PHYSICS

STUDY MATERIAL

LAWS OF MOTION

AIEEE

NARAYANA INSTITUTE OF CORRESPONDENCE COURSES

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PREFACE

Dear Student,

Heartiest congratulations on making up your mind and deciding to be an engineer to serve the society.

As you are planning to take various Engineering Entrance Examinations, we are sure that this **STUDY PACKAGE** is going to be of immense help to you.

At NARAYANA we have taken special care to design this package according to the **Latest Pattern of AIEEE,** which will not only help but also guide you to compete for AIEEE & other State Level Engineering Entrance Examinations.

The salient features of this package include :

- Power packed division of units and chapters in a scientific way, with a correlation being there.
- Sufficient number of solved examples in Physics, Chemistry & Mathematics in all the chapters to motivate the students attempt all the questions.
- All the chapters are followed by various types of exercises (Level-I, Level-II, Level-III and Questions asked in AIEEE and other Engineering Exams).

These exercises are followed by answers in the last section of the chapter. *This package will help you to know* what to study, how to study, time management, your weaknesses and improve your performance.

We, at NARAYANA, strongly believe that quality of our package is such that the students who are not fortunate enough to attend to our Regular Classroom Programs, can still get the best of our quality through these packages.

We feel that there is always a scope for improvement. We would welcome your suggestions & feedback.

Wish you success in your future endeavours.

THE NARAYANA TEAM

ACKNOWLEDGEMENT

While preparing the study package, it has become a wonderful feeling for the NARAYANA TEAM to get the wholehearted support of our Staff Members including our Designers. They have made our job really easy through their untiring efforts and constant help at every stage.

We are thankful to all of them.

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LAWS OF MOTION

LAWS OF MOTION

AIEEE Syllabus

Force and inertia – Newton 's Laws of Motion. Conservation of linear momentum and its applications, rocket propulsion, friction – laws of friction

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INTRODUCTION

Force is the measure of the interaction between different bodies which are either in contact or apart. When a force is applied on a body, either it changes or tries to change the bodies position. Force is a vector quantity. Every force has a definite direction and the result of its action depends on the direction and the magnitude of the force.

INERTIA

It is that property of the body by virtue of which it opposes any change in state of rest or uniform motion. Inertia of a body is directly proportional to its mass. Inertia is of three types (i) inertia of rest (ii) inertia of motion and (iii) inertia of direction

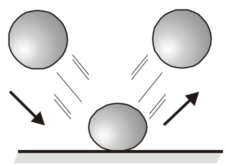
Examples :

- The passenger standing in a stationary motor car or trains falls back when it suddenly moves.
- The passenger standing in a moving motor car or train inclines forward when it suddenly stops.
- If a coin is placed on a card board which is placed on a tumbler, then on pulling the card board suddenly the coil falls into the tumbler.

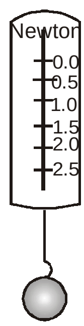
FORCE

A force is push or a pull.

- Since push or a pull has both magnitude and direction, so that force is a vector quantity.
- Forces occur in pairs. If object A exerts a force on object B, then B also exerts a force on A. For example, when a bat strikes a ball the bat exerts a force on the ball, but the ball exerts a force on the bat also.
- A force can cause an object to accelerate. If you kick a foot ball the ball's velocity changes while your foot is in contact with it.
- A force can deform an object. As you can see from fig. The ball when hits the floor, is deformed by the contact force exerted on it by the floor. The floor is deformed too, but since it is harder than the ball, its deformation is not as noticeable.



- Property 4, that a force causes an object to be deformed is often used to measure a force this is the principle of a spring scale.
- A spring scale indicates the amount of the spring is stretched or compressed. The magnitude of this force is proportional to the amount of the spring stretched (or compressed), and the direction of the force is along the spring.



UNIT OF FORCE

Unit of force in SI system in Newton.

One Newton force is that force which when acted on a body of mass one kilogram produces on acceleration of $1 m/sec^2$.

Unit of force in C.G.S system is dyne.

One dyne force is that force which when acted on a body of mass one gram produces an acceleration of $1 cm/sec^2$

1 newton = 10^5 dynes

1 kg wt = g newton

Dimensions of force is = $[M^1L^1T^{-2}]$

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GRAVITATIONAL UNIT OF FORCE

In SI system, kilogram weight (kg-wt) or kilogram force (kgf)

1 kg – wt = 1 kgf = 9.8 newton.

In C.G.S system, gram-weight (gm - wt) or gram - force (gmf)

FUNDAMENTAL FORCES OF NATURE

Different forces or interactions can be divided in the following four fundamental forces on the basis of their nature -

(a) Gravitational force or interaction

(b) Electromagnetic force or interaction

(c) Nuclear force or interaction

(d) Weak force or interaction

(A) GRAVITATIONAL FORCE

This force can be obtained from Newtons' gravitational law.

According to Newton's gravitational law

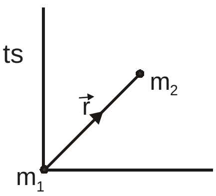
$F \propto m_1 m_2$

$F \propto \dfrac{1}{r^2}$

or $F \propto \dfrac{m_1 m_2}{r^2}$ or $F = G\dfrac{m_1 m_2}{r^2}$

In vector notation, the force acting on m_2 due to m_1

$\vec{F} = G\dfrac{m_1 m_2}{r^2}(\hat{r})$



G is constant which is called Gravitational constant. It is a universal constant. Its value is

$G = 6.67 \times 10^{-11}$ N-m^2 /kg^2

and dimensions are $[M^{-1}L^3T^{-2}]$

The range of this force is very large.

- This force acts in between the planets and its magnitude is very large. This force also acts in between atomic particles (e – e), (e – p), (p – p), (p – n) but its magnitude is very small. This force is weakest among all forces in nature
- Energy particle of this force is **Graviton.**
- This force is important in those circumstances in which one body taking part in the interaction is having astronomical size.
- Gravitational force of 6.67×10^{-11} newton acts between two bodies of mass 1kg each placed at a distance 1 m apart.

- The interaction time of this force is about 10^{-2} sec.
- A force of 2.3×10^{20} newton acts in between the moon and the earth whereas a force of 4.054×10^{-47} newton acts in between an electron and a proton of hydrogen atom.

(B) ELECTROMAGNETIC FORCE

- This force acts between charged or magnetised objects.
- The force acting between stationary or moving charges in electromagnetic force.
- Source of electrical forces are stationary and moving charges.
- Magnetic force acts only on moving charges.
- It can be attractive or repulsive.

  There is repulsive force between the charges of similar nature and attractive force between the charges of dissimilar nature.
- **Coloumb's law**

  $F \propto q_1 q_2$

  $F \propto \frac{1}{r^2}$ or $F \propto \frac{q_1 q_2}{r^2}$

  $F = K \frac{q_1 q_2}{r^2}$

  where K is a constant which depends upon the nature of the medium. For vaccum

  $$K = \frac{1}{4\pi \epsilon_0} = 9 \times 10^9 \ N - m^2 / C^2$$

  ϵ_0 is called permittivity of vacuum and its value is 8.85×10^{-12} $C^2/N - m^2$

  The range of this force is also very large.

  Electromagnetic force is 10^{36} times more stronger than the gravitation force but $\frac{1}{137}$ times weaker than the nuclear force.

(C) NUCLEAR FORCE

- This force acts within the nucleus of an atom.
- This force acts only among protons and neutrons within the nucleus of an atom.
- This force is maximum inside the nucleus and zero outside the nucleus.
- The range of the force is very small (~ 10^{-15} m)
- This force is strongest force of nature

- Its energy particle is **pion**.
- The magnitude of this force can be obtained from Yukawa potential :

$$U\ (r) = U = U_0 \frac{e^{-r/r_0}}{r}$$

where U_0 and r_0 are constants.

Nuclear force does not depend on charge i.e., it is charge independent. This force acts between proton-proton, neutron-neutron and neutron-proton in equal strength.

(D) WEAK FORCES

- β decay in radioactive disintegration is explained by this force.
- This force is weaker in comparison to nuclear and electromagnetic forces and is 10^{-25} times the nuclear force.

The range of this force is of the order of 10^{-15} m . The energy particle of this force is **boson**.

Neutron and proton in the nucleus decay due to weak forces as

$${}_1n^0 \rightarrow {}_1p^1 + \beta^{-1} + \bar{\nu} \text{ (Antineutrino)}$$

$${}_1p^1 \rightarrow {}_1n^0 + \beta^{+1} + \nu \text{ (Neutrino)}$$

This force is related with the transformation of neutron to proton or proton to neutron in β decay.

The nature of weak forces is still unknown.

COMPARATIVE STUDY OF FORCES

S.No.	Forces	Nature	Range	Relative strength	Energy particle
1.	Gravitational	attractive	infinite	1	graviton
2.	Electromagnetic	attractive or repulsive	infinite	10^{36}	photon
3.	Nuclear	attractive	very short	10^{39}	pion
4.	Weak	unknown	very short	10^{14}	boson

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NEWTON'S LAWS OF MOTION

- **First law :**

  Every body continues to remain in its state of rest or of uniform motion unless an external force is applied on it i.e. If a particle is at rest, it will remain at rest and if it is moving with constant speed, it will continue to move in the same direction with same constant speed unless an external force is applied on it.
- First law is also called law of inertia or Galileans' law
- First law defines force. According to it the device used for changing the state of a body or particle is called force.
- **Second law :**

  The rate of change of momentum of a particle is equal to the applied force and change in momentum is in the direction of applied force, i.e.

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

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

(a) First law can be obtained from second law.

(b) From this, law of conservation of linear momentum can be obtained, i.e.,

If $F = 0$, then $\frac{dp}{dt} = 0$

$\therefore$ $p = mv$ = constant or v = constant (since m = constant)

Examples:
- While catching a ball the cricketer moves hands backwards.
- Uses of springs and shockers in motor cars.

- **Third law -** To every action there is an equal and opposite reaction, i.e.,

$$\vec{F}_{12} = -\vec{F}_{21}$$

(a) Action and reaction act on different objects but act simultaneously.

(b) This law can be obtained from second law.

(c) Real force always exists in pair known as action - reaction pairs.

Examples:
- While catching a ball the cricketer moves hands backwards.
- On firing a bullet from the gun, a jerk acts in the opposite direction.
- Launching of a rocket or motion of a jet aeroplane.
- Pulling of a horse-cart.
- Moving of a boat in the opposite direction due to jumping of man from the boat.

LINEAR MOMENTUM

- The product of mass of a body (m) and velocity ($\vec{v}$) is called linear momentum, i.e., $\vec{p} = m\vec{v}$
- It is a vector quantity and its direction is in the direction of velocity.
- In SI system its unit is kg-m/s and dimensions are $[M^1L^1T^{-1}]$.
- If m_1 and v_1 are the mass and velocity of one body and m_2 and v_2 are the mass and velocity of another body, then

  $$\frac{p_1}{p_2} = \frac{m_1v_1}{m_2v_2}$$

  If $v_1 = v_2$ and $m_1 > m_2$

  then $p_1 > p_2$

  Thus the momentum of heavier body will be greater than the momentum of lighter body.
- If $p_1 = p_2$,

  then $m_1\ v_2 = m_2\ v_2$

  or $\frac{v_1}{v_2} = \frac{m_2}{m_1}$

  If $m_1 > m_2$ then $v_2 > v_1$

  i.e. momentum being same, the velocity of heavier body will be lesser than the velocity of lighter body

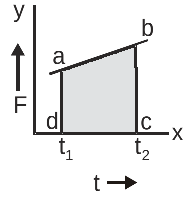
LAW OF CONSERVATION OF MOMENTUM

If no external force is acting on a body, then its linear momentum remains conserved or constant i.e. if F = 0, then

$$\frac{d\vec{p}}{dt} = 0 \text{ or } \vec{p} = m\vec{v} = \text{constant}$$

IMPULSE

- The impulse of constant force is equivalent to the product of the force and the time during which the force acts on the body.
- Impulse = (magnitude of force) time = Ft
- If the force change with time, then the impulse = $\int_0^t F dt$
- It is a vector quantity its unit is newton-sec.
- Relation between impulse and linear momentum



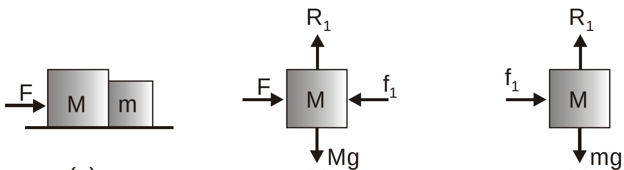
$$\text{Impulse} = \int_0^t \vec{F}\,dt = \int_0^t \frac{d\vec{P}}{dt}\,dt = \int_0^t d\vec{P} = \text{Change in momentum} = (m\vec{v} - m\vec{u})$$

If a graph is drawn between force and time, then area between (F – t) curve and time axis is equal to the impulse.

$\therefore$ Impulse between t_1 and t_2 = area abcd.

