

## **LAWS OF MOTION**

### **Important Points:**

1. Newton's First law explains the property of inertia and defines force.

**2. Inertia:**

It is the property of a body by virtue of which, it cannot change its state of rest or of uniform motion along a straight line, on its own. It depends upon the mass of the body.

**3. Inertia of Rest:**

It is the inability of a body to change by itself, its state of rest.

**E.g.** When a bus at rest starts suddenly passengers fall back.

**4. Inertia of Motion:**

It is the inability of a body to change by itself its state of uniform motion.

**E.g.** when a bus in uniform motion suddenly stops, the passengers fall forward.

**5. Inertia of Direction:**

It is the inability of a body to change by itself its direction of motion.

**E.g.** When a bus takes a turn passengers will be pushed outwards

6. Newton's second law gives the quantitative definition of force and defines the unit force.

**7. Momentum:**

The product of mass and velocity of a body is called linear momentum.  $P = mv$

**8. Units of Force:**

SI unit: Newton

CGS unit: dyne

$1 \text{ N} = 10^5 \text{ dynes}$ .

## 9. Impulsive Force:

Large force acting on a body for a short time interval is an impulsive force.

## 10. Impulse:

The impulse of a force is defined as the product of the average force and the time interval for which it acts.

$$\text{Impulse} = F \times t = mv - mu$$

## 11. Apparent weight of a person in a Lift:

a) If the lift moves up with an acceleration 'a',  $W' = W \left( 1 + \frac{a}{g} \right)$

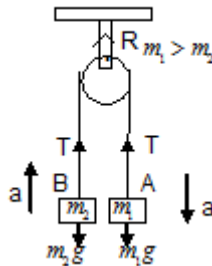
b) If the lift moves down with an acceleration 'a',  $W' = W \left( 1 - \frac{a}{g} \right)$

c) If the lift is freely falling under gravity i.e. If  $a = g$ ,  $W' = 0$

d) If the lift is moving up or down with uniform velocity,  $W' = W = mg$

## 12. Atwood Machine:

a) When two bodies of masses  $m_1$  and  $m_2$  are connected by a light string passing over a frictionless pulley and if  $m_1 > m_2$




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

$$\text{Tension in the string } T = \frac{2m_1m_2g}{m_1 + m_2},$$

$$\text{Force on the pulley } F = \frac{4m_1m_2g}{m_1 + m_2}$$

13. Two blocks are on a smooth horizontal surface in contact and a horizontal force acts on one of

them. The contact force between them is  $\frac{FM}{(M+m)}$ ; 

14. Newton third law states, for every action there is always an equal and opposite reaction.

$$\text{Action} = - \text{Reaction}$$

15. The property which opposes the relative motion between the surfaces in contact is called friction.

**16. Advantages of Friction:**

- i) Safe walking on the floor is due to the friction between the floor and the feet.
- ii) Nails and screws are driven in the walls or wooden surfaces due to friction.
- iii) Friction helps the fingers to hold a drinking water tumbler or pen.

**17. Disadvantages of Friction:**

- i) Friction results in the large amount of power loss in engines.
- ii) Due to friction, the wear and tear of the machine increases.
- iii) Due to friction, heat is generated which goes as a waste.

**18. Methods to Reduce Friction:**

- i) By Polishing.
- ii) By using Lubricants.
- iii) By using Ball bearings.
- iv) Streamlining.

**19. Types of Friction:**

- i) The force of friction when there is no relative motion between the bodies in contact is called static friction.
- ii) Static friction is a self adjusting force.
- iii) When the body is ready to slide the static friction becomes maximum and it is called Limiting Friction.

**b) Kinetic Friction:**

- i) The frictional force that exists between the bodies which are in relative motion with each other is called kinetic (or) sliding friction.

**c) Rolling Friction:**

- i) Rolling friction comes into play when a body such as a wheel rolls on a surface.
- ii) The rolling frictional force is inversely proportional to the radius of the rolling body.

**20. Laws of Friction:**

- i) Friction opposes relative motion between two surfaces in contact.
- ii) Friction is independent of the area of contact between the two surfaces.
- iii) Friction is directly proportional to the normal reaction acting on the body.

$$f \propto R \Rightarrow f = \mu R$$

Where  $\mu$  = coefficient of friction

**21.** Coefficient of static friction ( $\mu_s$ ) =  $\frac{f_{ms}}{R}$

**22.** Coefficient of kinetic friction ( $\mu_k$ ) =  $\frac{f_k}{R}$

**23.** Coefficient of rolling friction ( $\mu_r$ ) =  $\frac{f_r}{R}$

$$\mu_s > \mu_k > \mu_r$$

**24. Inclined Plane:**

If  $\theta$  is angle of inclination and  $\alpha$  is angle of friction

a) Normal reaction  $R = mg \cos \theta$

b) If  $\theta < \alpha$ , the body is at rest on the plane.

Frictional force =  $mg \sin \theta$  (self adjusting force)

c) If  $\theta = \alpha$ , the body just tends to slide down the plane

Frictional force =  $mg \sin \alpha = \mu_s mg \cos \alpha$

d) If  $\theta > \alpha$ , the body slides down with acceleration

Frictional force =  $\mu_k mg \cos \theta$

e) **Angle of repose** is the angle of the rough inclined plane for which body placed on it may just start sliding down.

