = force.

10. (c) The purpose of bending is to acquire centripetal force for circular motion. By doing so component of normal reaction will counter balance the centrifugal force.

11. (c) Work done in moving an object against gravitational force (conservative force) depends only on the initial and final position of the object, not upon the path taken. But gravitational force on the body along the inclined plane is not same as that along the vertical and it varies with the angle of inclination.

12. (b) In uniform circular motion of a body the speed remains constant but velocity changes as direction of motion changes.

As linear momentum = mass × velocity, therefore linear momentum of a body changes in a circle.

On the other hand, if the body is moving uniformly along a straight line then its velocity remains constant and hence acceleration is equal to zero. So force is equal to zero.

13. (d) Law of conservation of linear momentum is correct when no external force acts . When bullet is fired from a rifle then both should possess equal momentum but different kinetic energy. E $= \frac{P^2}{2m}$ $\therefore$ Kinetic energy of the rifle is less than that of bullet because $E \propto 1/m$

14. (a) As the fuel in rocket undergoes combustion, the gases so produced leave the body of the rocket with large velocity and give upthrust to the rocket. If we assume that the fuel is burnt at a constant rate, then the rate of change of momentum of the rocket will be constant. As more and more fuel gets burnt, the mass of the rocket goes on decreasing and it leads to increase of the velocity of rocket more and more rapidly.

15. (c) The apparent weight of a body in an elevator moving with downward acceleration *a* is given by $W = m(g - a)$.

16. (e) For uniform motion apparent weight = Actual weight
For downward accelerated motion,
Apparent weight < Actual weight

17. (a)

18. (a) By lowering his hand player increases the time of catch, by doing so he experience less force on his hand because $F \propto 1/dt$.

19. (b) According to Newton's second law,
$F = ma \Rightarrow a = F/m$
For constant *F*, acceleration is inversely proportional to mass *i.e.* acceleration produced by a force depends only upon the mass of the body and for larger mass acceleration will be less.

20. (c) In uniform circular motion, the direction of motion changes, therefore velocity changes.
As *P* = *mv* therefore momentum of a body also changes in uniform circular motion.

21. (e) According to third law of motion it is impossible to have a single force out of mutual interaction between two bodies, whether they are moving or at rest. While, Newton's third law is applicable for all types of forces.

22. (d) An inertial frame of reference is one which has zero acceleration and in which law of inertia hold good i.e. Newton's law of motion are applicable equally. Since earth is revolving around the sun and earth is rotating about its own axis also, the forces are acting on the earth and hence there will be acceleration of earth due to these factors. That is why earth cannot be taken as inertial frame of reference.

23. (b) According to law of inertia (Newton's first law), when cloth is pulled from a table, the cloth come in state of motion but dishes remains stationary due to inertia. Therefore when we pull the cloth from table the dishes remains stationary.

24. (e) A body subjected to three concurrent forces is found to in equilibrium if sum of these force is equal to zero.
i.e. $\vec{F}_1 + \vec{F}_2 + \vec{F}_3 + ... = 0$.

25. (e) From Newton's second law
Impulse = Change of momentum.
So they have equal dimensions

Newton's Laws of Motion

Self Evaluation Test -4

1. 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

2. A person is sitting in a travelling train and facing the engine. He tosses up a coin and the coin falls behind him. It can be concluded that the train is [SCRA 1994]
   (a) Moving forward and gaining speed
   (b) Moving forward and losing speed
   (c) Moving forward with uniform speed
   (d) Moving backward with uniform speed

3. A block can slide on a smooth inclined plane of inclination θ kept on the floor of a lift. When the lift is descending with a retardation a, the acceleration of the block relative to the incline is
   (a) $(g+a)\sin\theta$ (b) $(g-a)$
   (c) $g\sin\theta$ (d) $(g-a)\sin\theta$

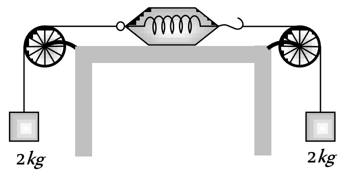
4. A 60 kg man stands on a spring scale in the lift. At some instant he finds, scale reading has changed from 60 kg to 50 kg for a while and then comes back to the original mark. What should we conclude ?
   (a) The lift was in constant motion upwards
   (b) The lift was in constant motion downwards
   (c) The lift while in constant motion upwards, is stopped suddenly
   (d) The lift while in constant motion downwards, is suddenly stopped

5. When a body is acted by a constant force, then which of the following quantities remains constant
   (a) Velocity (b) Acceleration
   (c) Momentum (d) None of these

6. 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

7. A spring balance and a physical balance are kept in a lift. In these balances equal masses are placed. If now the lift starts moving upwards with constant acceleration, then
   (a) The reading of spring balance will increase and the equilibrium position of the physical balance will disturb
   (b) The reading of spring balance will remain unchanged and physical balance will remain in equilibrium
   (c) The reading of spring balance will decrease and physical balance will remain in equilibrium
   (d) The reading of spring balance will increase and the physical balance will remain in equilibrium

8. As shown in the figure, two equal masses each of 2 kg are suspended from a spring balance. The reading of the spring balance will be



   (a) Zero
   (b) 2 kg
   (c) 4 kg
   (d) Between zero and 2 kg

9. 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 $\frac{1}{50}$ sec, then the force acted on the football should be
   (a) 2500 N (b) 1250 N
   (c) 250 N (d) 625 N