FREE BODY DIAGRAM

- A diagram showing in all external forces acting on an object is called "Free body diagram" F.B.D.
- In a specific problem, first we are required to choose a body and then we find the number of forces acting on it, and all the forces are drawn on the body, considering it as a point mass. The resulting diagram is known as free body diagram (FBD)
- For example, if two bodies of masses m and M are in contact and a force F on M is applied from the left fig. (a), the free body diagrams of M and m will be as shown in fig. (b) and (c)



(a) (b) (c)

IMPORTANT POINT

- Two forces in Newton's third law never occur in the same free-body diagram. This is because a free-body diagram shows forces acting on a single object, and the action-reaction pair in Newton's third law always act on different objects.

MOTION OF BODIES IN CONTACT

Force of contact - When two bodies whose masses are m_1 and m_2, rest on a frictionless surface in contact with each other, then the force with which one body presses the other body, is called force of contact.

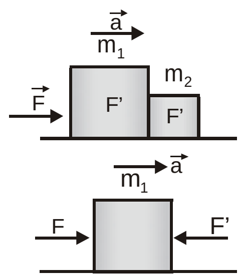
Force of contact and acceleration produced in the bodies -

(i) When two bodies are in contact with each other

(a) The acceleration produced in both bodies will be same. If 'a' be the acceleration, then

$$\text{acceleration} = \frac{\text{force}}{\text{mass}} \quad \text{or} \quad a = \frac{F}{(m_1 + m_2)}$$

Due to contact of mass m_1 and m_2 let the applied force be F' then for mass m_1



$$F - F' = m_1 a$$

$$\therefore \quad F' = F - ma$$

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

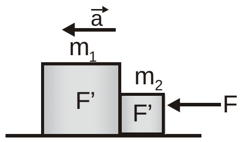
$$= \frac{Fm_2}{(m_1 + m_2)} \quad \text{or } F' = m_2 a$$

= force acting on mass m_2

(b) If a force F is applied on the body of mass m_2, then in this case the acceleration will be

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

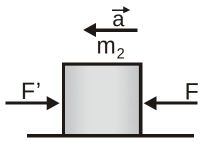
If due to contact of masses m_1 and m_2 the applied force is F'' then for mass m_2



$F - F' = m_2 a$

or $F' = F - m_2a$

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



$$= \frac{Fm_1}{(m_1 + m_2)}$$

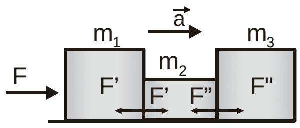
or $F' = m_1a$ = force of contact acting on mass m_1

(ii) If three bodies of masses m_1, m_2 and m_3 are kept in contact with each other -

If a force F acts on mass m_1 :

The acceleration produced in the system

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



If the force of contact between m_1 and m_2 masses is F', then

$F - F' = m_1a$

$F' = F - m_1a$

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

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

If the force of contact between the bodies of masses m_2 and m_3 is F'', then

$F'' = m_3a$

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

For the body of mass m_2

$F' - F'' = m_2\, a$

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

INERTIAL AND ACCELERATED FRAME OF REFERENCE

INERTIAL FRAME OF REFERENCE

- A non-accelerating frame of reference is called an inertial frame of reference. A frame of reference moving with a constant velocity is an inertial frame of reference.
- All the fundamental laws of physics have been formulated in respect of inertial frame of reference.
- All the fundamental laws of physics can be expressed as to have the same mathematical form in all the inertial frames of reference.
- The mechanical and optical experiments performed in an inertial frame in any direction will always yield the same results. It is called isotropic property of the inertial frame of reference.

Examples of inertial frames of reference

- A frame of reference remaining fixed w.r.t. distance stars is an inertial frame of reference.
- A space-ship moving in outer space without spinning and with its engine cut-off is also inertial frame of reference.
- For practical purposes, a frame of reference fixed to the earth can be considered as an inertial frame . Strictly speaking, such a frame of reference is not an inertial frame of reference, because the motion of earth around the sun is accelerated motion due to its orbital and rotational motion. However, due to negligibly small effects of rotation and orbital motion, the motion of earth may be assumed to be uniform and hence a frame of reference fixed to it may be regarded as inertial frame of reference.

NON-INERTIAL FRAME OF REFERENCE

- An accelerating frame of reference is called a non-inertial frame of reference.
- Newton's laws of motion are not directly applicable in non inertial frames.

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

PSEUDO FORCE

- Those forces which do not actually act on the particles but appear to be acting on the particles due to accelerated motion of frame of reference, are called pseudo forces.
- Fictitious force = –(mass of a particle × acceleration of non-inertial frame of reference with respect to an inertial frame of reference)

Note : Pseudo force should be applied in non-inertial frames only.

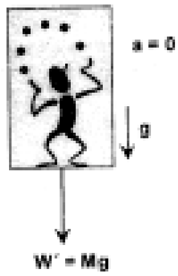
Examples :

- The additional force acting in rockets or lifts moving with accelerated velocity is pseudo force.
- If a body is placed on a rotating frame of reference (the frame of reference on earth), the coriolis and centrifugal forces appear to be acting due to rotation of frame of reference. They are not real forces but appear to be acting due to rotation of frame of reference. Therefore they are pseudo forces.

MOTION IN A LIFT

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

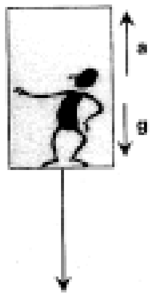
We consider the following cases :



Case (a) If the lift moving with constant velocity v upwards or downwards.

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

So apparent weight W' = Actual weight W.



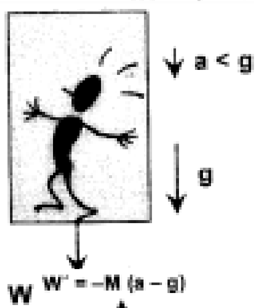
Case (b) If the lift accelerated (i.e. a = constant upwards acceleration) Then net force acting on the man are (i) weight W = Mg downward (ii) fictitious force F_0 = Ma downward

So apparent weight $W' = W + F_0$

or $W' = Mg + Ma$

$= M (g + a)$

Effective gravitational acceleration $g' = g + a$



Case (c) If the lift accelerated downward with accelertion a < g : Then ficitious force F_0 = Ma acts upward while weight of mass MW = Mg always acts downward, therefore

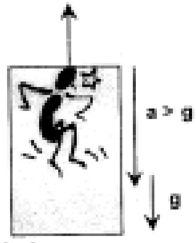
So apparent weight $W' = W + F_0$

or $W' = Mg - Ma = M (g - a)$

Effective graviational acceleration $g' = g - a$

Special case : If a = g then W' = 0 condition. of weightlessness

Thus, in a freely falling lift the man will experience weightlessness.



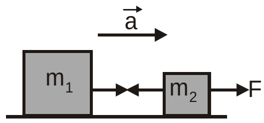
Case (d) If lift accelerates downward with acceleration a > g

Then as in Case (c)

Apparent weight $W' = M(g - a) = -M (a - g)$ is negative, i.e, the man will be accelerated upward and will stay at the ceiling of the lift.

MOTION OF BODIES CONNECTED TOGETHER BY STRINGS

(A) FOR TWO BODIES



Suppose two bodies of masses m_1 and m_2 are tied together and bodies are pulled by applying a force F on the body m_2.

If T is the tension produced in the string and 'a' is the acceleration produced in the system, then

$$\text{acceleration} = \frac{\text{force}}{\text{total mass}} = \frac{F}{(m_1 + m_2)}$$

Since acceleration is same for both bodies.

$\therefore$ For the body m_1,

$T = m_1 a$

For the body m_2

$F - T = m_2\, a$

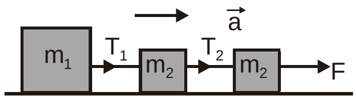
or $T = F - m_2 a = F - m_2 \dfrac{F}{(m_1 + m_2)}$

$\therefore$ Tension in the string

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

(B) FOR THREE BODIES

If three bodies of masses m_1 , m_2 and m_3 are tied by strings and pulled by a force F, the acceleration produced in the system



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

For the body of mass m_1,

$T_1 = m_1 a$

For the body of mass m_2,

$T_2 - T_1 = m_2 a$

For the body of mass m_3

$F - T_2 = m_3 a$

Solving these equations

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

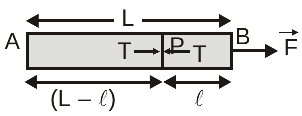
and $T_2 = \dfrac{(m_1 + m_2)\, F}{(m_1 + m_2 + m_3)}$

$= (m_1 + m_2)\, a$

ROPE LYING ON A HORIZONTAL SURFACE

A uniform rope of length L which is lying on a frictionless table is pulled by applying a constant force

Let the mass of the rope be m and its length be L. So the mass per unit length of the rope is (M/L)



If T is the tension in the rope at a distance ℓ from end B and acceleration of the rope is a, then for part PB

$$F - T = \text{mass of part PB} \times a = \frac{M}{L}\ell a$$

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For the part AP

$$T = \text{mass of part AP} \times a = \frac{M}{L}(L-\ell)a$$

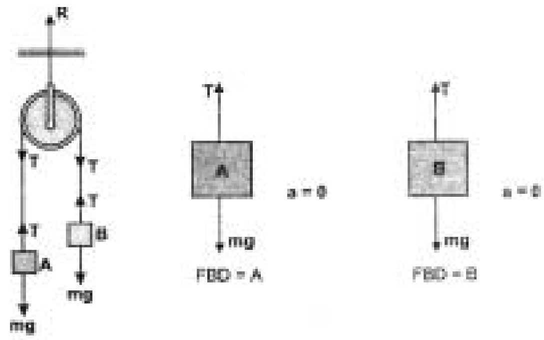
$$T = \frac{(L-\ell)}{\ell}(F-T)$$

or $$T = \left(1-\frac{\ell}{L}\right)F$$

PULLEY

A single fixed pulley changes the direction of force only and in general assumed to be massless and frictionless.

PULLEY-BLOCK PROBLEM



Case I

$m_1 = m_2 = m$

Tension in the string $T = mg$

Acceleration 'a' = zero

Reaction at the pulley

$R = 2T = 2mg$

[Strength of support or suspension]

Case II

$m_1 > m_2$

for mass m_1, $m_1g - T = m_1a$ ....(1)

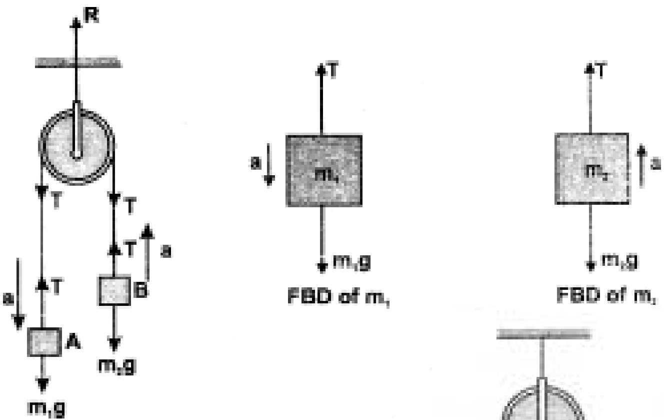
for mass m_2, $T - m_2g = m_2a$ ....(2)

Solving, we get

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

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

reaction at the pulley $R = 2T = \dfrac{4m_1m_2\,g}{(m_1+m_2)}$



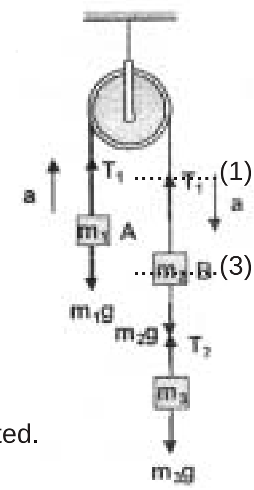
Case III

The forces acting on the system are shown in the fig.

For mass m_1 : $T_1 - m_1g = m_1a$ ....(1)

For mass m_2 : $m_2g + T_2 - T_1 = m_2a$ ....(2)

For mass m_3 : $m_3g - T_2 = m_3a$ ....(3)

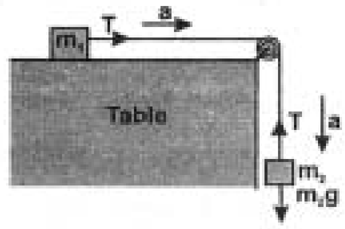


Solving these equations, we get $a = \left(\dfrac{m_2 + m_3 - m_1}{m_1 + m_2 + m_3}\right)g$

Putting the value of 'a' in equation (i) & (iii) tension, T_1 & T_2 can be calculated.

Case IV

(a) Without friction :



For mass m_1 : $T = m_1a$

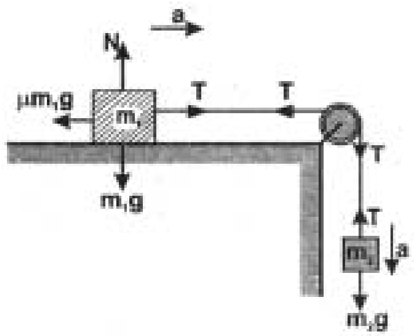
For mass m_2 : $m_2g - T = m_2a$

Solving, we get

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

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

(b) With friction :



(friction in between. surface and block)

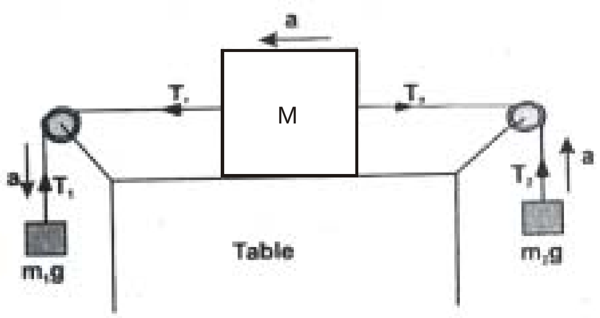
For mass m_1 : $T - \mu m_1g = m_1a$

For mass m_2 : $m_2g - T = m_2a$

Solving we get

Acceleration $a = \dfrac{(m_2 - \mu m_1)\, g}{(m_1+m_2)}$ or $T = \dfrac{m_1m_2(1+\mu)\, g}{(m_1+m_2)}$

Case V



($m_1 > m_2$)

$m_1g - T_1 = m_1a$ ....(1)

$T_2 - m_2g = m_2a$ ....(2)

$T_1 - T_2 = Ma$ ....(3)

Solving (i), (ii) and (iii), we get

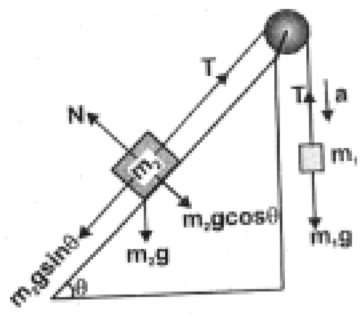
$$a = \frac{(m_1 - m_2)g}{(m_1+m_2+M)}$$

$$T_1 = m_1g\left[\frac{2m_2+M}{m_1+m_2+M}\right], \quad T_2 = m_2g\left[\frac{2m_1+M}{m_1+m_2+M}\right]$$

Case VI

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

(a) Without friction :



For m_1 : $m_1g - T = m_1a$

For m_2 : $T - m_2g\sin\theta = m_2a$

Solving, we get

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

$$T = \frac{m_1m_2(1+\sin\theta)g}{(m_1+m_2)}$$

(b) With friction :

For m_1 : $m_1g - T = m_1a$

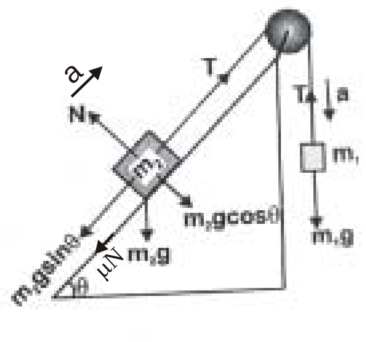
$N = m_2g \cos\theta$

$\mu N = \mu m_2 g \cos\theta$

For m_2 : $T - \mu m_2 g \cos\theta - m_2 g \sin\theta = m_2 a$

Acceleration $a = \left[\dfrac{m_1 - m_2(\sin\theta + \mu\cos\theta)}{m_1 + m_2}\right] g$

Tension $T = \dfrac{m_1 m_2[1 + \sin\theta + \mu\cos\theta]g}{(m_1 + m_2)}$

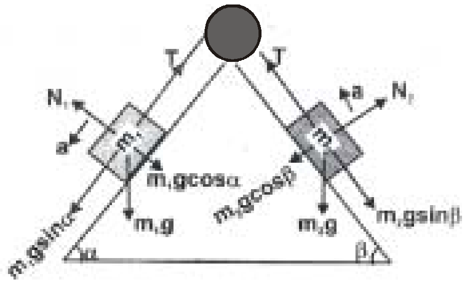


Case VII

Masses m_1 & m_2 are connected by a string passing over a pulley ($m_1 > m_2$)
For mass m_1 :
$m_1 g \sin\alpha - T = m_1 a$
For mass m_2 :
$T - m_2 g \sin\beta = m_2 a$

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

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

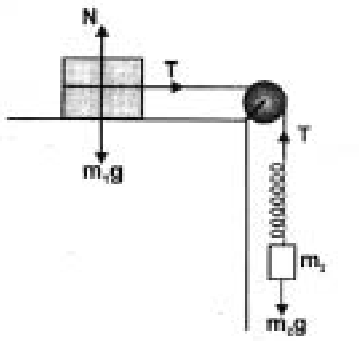


Case VIII

From case (IV-a) we know that the tension $T = \dfrac{m_1 m_2}{(m_1 + m_2)} g$

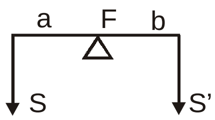
If x is the extension in the spring, then T = kx

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



CONDITION FOR BALANCE

Let S and S' be the weights of scale pans and a and b be the arms of the balance. As the beam remains horizontal when pans are empty, moments about fulcrum must be zero.



$\therefore\ Sa = S'\,b$ ......(1)

Suppose now that equal weights, W each, are put on the pans of the balance, the beam has to remain horizontal for balance to be true

$\therefore$ taking moments about F, we have

(S + W) a = (S' + W) b .....(2)

Using (1) or Wa = Wb or a = b i.e., arms of balance must be equal

Putting a = b, in equation (1)

We have S = S', weights of scale pans be equal

The method of Double weighing : The true weight of a body can be determined with the help of a false balance as follows :

(i) When arms are equal but weight of pans are unequal then the weight of body can be determined with the help of a false balance as follows :

Place the body having the true weight W in the lift pan & counter poise it with standard weights = W_1,

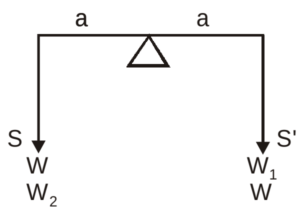
$\therefore$ (S + W) a = (S' + W_1)a or S + W = S' + W_1

S – S' = W_1 – W ....(1)

Now place the body in the right pan and counter poise it with standard weights = W_2

$\therefore$ (S + W_2) a = (S' + W) a or S + W_2 = S' + W

S – S' = W – W_2 ....(2)



equating R.H.S. of eq^n (1) and eq. (2)

$$W = \frac{W_1 + W_2}{2}$$

$\therefore$ true weight of body is equal to the arithmetic mean of the two apparent weights.

(ii) When the beam remains horizontal but neither arms are equal nor weights of scale pans are equal

$\therefore$ Sa = S'b ....(1)

Place the body with true weight W in the left arm and counter poise it with standard weights W_1

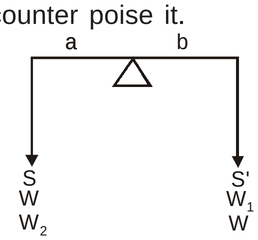
then (S + W)a = (S' + W_1)b

Using (1) we have Wa = W_1b ....(2)

Now put the body in right pan and standard weights W_2 in the left arm to counter poise it.

(S + W_2) a = (S' + W) b

using (1) we have W_2a = Wb or Wb = W_2a ....(3)



Multiply eq^n. (2) and eq^n. (3), we have

W^2 ab = W_1 W_2 ab or $W = \sqrt{W_1 W_2}$

Thus the true weight of the body in this case is the geometric mean of the two apparent weights.

FRICTION

When the surface of a body slides over surface of another body, each body exerts a force of friction on the other. Such friction is parallel to the surface. The force of friction on each body is in a direction opposite to its motion relative to the other body.

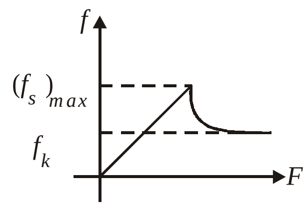
It is a self adjusting force, it can adjust its magnitude to any value between zero and the limiting (maximum) value.

i.e. $0 \le f \le f_{max}$

The friction force acting between any two surfaces at rest with respect to each other is called the force of static friction.

The frictional force acting between surfaces when there is relative motion with respect to each other, is called the force of kinetic friction or sliding friction.

LAWS OF FRICTION



The limiting force of friction is proportional to the normal force that keeps two surface in contact with each other, and is independent of the area of contact and the relative velocities between the two surfaces in contact.

i.e. $f_{max} = \mu N$

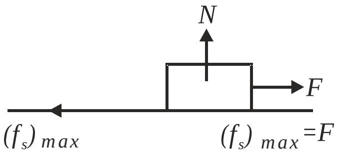
PROPERTIES OF FRICTION

1. If the body is at rest, the static frictional force f_s and the external force F parallel to the surface are equal in magnitude; and f_s is directed opposite to F. If the external force F increases f_s increases.
2. The maximum value of static friction is given by

$$\left(f_s\right)_{\max} = \mu_s N$$

Where, $\mu_s =$ coefficient of static friction.

N= normal reaction.



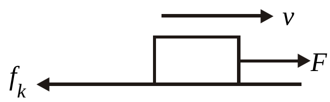
At this condition, the body is just about to move relative to the surface.

3. If external force exceeds $\left(f_s\right)_{\max}$, then the body slides on the surface.

Now frictional force rapidly decreases to a constant value given by

$$f_k = \mu_k N$$

Where μ_k is the co-efficient of kinetic friction.

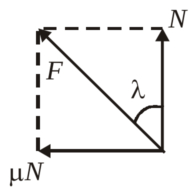


ANGLE OF FRICTION

At a point of rough contact, where slipping is about to occur, the two forces acting on each object are the normal reaction N and frictional force μN. The resultant of these two forces is F and it makes an angle λ with the normal where,

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

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



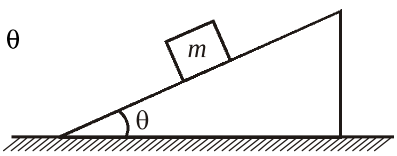
This angle λ is called the angle of friction.

ANGLE OF REPOSE

Suppose a block of mass m is placed on an inclined plane whose inclination θ can be increased or decreased. Let μ be the co-efficient of friction between the block and the plane. At a general angle θ, Normal Reaction is

$$N = mg\cos\theta$$

Limiting friction $\left(f_s\right) = \mu N = \mu mg\cos\theta$



and the pulling force,

$$F = mg\sin\theta$$

There is a critical value of angle θ, called angle of repose (α) at which pulling force and limiting friction are equal. Now if θ is further increased, the pulling force becomes more than the limiting friction f_s and the block starts sliding.

Thus, $\qquad \left(f_s\right)_{\max} = F \qquad$ at $\qquad \theta = \alpha$

$$\Rightarrow \quad \mu mg\cos\alpha = mg\sin\alpha$$

$$\Rightarrow \quad \mu = \tan\alpha$$

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$\Rightarrow \quad \alpha = \tan^{-1}(\mu)$

Here, we see that angle of friction (λ) is numerically equal to the angle of repose.

i.e. $\quad \lambda = \alpha$

POINTS TO REMEMBER

- A system is said to be isolated, when no external forces are acting on the system. For such a system, linear momentum remains constant.
- No external force is required to move a body uniformly, provided there is no friction. External force is required to stop a moving body; to change the speed of the body and also to change the direction of motion of the body.
- For a body of mass m, moving with velocity $\vec{v}$, its momentum $\vec{p} = m\vec{v}$. As m is constant during motion, we can write, force $\vec{F} = m\frac{d\vec{v}}{dt} = m\vec{a}$, where $\vec{a}$ is the instantaneous acceleration.
- When a body moves with high velocity, very near to the velocity of light, m varies considerably with velocity. In such a case, we can not write $\vec{F} = m\vec{a}$, but the relation $\vec{F} = \frac{d\vec{p}}{dt}$ is valid.
- To find the acceleration of the body, note all the forces acting on a body under consideration and then find the vector sum of all the forces $\vec{F}$ and finally use $\vec{F} = m\vec{a}$.
- If a body is in equilibrium, then it does not mean that no force acts on the body, but it simply means that the net force (resultant of any number of forces) acting on the body is zero. Further, for equilibrium, a body need not necesarily be at rest. A body in uniform motion along a straight line is also in equilibrium.
- An accelerated motion of a body is always due to a force. It can occur in two ways.

  (i) **Due to change in its speed only** : In this situation, the force must act on the body either in the direction of its motion or opposite to its direction of motion.

  (ii) **Due to change in direction only** : In this situation, the force must act perpendicular to the direction of motion of the body. Such a force makes the body move along a circular path.
- Action and Reaction are always equal and opposite and act on two different bodies.
- The forces of interaction between bodies forming a system are called internal forces. The resultant of internal forces is zero due to action and reaction. These forces do not cause any motion in the system.

  The forces exerted on bodies of a given system by bodies situated outside are called external forces.

  The external forces cause the motion or change in the system.
- The coefficient of limiting friction is slightly greater than the coefficient of kinetic friction.