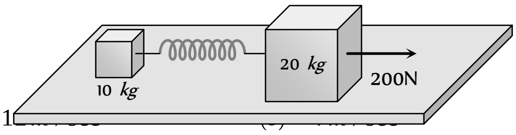
10. The engine of a jet aircraft applies a thrust force of $10^5\ N$ during take off and causes the plane to attain a velocity of 1 km/sec in 10 sec. The mass of the plane is
    (a) $10^2\ kg$ (b) $10^3\ kg$
    (c) $10^4\ kg$ (d) $10^5\ kg$

11. A force of 50 $dynes$ is acted on a body of mass 5 g which is at rest for an interval of 3 seconds, then impulse is [AFMC 1998]
    (a) 0.15×10^{-3} N-s (b) 0.98×10^{-3} N-s
    (c) 1.5×10^{-3} N-s (d) 2.5×10^{-3} N-s

12. Two weights w_1 and w_2 are suspended from the ends of a light string passing over a smooth fixed pulley. If the pulley is pulled up at an acceleration g, the tension in the string will be
    (a) $\frac{4w_1w_2}{w_1+w_2}$
    (b) $\frac{2w_1w_2}{w_1+w_2}$
    (c) $\frac{w_1w_2}{w_1+w_2}$

(d) $\frac{w_1 w_2}{2(w_1 + w_2)}$

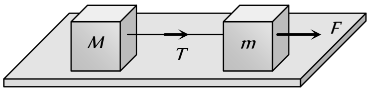
13. The masses of 10 kg and 20 kg respectively are connected by a massless spring as shown in figure. A force of 200 N acts on the 20 kg mass. At the instant shown, the 10 kg mass has acceleration $12\, m/\sec^2$. What is the acceleration of 20 kg mass



(a) 1[illegible] (b) [illegible]

(c) $10\, m/\sec^2$ (d) Zero

14. Two masses M and m are connected by a weightless string. They are pulled by a force F on a frictionless horizontal surface. The tension in the string will be



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

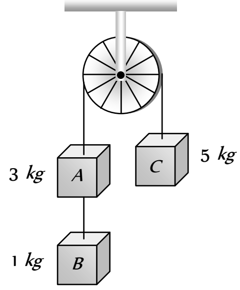
(c) $\frac{FM}{m}$ (d) $\frac{Fm}{M+m}$

15. In the above question, the acceleration of mass m is

(a) $\frac{F}{m}$ (b) $\frac{F-T}{m}$

(c) $\frac{F+T}{m}$ (d) $\frac{F}{M}$

16. Three weight A, B and C are connected by string as shown in the figure. The system moves over a frictionless pulley. The tension in the string connecting A and B is (where g is acceleration due to gravity)



(a) g

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

(c) $\frac{8g}{9}$

(d) $\frac{10g}{9}$

Answers and Solutions

(SET –4)

1. (b) Since, force needed to overcome frictional force.

2. (a) The coin falls behind him it means the velocity of train was increasing otherwise the coin fall directly into the hands of thrower.

3. (a) Acceleration of block in a stationary lift = $g\sin\theta$

If lift is descending with acc. then it will be $(g-a)\sin\theta$.

but in the problem acceleration = – a (retardation)

$\therefore$ Acceleration of block = $[g-(-a)]\sin\theta$ = $(g+a)\sin\theta$

4. (c) For upward acceleration apparent weight $= m(g+a)$

If lift suddenly stops during upward motion then apparent weight = $m(g-a)$ because instead of acceleration, we will consider retardation.

In the problem it is given that scale reading initially was 60 *kg* and due to sudden jerk reading decreasing and finally comes back to the original mark *i.e.,* 60 *kg*.

So, we can conclude that lift was moving upward with constant speed and suddenly stops.

5. (b) $F = ma$ for a given body if $F =$ constant then a = constant.

6. (c) $R = m(g+a) = m(g+4g) = 5mg$

7. (d) The fictitious force will act downwards. So the reading of spring balance will increase. In case of physical balance, the fictitious force will act on both the pans, so the equilibrium is not affected.

8. (b) In this case, one 2 *kg wt* on the left will act as the support for the spring balance. Hence its reading will be 2 *kg*.

9. (c) Force on the football $F = m\dfrac{dv}{dt}$

$$F = \frac{m(v_2 - v_1)}{dt} = \frac{0.5 \times (10-0)}{1/50} = 250N.$$

***

10. (b) Acceleration produced in jet = $\dfrac{\text{Change in velocity}}{\text{Time}}$

$$a = \frac{(10^3 - 0)}{10} = 100 m/s^2$$

$$\therefore \text{ Mass} = \frac{\text{Force}}{\text{Acceleration}} = \frac{10^5}{10^2} = 10^3 kg.$$

11. (c) Impulse = Force × Time = $50 \times 10^{-5} \times 3$

$= 1.5 \times 10^{-3}$ *N-s*

12. (a) $T = \dfrac{2m_1m_2}{(m_1+m_2)}(g+a) = \dfrac{2m_1m_2(g+g)}{m_1+m_2}$

$$\Rightarrow T = \frac{4m_1m_2}{m_1+m_2}g = \frac{4w_1w_2}{w_1+w_2}$$

13. (b) As the mass of 10 *kg* has acceleration 12 *m/s* therefore it apply 120*N* force on mass 20*kg* in a backward direction.

$\therefore$ Net forward force on 20 *kg* mass = 200 – 120 = 80*N*

$$\therefore \text{ Acceleration} = \frac{80}{20} = 4 m/s^2.$$

14. (a) $T = M \times a = M \times \left(\dfrac{F}{m+M}\right)$

15. (b) Net force on mass *m*, $ma = F - T \therefore a = \dfrac{F-T}{m}$

16. (d) $T = \dfrac{2 \times m_B m_C}{m_A + m_B + m_C} \times g = \dfrac{2 \times 1 \times 5}{3+1+5} \times g = \dfrac{10}{9}g.$