SOLVED EXAMPLES

Example - 1 The position x of a body of mass 2 kg varies with time t as

$x = (2t^2 + 3t - 4)$ m

Force acting on the body is -

(1) 4N (2) 8N

(3) 2N (4) 16 N

Solution : $x = (2t^2 + 3t - 4)$ m

Velocity $v = \frac{dx}{dt} = (4t + 3)$ m/s

Acceleration $f = \frac{d^2x}{dt^2} = 4$ m/s^2

Force = mass × acceleration

= 2 × 4 = 8N

Answer is (2)

Example - 2 A body of mass 2kg moving with a speed of 100 m/s hits a wall and rebounds with the same speed. If the contact time is (1/50)s, the force applied on the wall is

(1) 10^4N (2) 2×10^4 N

(3) 4N (4) 8N

Solution : Initial momentum of the body = mv

= 2 × 100 = 200 N-s

Final momentum = –200 N-s

Change of momentum of the body

= –200 – (200) = – 400 m/s

Momentum given to the wall = +400 N-s

Time = $\frac{1}{50}$ s

∴ Momentum given per second

$\frac{400}{1/50} = 2\times10^4$N = Force applied on the wall

Answer is (2)

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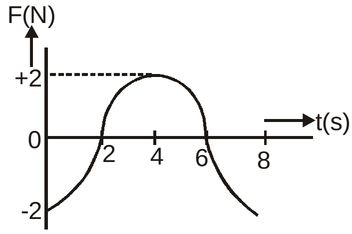
Example - 3 For a motion in a straight line the force-time graph is shown in figure. The parts of the curve are circular. The momentum gained in the time interval t = 0 to t = 8s, in N-s will be



(1) zero (2) 4π

(3) -2π (4) 6π

Solution : The total momentum gained = $\int_{t_1}^{t_2} F dt$

= Area between F-t curve and time axis.

= zero, because the area in negative direction is equal to the area in positive direction.

Answer is (1)

Example - 4 A cricket ball of mass 150 gm moves at a speed of 12 m/s and after hitting by the bat it is deflected back at the speed of 20 m/sec. If the bat and the ball remained in contact for 0.02 sec then calculate the impulse and average force exerted on the ball by the bat. [Assume the ball always moves normal to the bat].

Solution : According to the problem the change in momentum of the ball

$\Delta p = p_f - p_i = m\ (v - u) = 150 \times 10^{-3}\ [20 - (-12)] = 4.8$

$\therefore$ impulse = change in momentum = **4.8 N-s**

and $F_{av} = \frac{\Delta p}{\Delta t} = \frac{4.80}{0.02}$ = **240 N**

Example - 5 A cricket ball is deflected by a batsman at 45º without changing its speed which is 54 km/hr. If the mass of the ball is 0.15 kg, then what is the impulse given to ball?

Solution : Initial momentum $\vec{p_i}$ in component form is $\vec{p_i} = \hat{i}$ (mu sin 22.5) $-\hat{j}$ (mu cos 22.5º)

Similarly the final momentum is $\vec{p_f} = \hat{i}$ (mu sin 22.5) $+\hat{j}$ (mu cos 22.5º)

$\therefore\ \vec{p_f} - \vec{p_i}$ = (2 mu cos 22.5º) $\hat{i}$

So the magnitude of impulse $= |\vec{p_f} - \vec{p_i}|$

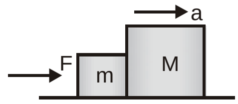
$= 2 \times 0.15 \times \frac{54 \times 10^3}{3600} \times \cos 22.5^o = 4.15$ N

Example - 6 Two blocks of mass m = 2kg and M = 5kg are in contact on a frictionless table. A horizontal force F = (35 N) is applied to m. Find the force of contact between the block, will the force of contact remain same if F is applied to m ?

Solution : As the blocks are rigid under the action of a force F, both will move with same acceleration

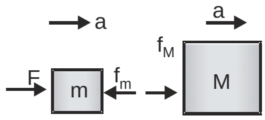
$a = \frac{F}{m+M} = \frac{35}{2+5} = 5\ m/sec^2$

Now as the mass of larger block is M and its acceleration a,



so force of contact = action on it

or $f_m = Ma = 5 \times 5 = 25$ N



If the force is applied to M then its action on m will be

$f_m = ma = 2 \times 5 = 10$ N

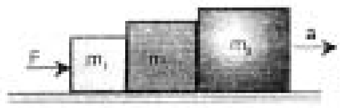
From this problem, it is clear that acceleration does not depends on the fact that whether the force is applied to m or M, but force of contact does.

Example - 7 Three blocks of masses $m_1 = 1$ kg, $m_2 = 1.5$ kg and $m_3 =$ 2kg are in contact with each other on a friction less surface as shown in fig. find (a) horizontal force F needed to push the block as on unit with an acceleration of 4 m/sec^2 (b) The resultant force on each block and (c) The magnitude of contact force between blocks.

Solution : (a) $F = (m_1 + m_2 + m_3)\,a$

or $F = (1 + 1.5 + 2) \times 4$

$= 4.5 \times 4 = 18$ N



(b) for m_1 resultant force $F - f_1 = m_1 a$

$= 1 \times 4$

or $F - f_1 = 4$N .... (1)

for m_2 resultant force $f_1 - f_2 = m_2\,a$

or $= 1.5 \times 4 = 6$

or $f_1 - f_2 = 6$N ....(2)

and resultant force on m_3, $f_2 = m_3 a$

$= 2 \times 4$

or $f_2 = 8$ N ......(3)

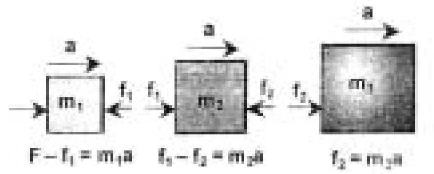


Fig. Free body diagrams for m_1, m_2 and m_3

f_1 = contact force bet^n. m_1 and m_2

f_2 = contact force bet^n. m_2 and m_3

(c) Contact force between, m_2 and $m_3 = f_2 = 8$N

from equation (2) and equation (3)

$f_1 = f_2 + 6 = 8 + 6 = 14$N

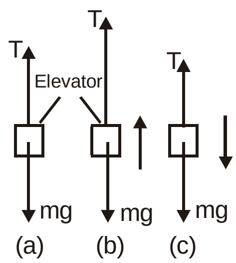
Example - 8 The mass of an elevator (lift) is 500 kg. Calculate the tension in the cable of the elevator when the elevator is (i) stationary, (ii) ascending with an acceleration of 2.0 ms^{-2}, (iii) descending with the same acceleration. (g = 9.8 N kg^{-1})

Solution : The gravity - force on the elevator is mg = 500 × 9.8 = 4900 N

When the elevator is stationary (acceleration is zero), the net force on it will be zero (fig.a) that is,

$T - mg = 0$

or $T = mg = 4900$ N



When the elevator is accelerated upward, the net force on it will be in the upward direction. Therefore, the tension T will be greater than the gravity force mg (fig.b). According to Newton's second law, the net force (T – mg) will be equal to mass m × acceleration a. That is,

$T - mg = ma$

or $T = mg + ma = 4900 + 500 \times 2.0 = 5900$ N

When the elevator is accelerated downward, net force will be in the downward direction and the tension T will be less than mg (fig.c) Again by Newton's law, we have

$mg - T = ma$

or $T = mg - ma = 4900 - 500 \times 2.0 = 3900$ N

Example - 9 An elevator and its load weight a total of 1600 ℓb. Find the tension T in the supporting cable when the elevator, originally moving downward at 20 fts^{-1} is brought to rest with constant acceleration in a distance of 50 ft.

Solution : The elevator moving downward stops after a distance of 50 ft. Therefore, by the formula $v^2 = u^2 + 2as$,

we have

$0^2 = 20^2 + 2a \times 50$

$\therefore \quad a = -4 \text{ft s}^{-2}$

Let T be the tension in the cable. Then, we have

$T = m(g - a)$

Here m = 1600 ℓb. In FPS system, $g = 32 \text{ ft s}^{-2}$

$\therefore T = 1600\{32 - (-4)\} = 57600 \text{ poundals} = \frac{57600}{32} = 1800\ \ell\text{b. wt.}$

Example - 10 A lift of mass 2000 kg is supported by thick steel ropes. If the maximum upward acceleration of the lift be 1.2 ms^{-2} and the breaking stress for the ropes be 2.8×10^8 N m^{-2}, what should be the minimum diameter of the ropes? ($g = 9.8\ ms^{-2}$)

Solution : When the lift is accelerated upward, the tension T in the rope is greater than the gravity-force mg. If the acceleration of the lift be a, then by Newton's law, we have

$T - mg = ma$

or $T = mg + ma = m(g + a)$

Mass of the lift m = 2000 kg and maximum acceleration a = 1.2 ms^{-2}. Hence maximum tension in the rope is

$T = 2000(9.8 + 1.2) = 22,000$ N.

If r be the radius of the rope, then the stress will be $T/\pi r^2$

$\therefore \frac{T}{\pi r^2} = 2.8 \times 10^8\ Nm^{-2}$ (given)

or $r^2 = \frac{T}{\pi \times (2.8 \times 10^8)} = \frac{22000}{(22/7) \times (2.8 \times 10^8)} = \frac{1}{4 \times 10^4}$

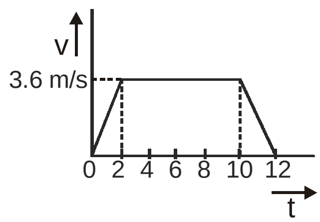
$\therefore \quad r = \frac{1}{200} = 0.005$ m.

Example - 11 A lift is going up, the total mass of the lift and the passenger is 1500 kg. The variation in speed of lift is as shown in fig. What will be the tension in the rope pulling the lift at (i) 1 sec, (ii) 6 sec, (iii) 11 sec.

Solution : A slope of v – t curve gives acceleration

$\therefore$ At, t = 1 sec

$a = \frac{3.6 - 0}{2} = 1.8\ m/s^2$



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lift is moving up

$\therefore$ T = m (g + a) = 1500 (9.8 + 1.8) = 17400 N

at t = 6 sec a = 0

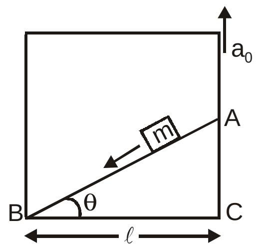
$\therefore$ T = mg = 1500 × 9.8 = 14700 N

at t = 11 sec a = $\frac{0-3.6}{2}$ = –1.8 m/s^2 lift is moving down.

$\therefore$ T = mg (g – a) = 1500 (9.8 – 1.8) = 12000 N

Example - 12 A lift is moving upwards with acceleration a_0. An inclined plane is placed in this lift. What is the time taken by a body of mass m in sliding down from the top of this plane to the bottom (If length of the base of the plane is ℓ and angle is θ)

Solution : As the lift is moving up so the apparent weight of the body is m (g + a_0) and its component along the plane is m (g + a_0) sin θ due to which the acceleration down the plane is (g + a_0) sin θ



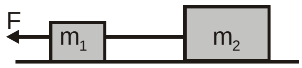
length of inclined plane AB = $\ell/\cos\theta$ using

s = ut + $\frac{1}{2}$ at^2 and u = 0, a = (g + a_0) sin θ

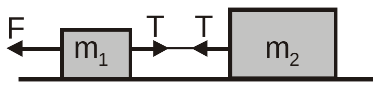
$$\frac{\ell}{\cos\theta} = \frac{1}{2}(g + a_0)\sin\theta\, t^2$$

$$\therefore \quad t = \sqrt{\frac{2\ell}{(g+a_0)\sin\theta\cos\theta}}$$

Example - 13 Two bodies whose masses are m_1 = 50 kg and m_2 = 150 kg are tied by a light string and are placed on a friction less horizontal surface. When m_1 is pulled by a force F, an acceleration of 5 ms^{-2}is produced in both the bodies. Calculate the value of F. What is the tension in the string?



Solution : The force F is pulling both the bodies together. Hence if the acceleration produced in the direction of force be a, then by newton's law of motion, we have



(net) force = mass × acceleration

F = (m_1 + m_2) × a = (50 + 150) × 5 ms^{-2} = 1000 N

To determine the tension in the string, we have to consider the force acting on the bodies separately. When m_1 is pulled by the force F, then m_1 pulls m_2 through the string by a force T. This force is the tension in the string which acts on m_2 in the forward direction (see fig) m_2 also pulls m_1 by the same (reactionary) force T. Hence the tension T of the string acts on m_1 in the backward direction.

Thus, a 'net' force F – T acts on m_1 in the forward direction. Hence,by Newton's law applied for m_1 alone, we have

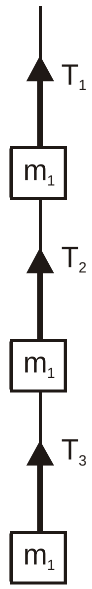
F – T = m_1a

or T = F – m_1 a = 1000 – (50 × 5) = **750 N**

We can determine T also by applying Newton's law for the motion of m_2 alone. On m_2 there is a net force T in the forward direction

$\therefore$ $T = m_2 a = 150 \times 5 = 750$ N

Example - 14 The masses m_1, m_2 and m_3 of the three bodies shown in fig. are 5, 2, 3 kg respectively. Calculate the values of the tension T_1, T_2 and T_3 when (a) the whole system is going upward with an accelerating of $2ms^{-2}$, (b) the whole system is stationary ($g = 9.8$ ms^{-2})



Solution : (a) All the three bodies m_1, m_2 and m_3 are moving upward together. The force pulling the system upward is T_1 and the downward gravity-force is $(m_1 + m_2 + m_3)$ g. Hence the net force on the system is $T_1 - (m_1 + m_2 + m_3)$ g. According to Newton's second law, this force is equal to total mass × acceleration. If a be the acceleration of the system in the upward direction, then

$$T_1 = (m_1 + m_2 + m_3)\ g = (m_1 + m_2 + m_3)\ a$$

or $$T_1 - (5 + 2 + 3) \times 9.8 = (5 + 2 + 3) \times 2$$

$\therefore$ $$T_1 = 20 + 98 = 118 \text{ N}$$

The force pulling m_2 and m_3 in the upward direction is T_2 and the gravity-force on them is $(m_2 + m_3)$ g. Hence the net force in the upward direction is $T_2 - (m_2 + m_3)$ g . Again, by Netwon's law, we have

$$T_2 - (m_2 + m_3)\ g = (m_2 + m_3)g$$

$$T_2 - (2 + 3) \times 9.8 = (2 + 3) \times 2$$

$$T_2 = 10 + 49 = 59 \text{ N}$$

The net force on m_3 in the upward direction is $T_3 - m_3g$.

Hence by Newton's law, we have

$$T_3 - m_3g = m_3a$$

or $$T_3 - 3 \times 9.8 = 3 \times 2$$

$\therefore$ $$T_3 = 6.0 + 29.4 = 35.4 \text{ N}$$

(b) If the whole system is stationary (or moving with uniform velocity), then a = 0. Hence from equation. (i), (ii) and (iii), we have

$$T_1 = (m_1 + m_2 + m_3)\ g = 10 \times 9.8 = 98 \text{ N}$$

$$T_2 = (m_2 + m_3)\ g = 5 \times 9.8 = 49 \text{ N}$$

$$T_3 = m_3\ g = 3 \times 9.8 = 29.4 \text{ N}$$

Example - 15 Two blocks of masses 2.9 kg and 1.9 kg are suspended from a rigid support S by two inextensible wires each of length 1 m. The upper wire has negligible mass and the lower wire has a uniform mass of 0.2 kg m^{-1}. The whole system of blocks, wires and support have an upward acceleration of 0.2 ms^{-2}. Acceleration due to gravity is 9.8 ms^{-2}. (i) Find the tension at the mid-point of the lower wire. (ii) Find the tension at the mid-point of the upper wire.

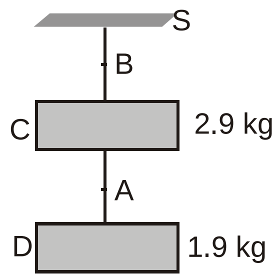
Solution : Suppose, the tension at the point A is T_A. Then

$$T_A - mg = ma$$

or $$T_A = m\ (a + g)$$

where m = 1.9 kg + mass of the wire of length

$$AD = 1.9 + \frac{1}{2} \times 0.2 = 2.0 \text{ kg}$$



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$\therefore \quad T_A = 2.0 \times (0.2 + 9.8) = 20$ N

(ii) Suppose, the tension at the point B is T_B, then

$T_B = M(a + g)$

where M = 2.9 kg + 1.9 kg + mass of the wire CD = 2.9 + 1.9 + 0.2 = 5.0 kg

$\therefore \; T_B = 5.0 \times (0.2 + 9.8) = 50$ N

Example - A bucket of mass 25kg is raised by a 50 kg man in two different ways as shown in fig. What is the action on the floor by the man in the two cases? If the floor yields to a normal force of 700 N, which mode should the man adopt to lift the bucket without the floor yielding?

Solution : Here, mass of the bucket, m = 25 kg

mass of the man, M = 50 kg

Force applied to lift the bucket, F = mg = 25 × 9.8 = 245 N

Weight of the man, Mg = 50 × 9.8 = 490 N

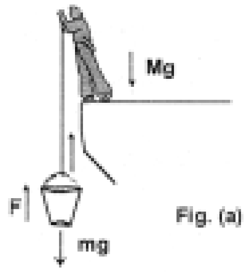


Fig. (a)

fig (a) When the bucket is raised by the man by applying force F in upward direction, reaction equal and opposite to F will act on the floor in addition to the weight of the man.

Therefore, action on the floor = Mg + F = 490 + 245 = 735 N

Since the floor yields to a normal force of 700 N, So man should not adopt this mode to lift the bucket

Fig. (b) When the bucket is raised by the man by appling force F over the rope (passed over the pulley) in downward direction, reaction equal and opposite to F will act on the floor.

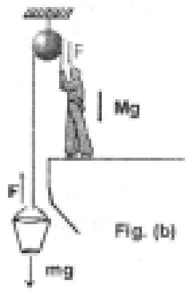
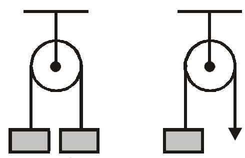


Fig. (b)

Therefore, action on the floor = Mg – F = 490 – 245 = 245 N

The mode (b) should be adopted by the man to lift the bucket.

Example - 17 The pulley arrangement of figures (a) and (b) are indentical. The mass of the rope is negligible. In figure (a) the mass m is lifted by attaching a mass 2 m to the other end of the rope. In figure (b) mass m is lifted up by pulling the other end of the rope with a constant downward force F = 2mg.
The ratio of acceleration in the two cases will be



(1) 1 : 1 (2) 1 : 3

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

Solution : Let in the case shown in figure (a), then tension in the string be T and acceleration produced is a, then

$T - mg = ma$ ....(1)

and $2mg - T = 2ma$ ....(2)

From equation (1) and (2)

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

Let in the case shown in figure (b), the tension in the string be T' and acceleration be a', then

$T' - mg = ma'$ ....(3)

$T' - 2mg = 0$ ....(4)

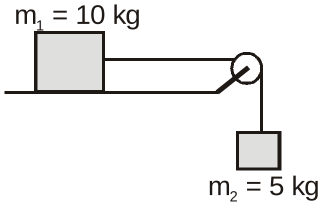
from equation (3) and (4)

$a' = g$

$\therefore \quad \frac{a}{a'} = \frac{g/3}{g} = \frac{1}{3}$

$\therefore$ Answer is (2)

Example - 18 A body of mass 10 kg is placed on a horizontal smooth table. A string is tied with it which passes over a frictionless pulley. The other end of the string is tied with a body of mass 5 kg. When the bodies move, the acceleration produced in them, is



(1) 9.8 m/s^2 (2) 4.8 m/s^2

(3) 4.25 m/s^2 (4) 3.27 m/s^2

Solution : Due to gravitational force 5g acting on the body of mass 5kg. both bodies move. Let the acceleration produced in the system be a, then

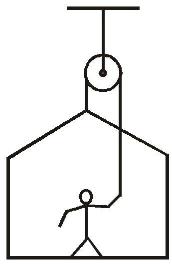
$m_2 g = (m_1 + m_2)\, a$

$$a = \frac{m_2 g}{(m_1 + m_2)} = \frac{5g}{(5+10)} = \frac{g}{3} = \frac{9.8}{3}$$

$= 3.27 \ m/s^2$

$\therefore$ Answer is (4)

Example - 19 The following figure shows a painter in a platform suspended along the building. When the painter pulls the rope the force exerted on the floor is 450 N while the weight of the painter is 1000N. If the weight of the platform is 250 N, the acceleration produced in the platform will be ($g = 10 \ m/s^2$)



(1) 4 m/s^2 (2) 2 m/s^2

(3) 5 m/s^2 (4) 6 m/s^2

Solution : Let the acceleration be a and mass of the painter $\frac{1000}{10}$ = 100 kg. If the pull applied to the rope by the painter is F, then the rope will also apply same amount of force. From Newton's law

$F + 450 - 1000 = 100a$

or $F - 550 = 100a$ ....(1)

Mass of platform = $\frac{250}{10}$ = 25 kg

$\therefore \quad F - 450 - 250 = 25\,a$

or $F - 700 = 25a$

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from equation (1) and (2)

$a = 2 m/s^2$

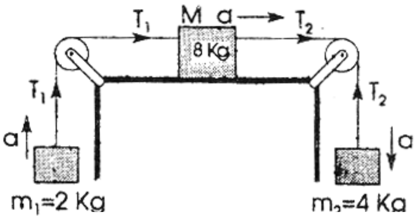
$\therefore$ Answer is (2)

Example - 20 In the following figure, if the table and pulley are frictionless and strings are weightless, then the acceleration of the system will be -

(1) $3.2\ m/s^2$ (2) $2.5\ m/s^2$

(3) $1.8\ m/s^2$ (4) $1.4\ m/s^2$

Solution : From the figure,



$m_2g - T_2 = m_2a$ ....(1)

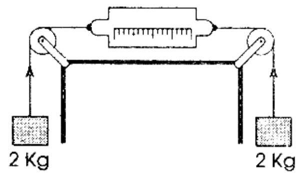
$T_1 - m_1g = m_1a$ ....(2)

or $T_2 - T_1 = Ma$ ....(3)

solving (1) , (2) and (3)

$a = 1.4\ m/s^2$

Example - 21 Two 2kg weights are suspended from a spring balance as shown in figure. The reading in the scale of the spring balance will be -



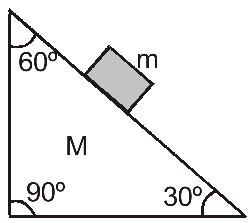
(1) zero (2) 4 kg-wt

(3) 2 kg-wt (4) 1 kg-wt

Solution : Spring balance is rest therefore tensions will be same in both strings. Let it be T. Since the weights are also at rest. So T = 2g = 2kg-wt. Here one weight, acts as a support of another weight.

$\therefore$ Answer is (3)

Example - 22 A triangular block of mass M with angles 30º, 60º and 90º rests with its 30º – 90º side on a horizontal smooth table. A cubical block of mass m is placed on 30º – 60º side of the block. With what acceleration should M be moved relative to stationary table so that the mass m remains stationary relative to the triangular block?



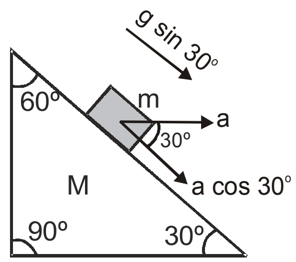
(1) $5.66\ m/s^2$ (2) $4.32\ m/s^2$

(3) $9.8\ m/s^2$ (4) $4.9\ m/s^2$

Solution : Acceleration of the block of mass m along the inclined plane in downward direction

$= g \sin\theta = g \sin 30^\circ$

If the block m is to remain stationary, then



$g \sin 30^\circ = a \cos 30^\circ$

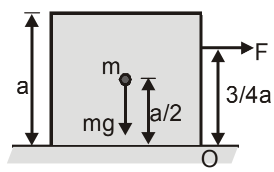
or $a = g\dfrac{\sin 30^\circ}{\cos 30^\circ} = g \tan 30^\circ$

$= 9.8 \times \dfrac{1}{\sqrt{3}} = \dfrac{9.8}{1.732}$

$= 5.66\ m/s^2$

$\therefore$ Answer is (1)

Example - 23 A cube having mass m and side a is placed on horizontal surface as shown in the figure. A horizontal force F is acting perpendicular to one of the surface, the force is at a point at a height of 3a/4 from the base. The minimum force required that the cube turns about one of its edges is



(1) (3/2) mg (2) mg

(3) (2/3) mg (4) 3/4 mg

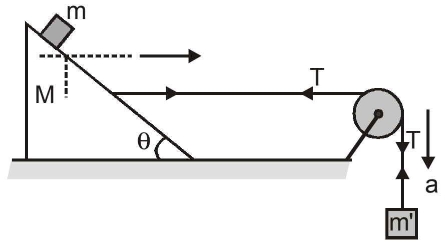
Solution : The cube will turn about an edge O if the torque at O satisfies the following condition

$$F\ (3/4)\ a > mg\ a/2 \text{ or } \quad F > \frac{2}{3}\ mg$$

$\therefore$ F minimum = (2/3) mg

Hence the answer is (3)

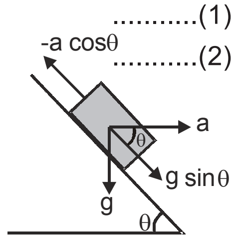
Example - 24 What should be the value of m' (mass of suspended block) so as to prevent the smaller block m from sliding over the triangular block of mass M. All surfaces are friction less and the string and pulley are light.



(1) $m' = \dfrac{m+M}{\cot\theta - 1}$ (2) $m' = \dfrac{\cot\theta - 1}{m+M}$

(3) $m' = \dfrac{m+M}{\tan\theta - 1}$ (4) $m' = \dfrac{M-m}{\cot\theta - 1}$

Solution : Writing force equations



$m'a = m'g - T$ ....(1)

$T = (m + M)\ a$ ....(2)

$m'\ a = m'g - (m + M)\ a$

$\therefore \quad a\ (m' + m + M) = m'g$

or $\quad a = a = \dfrac{m'g}{m'+m+M}$ ....(3)

For the block having mass m, not to slide it is necessary that $a \cos\theta = g \sin\theta$

$$\frac{m'g}{m'+m+M}\cos\theta = g\sin\theta$$

$\therefore \quad m' = (m' + m + M) \tan\theta$

or $\quad m'\ (1 - \tan\theta) = (m + M) \tan\theta$

$$m' = \frac{(m+M)\tan\theta}{1-\tan\theta} = \frac{m+M}{\cot\theta - 1}$$

Hence the answer is (1)

Example - 25 A mass of 400 kg is suspended by two ropes from points A and B on the roof and the wall. The tension in rope OA is .

(1) 200 kg weight (2) 300 kg weight
(3) 400 kg weight (4) 600 kg weight

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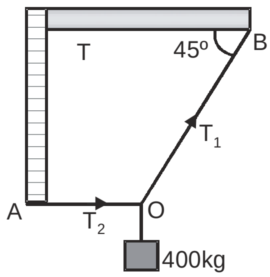
Solution : On resolving tension T_1, the horizontal and vertical components for T_1 are



$T_1 \sin 45^o = Mg = 400 \times g$

and $T_1 \cos 45^o = T_2$

$$\tan 45^o = \frac{400 \times g}{T_2}$$

$\therefore \quad T_2 = 400\text{ g} \quad = 400\text{ kg wt.}$

Hence the answer is (3)

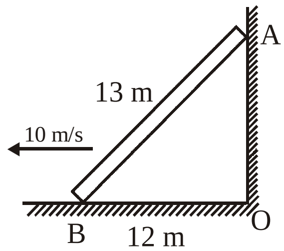
Example - 26 A rod AB whose length is 13m rests on two perpendicular surfaces as shown in the figure and starts sliding. At a particular time end B is at a distance of 12 m from vertical surface and its velocity is 10 m/s. What is the velocity of A at this time :

(1) 10 m/s (upwards) (2) 24 m/s (upwards)

(3) 24 m/s (downwards) (4) 10 m/s (horizontal)

Solution : If length of rod is ℓ and at any time the coordinates of A and B are (0, y) and (x, 0) then $\ell^2 = x^2 + y^2$ now when Differentiating with respect to time

$$0 = 2x\frac{dx}{dt} + 2y\frac{dy}{dt}$$



$$\therefore \quad \frac{dy}{dt} = -\frac{x}{y}\frac{dx}{dt}$$

or $\left(\frac{dy}{dt}\right) = V_A \; , \frac{dx}{dt} = V_B$

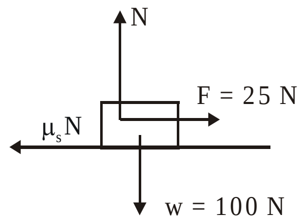
$$V_A = -\frac{x}{y}V_B$$

or $V_B = 10$ m/s, $x = 12$ and $y = 5$

$V_A = -12/5 \times 10 = -24$ m/s negative (–) sign indicates that velocity V_A is downwards,

Hence the answer is (3)

Example - 27 A block of weight 100 N lying on a horizontal surface just begins to move when a horizontal force of 25 N acts on it. Determine the coefficient of static friction.



Solution :

As the 25 N force brings the block the point of sliding, the frictional force = $\mu_s N$.

from free body diagram : $N = 100$

$$\mu_s N = 25 \Rightarrow \mu_s = 0.25$$

Example - 28 *A* 5 kg block slides down a plane inclined at 30^o to the horizontal. Find

(a) the acceleration of the block if the plane is frictionless

(b) the acceleration if the coefficient of kinetic friction is 0.2.

Solution :

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(a) The only force causing acceleration is mg sin30°

mg sin 30° = ma
a = g sin 30°,

a = g/2 $\Rightarrow$ 4.9 m/s^2

(b) Here friction force (μN) acts opposite to mg sin30°

N = mg cos 30°

mg sin 30° $-\mu_k N$ = ma

a = g sin 30° - $-\mu_k g \cos 30°$

a = 3.20 m/s^2

Example - 29 Find the time required by a block to come to rest from a speed of 10 m/s moving on a horizontal surface where $\mu_k = 0.2$. What is the distance covered before stopping ?

Solution : If the block is moving towards right and slowing down, the force of friction and hence acceleration is directed towards left.

$$a = \frac{\text{force}}{\text{mass}} = -\frac{\mu mg}{m} = -\mu g$$

Now $u = 10\ m/s,\ v = 0$

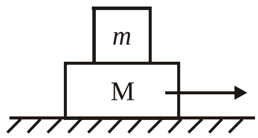
$v = u + at$

$0 = 10 - \mu_k gt$

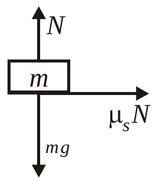
Let displacement = s

$$s = \frac{v^2 - u^2}{2a} = \frac{0^2 - 10^2}{2(-\mu g)} = 25.5m$$

Example - 30 A block of mass m is placed on another block of mass M lying on a smooth horizontal surface. The coefficient of static friction between m and M is μ_s. What is the maximum force that can be applied to M so that the blocks remain at rest relative to each other ?



Solution : Draw the free body diagrams of blocks at the moment when F is at its maximum value and *m* is just about to slide relative to M.



Frictional force between m and M = $\mu_s N$

(*N* = normal reaction between the blocks)

Due to the friction force, M will try to drag m towards right and hence frictional force will act on m towards right.

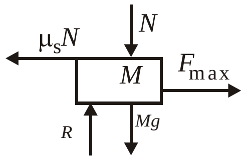
Let a = acceleration of each block (as they move together)
R = normal reaction between M and surface.

From free body diagram of m :

N = mg

$\mu_s N$ = ma ...(i)

From free body diagram of M :



N + Mg = R

$F_{\max} - \mu_s N = Ma$ ...(ii)

Combining these two equations(i) and (ii), we get

$F_{\max} = \mu_s (m + \mathrm{M}) g$

Hence, $\mu_s (m + \mathrm{M}) g$ is the critical value of force F.

If F is greater than this critical value, m begins to slip relative to M and their accelerations will be different.

If F is smaller than this critical value, *m* and M move together, with same acceleration, i.e. without any relative motion.

EXERCISES

LEVEL - I

1 Which of the following relations is wrong -

(1) $\vec{F} = m\frac{d\vec{r}}{dt}$ (2) $\vec{F} = m\frac{d^2r}{dt^2}$

(3) $\vec{F} = m\frac{d\vec{v}}{dt}$ (4) $F = \frac{m(v-u)}{t}$

2 A passenger in a uniformly moving train throws a ball upwards. The ball will return -

(1) in the passenger's hand (2) by the side of the passenger

(3) in front of the passenger in direction of motion

(4) Behind the passenger in the direction opposite to the motion of train

3 A force of 10 N is applied to a mass of 10gm for 10 seconds. The change of momentum in kgm/sec units will be-

(1) 10 (2) 100

(3) 1000 (4) 0.01

4 A ball moving with a velocity 20 m/sec has a mass of 50 gm. If collides against a wall normally and is rebounded normally with the same speed. If the time of impact of the ball and the wall is 40 milli seconds, the average force exerted on the wall in dynes is -

(1) zero (2) 1.25×10^7

(3) 2.5×10^7 (4) 5×10^6

5 A boy holds a hydrogen filled balloon with a string. He is sitting in a train moving with uniform velocity on a straight track. The string is vertical. On applying brakes the balloon will -

(1) be thrown forward (2) be thrown backward

(3) remain vertical (4) fall downwards

6 Which of the following statements is false -

(1) the mass of two bodies will be same if they exhibit same inertia

(2) the weight of a body at the centre of the earth is zero

(3) if a ball is thrown vertically upwards by a man sitting in a uniformly moving car, then the ball will fall behind the man

(4) the mass of a body remains constant at all places.

7 The correct statement in the following is -

(1) a body can have acceleration even if its velocity is zero

(2) if the velocity of the body be zero, it will necessarily have acceleration

(3) if the speed of a body is constant its acceleration also will be constant

(4) a body moving with a variable speed has zero acceleration

8 What will be the angle between two forces of equal magnitude, if the magnitude of resultant force is equal to any one of the two -

(1) 0^o (2) 60^o

(3) 90^o (4) 120^o

9 A beaker filled with liquid is placed in the pan of a spring balance. If you dip your finger in it, the reading of the balance will be -

(1) increased (2) unchanged

(3) decreased

(4) may increase or decrease according to the nature of liquid

10 A body of mass m is thrown vertically upwards with a velocity v,. It reaches to a height h and returns after t seconds. Then, the total change in its momentum is -

(1) zero (2) mv

(3) mgt (4) mght

11 A body is in equilibrium under the action of three forces on it. For this it is necessary that the three forces
(1) are in or should be in a straight line
(2) should pass through the same point and do not lie in the same plane
(3) should pass through the same point and lie in the same plane
(4) should be mutually perpendicular to each other and pass through a common point

12 Newton's third law of motion gives -
(1) definition of force (2) magnitude of force
(3) explanation of the force (4) none of these

13 Wrong relation is -
(1) $\vec{F} = m\vec{a}$ (2) $\vec{a} = d\vec{v}/dt$
(3) $\vec{F} = d\vec{p}/dt$ (4) $\vec{F} = m\vec{v}$

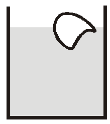
14 Newton's third law of motion implies that action and reaction are equal and opposite and -
(1) act on the same object
(2) act on two different objects under mutual inter actions
(3) act on two different objects, not inter acting mutually
(4) act only on different objects when they collide

15 A machine gun fires bullets of 50 gm at the speed of 1000 m/sec. If an average force of 200 N is exerted on the gunner, the maximum number of bullets fired per minute is -
(1) 240 (2) 120
(3) 60 (4) 30

16 The Newton's laws of motion are valid in -
(1) inertial frames (2) non-inertial frames
(3) rotating frames (4) accelerated frames

17 Swimming is possible owing to be -
(1) First law of motion (2) Second law of motion
(3) Third law of motion (4) Newton's law of gravitation

18 A body floats in liquid contained in beaker. If the whole system (shown in fig.) falls under gravity then the up-thrust on the body is -



(1) 2mg (2) zero
(3) mg (4) less than mg

19 Ratio of weight of a man in a stationary lift & weight of a man in a lift moving down-ward with an acceleration a is 3 : 2 then acceleration of lift is -
(1) g/3 (2) g/2
(3) g (4) 2g

20 A body of mass 2kg has an initial velocity of 3 m/s along OE and it is subjected to a foce of 4 newtons in a direction perpendicular to OE. The distance of body from O after 4 seconds will be -
(1) 12 metres (2) 20 metres
(3) 8 metres (4) 48 metres

21 When a horse pulls a cart then the force with which horse moves forward is applied by -
(1) cart on horse (2) earth on horse
(3) earth on cart (4) horse on earth

22 A ball of mass 200 gm moving with velocity of 20 m/s a player catches it. If time taken to catch the ball is 0.5 sec then force applied on players hands will be -
(1) 8N (2) 4N
(3) 2N (4) 0N

23 A lift is moving upwards with acceleration 3.675 m/s^2 then weight at a person will be -
(1) up to 37.5 % less (2) up to 37.5% more
(3) up to 17.5 % more (4) remain same

24 A man is at rest in the middle of a pond a perfectly smooth ice. He can get himself to the shore by making use of Newton's -
(1) first law (2) second law
(3) third law (4) all the laws

25 A body is suspended by a string connected on ceiling of a lift. When lift accelerates then tension in string found to be doubled then acceleration will be -
(1) 4.9 m/s^2 (2) 9.8 m/s^2
(3) 19.6 m/s^2 (4) 2.45 m/s^2

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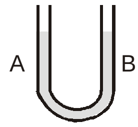
LEVEL - II

1 A block of mass M is pulled with a rope on a frictionless surface. If a force P is applied at the free end of the rope, the force exerted by the rope on the block will be (mass of rope is m) -

(1) $\frac{Pm}{(M+m)}$ (2) $\frac{PM}{(M+m)}$

(3) $\frac{P}{M-m}$ (4) $\frac{P}{M(M+m)}$

2 In a U-tube the liquid levels are equal in the state of equilibrium. If the U-tube is taken to the right with an accelerated motion, the liquid level -



(1) will be higher in arm A than in arm B
(2) will bel lower in arm A than in arm B
(3) will remain equal in both the arm
(4) A gap will be created between the liquid in two arms

3 A parrot is sitting on the floor of a closed glass cage which is in a boy's hand. If the parrot starts flying with a constant speed, the boy will feel the weight of the cage as -

(1) unchanged (2) reduced
(3) increased (4) Nothing can be said

4 Under the action of external forces a particle can remain stationary when -

(1) a constant force is applied to the particle (2) a variable force is applied on the particle
(3) at least three forces be applied on the particle (4) The vector sum of the applied force is zero

5 A retarding force to stop a train has a specific magnitude. If the speed of the train is doubled, how far will this retarding force stop the train at -

(1) equal distance (2) 4 times the earlier distance
(3) 8 times the earlier distance (4) a twice the earlier distance

6 1 gm weight is equal to -

(1) 980 dynes (2) 98 dyne
(3) 9.8 dyne (4) 0.98 dyne

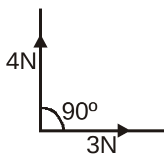
7 A simple pendulum is suspended vertically from the ceiling of a car. If the car is moving with an acceleration of 0.49 m/sec^2, the string of the simple pendulum will make an angle with the vertical whose magnitude will be -

(1) 0^o (2) $\tan^{-1}(0.05)$
(3) $\tan^{-1}(1/\sqrt{2})$ (4) $\tan^{-1}(\sqrt{3})$

8 A railway carriage is moving on a horizontal track with an acceleration 'a'. A passenger sitting in the carriage drops a stone. The acceleration of the stone relative to rail track will be -

(1) a (2) g
(3) $(a^2 + g^2)^{1/2}$ (4) zero

9 As shown in figure two forces are acting on a body. If its mass is 5kg, the value of acceleration generated is -

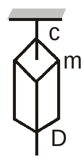


(1) 2 m/sec^2 (2) 3 m/sec^2
(3) 1 m/sec^2 (4) 4 m/sec^2

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

(1) by jumping (2) by spitting or sneezing
(3) by rolling your body on the surface (4) by running on the plane

11 A heavy block of mass m is supported by a string C from the ceiling as shown in the figure. Another string D is attached to its bottom. If D is given a sudden jerk, then -



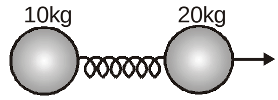
(1) string C will break (2) string D will break

(3) Both C and D will break (4) None of the string will break

12 A car running at 30 km/hr stops after travelling 8m distance on applying brakes. If same type of car is running at 60 km/hr it stops after travelling how much distance on applying brakes -

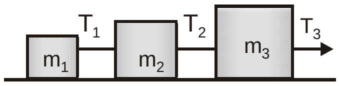
(1) 8 metres (2) 16 metres
(3) 24 metres (4) 32 metres

13 Two masses 10 kg and 20 kg are connected with a massless spring as shown in the figure. A force of 200 N is acting on the mass 20 kg. When the acceleration of 10 kg mass is $12 m/s^2$, the acceleration of 20 kg mass is -



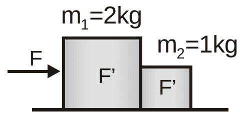
(1) $12\ m/sec^2$ (2) $4\ m/sec^2$
(3) $10\ m/sec^2$ (4) zero

14 Three block are connected as shown in fig., on a horizontal frictionless table and pulled to the right with a force T_3 = 60 N. If m_1 = 10 kg. m_2 = 20 kg. m_3 = 30 kg. the tension T_2 is -



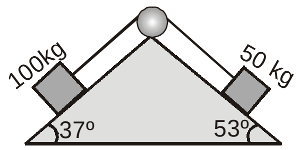
(1) 10 N (2) 20 N
(3) 30 N (4) 60 N

15 In the following figure, two blocks on m_1 = 2kg and m_2 = 1kg are in contact with a frictionless table. A horizontal force F = 3N is applied to mass m_1, the contact force between m_1 and m_2 will be -



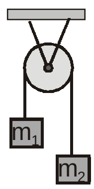
(1) 1N (2) 2N
(3) 3N (4) zero

16 Two blocks are connected by a cord passing over a small frictionless pulley and resting on frictionless planes as shown in the figure. The acceleration of the blocks is -



(1) $0.33\ m/s^2$ (2) $0.66\ m/s^2$
(3) $1\ m/s^2$ (4) $1.33\ m/s^2$

17 Two masses are suspended vertically on a pulley their acceleration is -



(1) $\frac{m_1}{m_2}g$ (2) $\frac{m_2}{m_1}g$

(3) $\left(\frac{m_2-m_1}{m_1+m_2}\right)g$ (4) $\left(\frac{m_1+m_2}{m_2-m_1}\right)g$

18 Two blocks of mass m_1 & m_2 connected with a light spring, placed on a frictionless table. They are left after pulling, with same force then the ratio of acceleration produced in them -

(1) $\frac{m_1}{m_2}$ (2) $\frac{m_2}{m_1}$

(3) $\frac{m_1-m_2}{m_1+m_2}$ (4) $\frac{4m_1m_2}{(m_1+m_2)^2}$

19 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 -

(1) $\frac{Fx}{L-x}$ (2) $\frac{FL}{L-x}$

(3) $\frac{FL}{x}$ (4) $\frac{F(L-x)}{L}$

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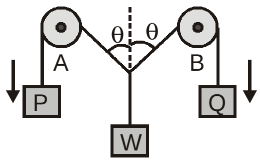
20 A weight W is tied to two strings passing over the frictionless pulleys A and B as shown in the figure. If weights P and Q move downwards with speed V, the weight W at any instant rises with the speed -



(1) $V \cos\theta$ (2) $2V \cos\theta$

(3) $V/\cos\theta$ (4) $2V/\cos\theta$

21 A body of weight W_1 is suspended by a chain of weight W_2 from ceiling of a room. With how much force ceiling pulls the chain -

(1) W_1 (2) W_2

(3) $W_1 + W_2$ (4) $W_1 + W_2/2$

22 A person says that he measured acceleration of a particle non-zero, while any force is not acting on particle then -

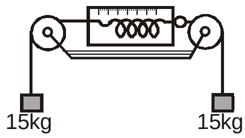
(1) he is telling false

(2) speed of his clock may be slow

(3) His metre scale may be longer than standard scale

(4) It may be non-inertial frame of reference

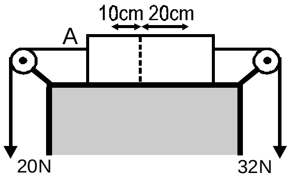
23 As shown in the figure two masses is 15 kg each are suspended through two strings tied to a spring balance after passing over frictionless pulleys. The reading of the balance will be -



(1) zero (2) 15 kg

(3) 30 kg (4) 7.5 kg

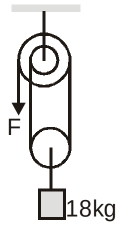
24 In fig a uniform rod of 3kg & length 30 cm is shown. String shown in figure are being pulled with constant forces of 20 N & 30 N. What will be the acceleration of rod -



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

(3) 4 m/s^2 (4) 6 m/s^2

25 A force F is applied on free end of a string such mass of 18 kg remain stationary value of F will be -



(1) 180 N (2) 90 N

(3) 60 N (4) 30 N

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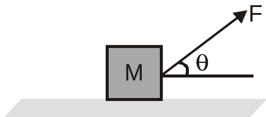
LEVEL - III

1 Two forces $(8\hat{i}+10\hat{j})$ N and $(4\hat{i}+8\hat{j})$ N are acting on a body of mass 6kg then acceleration produced in the body in m/s^2 will be -

(1) $(3\hat{i}+2\hat{j})$ (2) $12\hat{i}+18\hat{j}$

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

2 A block of mass M placed on a smooth horizontal surface is pulled by a constant force F acting at an angle θ with the horizontal. The acceleration produced in the block is a. Then -



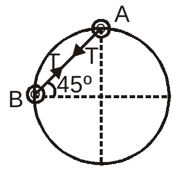
(1) If a ≤ g/tanθ, the acceleration is along the horizontal direction

(2) If a ≤ g/tanθ, the normal reaction is N = M (g – a tanθ)

(3) The acceleration a will not be parallel to the applied force F.

(4) all of the above

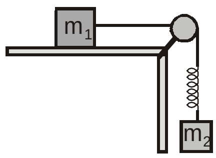
3 Two objects A and B each of mass m are connected by a light inextensible string. They are restricted to move on a frictionless ring of radius R in a vertical plane (as shown in fig). The objects are released from rest at the position shown. Then, the tension in the cord just after release is -



(1) zero (2) mg

(3) $\sqrt{2}$ mg (4) mg/$\sqrt{2}$

4 In the arrangement shown in figure m_1 = 8kg, m_2 = 2kg and spring constant K = 1600 N/m. All surfaces are smooth then -



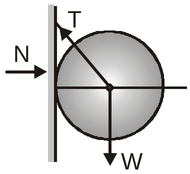
(1) Tension in string, T = 17.2N

(2) Tension in string, T = 15.68 N

(3) Extension in spring is 9.8 mm

(4) Extension in spring is 12 mm

5 A metallic sphere is suspended on stationary wall with the help of a spring. Forces as shown in the fig. are acting on the sphere. Which statement/statements in following is true -



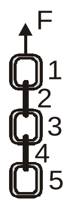
(a) $\mathbf{N} + \mathbf{T} + \mathbf{W} = 0$ (b) $T^2 = N^2 + W^2$

(c) T = N + W (d) N = W tanθ

(1) a, b, c (2) b, c, d

(3) a, b, d (4) a, b, c, d

6 A chain has five rings. The mass of each ring is 0.1 kg. This chain is pulled upwards by a force F producing an acceleration of 2.50 m/s^2 in the chain. Then the force of action (reaction) on the joint of second and third ring from the top is -



(1) 0.25 N (2) 1.23 N

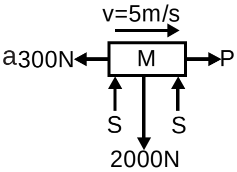
(3) 3.69 N (4) 6.15 N

7 A machine-gun of mass M fires n bullets per second. The mass of each bullet is m and speed is v. Force acting on the machine-gum is -

(1) $\frac{mn}{v}$ (2) mnv

(3) $\frac{mv}{n}$ (4) $\frac{vn}{m}$

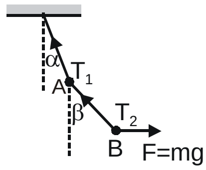
8 Force are acting on a body according to fig. If body is moving horizontally at a constant speed of 5 m/s then value of P and S respectively will be -



(1) 0N, 0N (2) 300 N, 200 N

(3) 300 N, 1000 N (4) 2000 N, 300 N

9 A & B are two particles of mass m each, are kept stationary as shown in fig. by applying a horizontal force F = mg on B then -



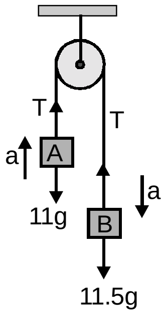
(a) $\tan \beta = 2 \tan \alpha$ (b) $2T_1 = 5T_2$

(c) $T_1 \sqrt{2} = T_2 \sqrt{5}$ (d) none of these

(1) a, b (2) b, c

(3) c, d (4) a, c

10 In fig. speed of each particle after 4 sec. -



(1) 0.872 m/s (2) 8.72 m/s

(3) 0.218 m/s (4) 2.18 m/s

11 Linear momentum of P of a body performing one dimensional motion is changing according to $P = at^3 + bt$ where a and b are positive constants then net force acting on the body is proportional to -

(1) t^2 (2) a constant

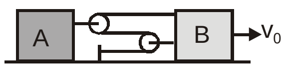
(3) t (4) 1/t

12 Two monkey A & B are of masses M and m respectively (M > m). They are holding a rope which is passing through a stationary smooth pulley.They moves on rope such that upward acceleration of B becomes double of downward acceleration of A then tension in the rope will be -

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

(3) $\frac{3Mmg}{2(M+m)}$ (4) $\frac{3Mmg}{(M+m)}$

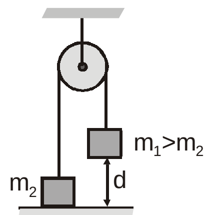
13 Block B is moving towards right with constant velocity v_0. Velocity of block A with respect to block B is (Assume all pulleys and strings are ideal)



(1) $v_0/2$ left (2) $v_0/2$ right

(3) $3/2v_0$ right (4) $3/2v_0$ left

14 If masses are released from the position shown in fig. then speed of mass m_1 just before to collide on floor will be



(1) $[2m_1gd/(m_1+m_2)]^{1/2}$ (2) $[2(m_1-m_2)gd/(m_1+m_2)]^{1/2}$

(3) $[2(m_1-m_2)gd/m_1]^{1/2}$ (4) none of these

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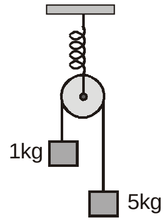
15 A frictionless pulley of negligible weight is suspended from a spring balance as shown in fig. Masses of 1kg and 5 kg are tied to the ends of string which passes over the pulley. The masses move due to gravity. The reading of the balance will be

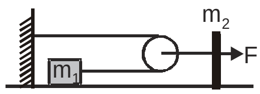


(1) more than 6 kg
(2) 6 kg
(3) less than 3 kg
(4) less than 6kg and more than 3kg

16 Two bodies A and B are thrown upwards simultaneously with same speed. Mass of A is more than that of B. If same constant resistive force is applied on both bodies by air then -

(1) Both bodies will reach up to same height
(2) A will reach up to more height than B
(3) B will reach upto more height than A
(4) Any one of above three may be possible, it depends on initial speed of both bodies

17 In the arrangement shown in fig. friction between block & table is negligible. If F is pulling force and m_1 & m_2 are known masses then tension in string will be -



(1) $m_1F/(m_1 + m_2)$
(2) $2m_1F/(m_1 + m_2)$
(3) $2m_1F/(4m_1 + m_2)$
(4) none of these

18 A person is standing on a floor of lift, releases a coin. Coin reaches on floor in time t_1 if lift is stationary. and coin reaches on floor in time t_2 if lift is moving with uniform velocity -

(1) $t_1 = t_2$
(2) $t_1 < t_2$
(3) $t_1 > t_2$
(4) $t_1 < t_2$ or $t_1 > t_2$ depends on lift on moving downwards or upwards

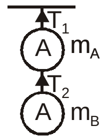
19 A smooth wedge is kept in a chamber. Chamber is suspended close to earth surface. A block B is kept on top of wedge. It takes time T to slip over length of wedge. If block is kept on top of wedge & suddenly string breaks then at this time block -

(1) will take more time than T to slip over wedge
(2) will take less than T to slip over wedge
(3) will remain on top of wedge
(4) will fall away from wedge

20 A particle is seen from reference frame s_1 & s_2. Reference frame s_2 is moving with acceleration a with respect to reference frame s_1. Assuming F_1 & F_2 are pseudo force on particle, while we see from frames s_1 & s_2 respectively. Which of following is not possible -

(1) $F_1 = 0, F_2 \neq 0$
(2) $F_1 \neq 0, F_2 \neq 0$
(3) $F_1 \neq 0, F_2 = 0$
(4) $F_1 = 0, F_2 = 0$

21 Two bodies A & B of mass m_A & m_B are connected by a string as shown in fig. If they are accelerated upwards then ratio of tension $T_1 : T_2$ -



(1) $(m_A + m_B)/m_B$
(2) $(m_A + m_B)/m_A$
(3) $\dfrac{m_A + m_B}{m_A - m_B}$
(4) $\dfrac{m_A - m_B}{m_A + m_B}$

22 If downward acceleration is given to the system in the figure of the privisous questino then ratio in string $T_1 : T_2$ is -

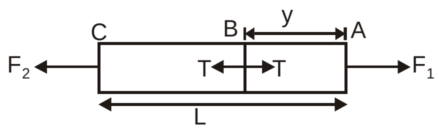
(1) $(m_A + m_B)/m_B$
(2) $(m_A + m_B)/m_A$
(3) $\dfrac{m_A + m_B}{m_A - m_B}$
(4) none of these

23 When same force is applied on n different bodies then accelerations produced in them are respectively $1, \frac{1}{2}, \frac{1}{3}, \frac{1}{4}, ...\frac{1}{n}$ (all in m/s²). If all these bodies are joined together & same force is applied then acceleration will be -

(1) $\frac{n}{2}$ (2) $\frac{2}{n[n+1]}$

(3) $\frac{n^2}{2}$ (4) $\frac{n^2(n+1)}{2}$

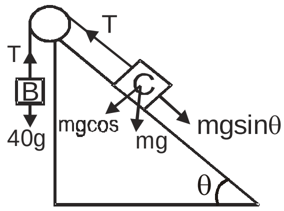
24 On a rod of length L & mass m how much tension will be at a distance y from F_1 when two dissimilar forces F_1 & F_2 ($F_2 < F_1$) are applied on the rod -



(1) $F_1\left(1-\frac{y}{L}\right)+F_2\left(\frac{y}{L}\right)$ (2) $\frac{M}{L}y+\left(\frac{F_1-F_2}{M}\right)$

(3) $F_1\left(1+\frac{y}{L}\right)+F_2\left(\frac{y}{L}\right)$ (4) $\frac{M}{L}y\left(\frac{F_1+F_2}{M}\right)$

25 A 50 kg mass is on an inclined plane at one end of a massless string passing through a smooth pulley of inclined plane and at other end of the string a 40 kg mass is suspended as shown in fig. distance travelled by 50 kg mass in 4 sec. will be (angle of inclination of plane is 30º) -



(1) 13.04 m (2) 1.63 m

(3) 1.304 m (4) 16.3 m

QUESTIONS ASKED IN VARIOUS EXAMS

1 An elevator weighing 6000 kg is pulled upwards by a cable with an acceleration of 5 ms^{-1} . Taking g to be 10 ms^{-2}. Then the tension in the cable is **[Manipal MEE-1995]**

(1) 6000 N (2) 9000 N
(3) 60000 N (4) 90000 N

2 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 metre/sec^2) **[MP PMT-1995]**

(1) Stands still
(2) Moves downwards at a constant velocity of 4 metre/sec.
(3) Accelerates downward with an acceleration equal to 4 metres/sec^2
(4) Acelerates upward with an acceleration equal to 4 metres/sec^2

3 A vehcile of 100 kg is moving with a velocity of 5 m/sec. To stop it in 1/10 sec. The required force in opposite direction is - **[MP PET-1995]**

(1) 5000 Newton (2) 500 Newton
(3) 50 Newton (4) 1000 Newton

4 n bullets per sec. each of mass m moving with velocity v strike normally on a wall. The collision is elastic then force on wall is - **[RPMT-1995]**

(1) zero (2) mnv
(3) 2 mnv (4) 4 mnv

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

(1) increases (2) decreases
(3) first increases then decreases (4) remains same

6 When a horse pulls the tonga, the tonga moves forward due to - **[RPET-1996]**

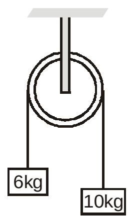
(1) Force exerted by horse in forward diretion
(2) Reaction of the tonga
(3) Reaction of the hindimbs of the horse on the gound
(4) None of the above

7 The engine of a car produces acceleration 4m/s^2 in the car. If this car pulls another car of same mass. What will be the acceleration produced - **[RPET-1996]**

(1) 1 m/s^2 (2) 1.5 m/s^2
(3) 2 m/s^2 (4) 4 m/s^2

8 A light string passes over a frictionless pulley. To one of its ends a mass of 6 kg is attached and to its other end a mass of 10 kg is attached. The tension in the string will be - **[RPET-1996]**

(1) 50 N
(2) 75 N
(3) 100 N
(4) 150 N



9 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 - **[CPMT-1996]**

(1) $10\sqrt{2}$ kg (2) $2\sqrt{10}$ kg
(3) 10 kg (4) 20 kg

10 A block of mass 2kg is joined to a body of mass 1kg. Block is placed on a horizontal table and the string moves over a pulley, which is at the edge of the table. Mass of 1kg is suspended by the string. If table is frictionless then acceleration of block and tension in string are respectively - **[RPET-1997]**

(1) 4.38 m/s^2, 6.54 N (2) 4.38 m/s^2, 9.86 N

(3) 3.27 m/s^2, 6.54 N (4) 3.27 m/s^2, 9.86 N

11 A force of 6N acts on a body at rest of mass 1kg . During this time, the body attains a velocity of 30 m/s. The time for which the force acts on the body is - **[CPMT-1997]**

(1) 10 sec. (2) 8 sec.

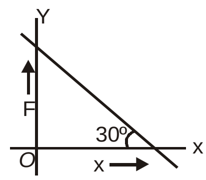
(3) 7 sec. (4) 5 sec.

12 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 N and t in sec. The force on bullet becomes zero as soon as it leaves barrel. What is average impulse imparted to bullet- **[CPMT-1998]**

(1) 9 Ns (2) zero

(3) 0.9 Ns (4) 1.8 Ns

13 The value of force constant between the applied elastic force F & displacement will be - **[RPMT-1998]**



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

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

14 If a ladder is not in equillibrium against a smooth vertical wall, then it can be made in equillibrium by - **[CPMT-1998]**

(1) increasing the angle of inclination (2) decreasing the angle of inclination

(3) increasing the legngh of the ladder (4) decreasing the length of the ladder

15 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 = 0.5 kg) flies upward in the cage with an acceleration of 2 m/s^2. The spring balance will now reacord a weight of - **[MP PMT-1999]**

(1) 24 N (2) 25 N

(3) 26 N (4) 27 N

16 A truck of mass 500 kg moving with constant speed 10 m/s. If sand is dropped into the truck at the constant rate 10 kg/minute, the force required to maintain the motion with constant velocity is **[RPET-1999]**

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

(3) $\frac{7}{5}$ N (4) $\frac{3}{2}$ N

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

(1) 1N (2) 3N

(3) 4N (4) 5N

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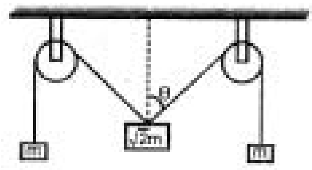
18 A man slips on a frictionless inclined plane leaving a bag from the same height to the ground. If the velocities of the man and bag are v_M & v_B respectively on reaching the ground, lthen - **[CPMT-2000]**

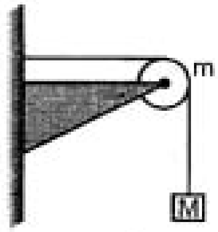
(1) $v_B > v_M$ (2) $v_B < v_M$
(3) $v_B = v_M$ (4) v_B & v_M con't be related

19 The pulleys and strings shown in fig. are smooth and of negligible mass. For the system to remain in equailibrium, the angle θ should be - **[IIT screening-2001]**



(1) 0º (2) 30º
(3) 45º (4) 60º

20 A string of negligbile mass going over a clamped pulley of mass m supports a block of mass M as shown in figure. The force on the pulley by the clamp is given by - **[IIT sereening-2001]**



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

21 A golf ball of mass 0.05 kg placed on a tee, is struck by a golf club. The speed of the golf ball as it leaves the tee is 100 m/s, the time of contact between them is 0.02 s. If the force decreases to zero linearly with time, then the force at the beginning of the contact is - **[CBSE-2001]**

(1) 500 N (2) 250 N
(3) 200 N (4) 100 N

22 A force $\vec{F} = 6t^2\hat{i} + 4t\hat{j}$, is acting on a particle of mass 3kg then what will be velocity of particle at t = 3 sec. if at t = 0, particle is at rest - **[CPMT-2002]**

(1) $18\hat{i} + 6\hat{j}$ (2) $18\hat{i} + 12\hat{j}$
(3) $12\hat{i} + 6\hat{j}$ (4) None

23 A monkey of mass 20 kg is holding a vertical rope. The rope will not break when a mass of 25 kg is suspeneded 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) **[CPMT-2003]**

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

24. A ball of mass 0.2 kg is thrown vertically upwards by applying a force by hand. If the hand moves 0.2 m while applying the force and the ball goes upto 2 m height further, find the magnitude of the force. Consider g = 10 m/s^2 **[AIEEE - 2006]**

(1) 22 N (2) 4 N
(3) 16 N (4) 20 N

25. A 2kg block slides on a horizontal floor with a speed of 4 m/s. It strikes a uncompressed spring, and compresses it till the block is motionless. The kinetic friction force is 15 N and spring constant is 10,000 N/m. The spring compresses by **[AIEEE- 2007]**

(1) 5.5 cm (2) 2.5 cm
(3) 11.0 cm (4) 8.5 cm

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ANSWERS

EXERCISES

LEVEL - I

1. (1)	2. (1)	3. (2)	4. (4)	5. (2)
6. (3)	7. (1)	8. (4)	9. (1)	10. (3)
11. (3)	12. (3)	13. (4)	14. (2)	15. (1)
16. (1)	17. (3)	18. (2)	19. (1)	20. (2)
21. (2)	22. (1)	23. (2)	24. (3)	25. (2)

LEVEL - II

1. (2)	2. (1)	3. (1)	4. (4)	5. (2)
6. (1)	7. (1)	8. (2)	9. (3)	10. (2)
11. (2)	12. (4)	13. (2)	14. (3)	15. (1)
16. (4)	17. (3)	18. (2)	19. (4)	20. (3)
21. (3)	22. (4)	23. (2)	24. (3)	25. (2)

LEVEL - III

1. (4)	2. (4)	3. (4)	4. (1)	5. (3)
6. (3)	7. (2)	8. (3)	9. (4)	10. (1)
11. (1)	12. (2)	13. (2)	14. (2)	15. (2)
16. (2)	17. (3)	18. (1)	19. (3)	20. (4)
21. (1)	22. (1)	23. (2)	24. (1)	25. (1)

QUESTIONS ASKED IN VARIOUS EXAMS

1. (4)	2. (4)	3. (1)	4. (3)	5. (3)
6. (3)	7. (3)	8. (2)	9. (1)	10. (3)
11. (4)	12. (3)	13. (2)	14. (1)	15. (3)
16. (1)	17. (3)	18. (3)	19. (3)	20. (4)
21. (1)	22. (1)	23. (1)	24. (1)	25. (1)

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