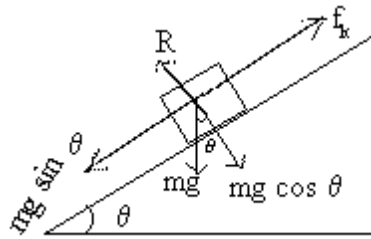
f) Net force down the plane

$$F = mg (\sin \theta - \mu_k \cos \theta)$$

g) Acceleration down the plane

$$a = g (\sin \theta - \mu_k \cos \theta)$$

This is independent of the mass of the body



h) Pulling force  $F = \frac{W \sin \phi}{\cos(\theta - \phi)}$  and pushing force  $F = \frac{W \sin \phi}{\cos(\theta + \phi)}$  where W is the weight of body,  $\phi$  is the angle of friction and  $\theta$  is the angle made by F with the horizontal

i) Pulling is easier than pushing.

## 25. Circular Motion:

a) Uses of centrifugal forces and centrifugal machines.

i) Cream is separated from milk.

ii) Sugar crystals are separated from molasses.

iii) Precipitate is separated from solution.

iv) Hemato centrifuge, Grinder, Washing machine, etc.

b) The angle through which a cyclist should lean while taking sharp turnings is given by the

$$\text{relation } \theta = \tan^{-1} \left( \frac{v^2}{rg} \right).$$

c) Safe speed on an unbanked road when a vehicle takes a turn of radius r is  $v = \sqrt{\mu rg}$

Where  $\mu$  = coefficient of friction.

d) **Angle of Banking** is given by  $\tan \theta = v^2/rg$  and the height of banking is given by

$$h = L \sin \theta \text{ where } L \text{ is the width of the road.}$$

$$\text{If } \theta \text{ is very small, then } \theta = \frac{v^2}{rg} = \frac{h}{L}$$

## Very Short Answer Questions

**1. What is inertia? What gives the measure of inertia?**

**A.** If the net external force is zero, a body at rest continues to be at rest and a body in motion continues to move with uniform velocity. This property of a body is called inertia.

Mass is the measure of inertia.

**2. According to Newton's third law, every force is accompanied by an equal and opposite force. How can a movement ever take place?**

**A.** Action and reaction act on two different bodies. Hence movement of each body is due to either action or reaction.

**3. When a bullet is fired from a gun, the gun gives a kick in the backward direction. Explain.**

**A.** This is due to the law of conservation of linear momentum. When a bullet is fired from a gun, the gun moves back due to reaction. This is called the recoil of the gun.

**4. Why does a heavy rifle not recoil as strongly as a light rifle using the same cartridges?**

**A.** From the law of conservation of momentum  $MV = mv \Rightarrow V = \frac{mv}{M}$

Hence a heavy rifle does not recoil as strongly as a light rifle because of its heavy mass

**5. If a bomb at rest explodes into two pieces, the pieces must travel in opposite directions. Explain.**

**A.** Since the initial momentum of the bomb is zero, its final momentum should be zero. If the bomb breaks into two pieces of masses  $m_1$  and  $m_2$  moving with velocities  $v_1$  and  $v_2$ , then

$m_1 v_1 + m_2 v_2 = 0$  Or  $m_1 v_1 = - m_2 v_2$  Hence the two pieces move in opposite directions.

**6. Define force. What are the basic forces in nature?**

**A: Force:**

A physical quantity that changes or tries to change the state of rest (or) of uniform motion along a straight line. Basic forces in nature are

- |                         |                           |
|-------------------------|---------------------------|
| 1) Gravitational forces | 2) Electromagnetic forces |
| 3) Weak nuclear forces  | 4) Strong nuclear forces  |

**7. Can the coefficient of friction be greater than one?**

- A. . In general, coefficient of friction is less than one. For a heavily polished surface the frictional force increases due to the increase of inter atomic forces. In such a case coefficient of friction will be greater than one.

**8. Why does the car with flattened tyre stop sooner than the one with inflated tyres?**

- A. Flattened tyre has more area of contact with the road. Hence rolling friction increases and there by a car with flattened tyre stops sooner.

**9. A horse has to pull harder during the start of the motion than later. Explain?**

- A. Static friction is more than kinetic friction. Hence the horse has to pull the cart harder during start of the cart.

**10. What happens to the coefficient of friction, if the weight of the body is doubled?**

- A. Coefficient of friction remains same as it is independent of weight of the body.

## Short Answer Questions

1. A stone of mass 0.1kg is thrown vertically upwards. Give the magnitude and direction of the net force on the stone a) During Its Upward Motion. b) During Its Downward Motion. c) At the highest point, where it momentarily comes to rest?

A:  $m = 0.1\text{kg}$

a) During up ward motion

Gravitational force ( $F$ ) =  $mg = 0.1 \times 9.8 = 0.98\text{N}$

b) During downward motion

Gravitational force ( $F$ ) =  $mg = 0.1 \times 9.8 = 0.98\text{N}$

c) At the highest point, final velocity becomes zero, but acceleration acts down wards

Gravitational force ( $F$ ) =  $mg = 0.1 \times 9.8 = 0.98\text{N}$

2. Define the terms momentum and impulse. State and explain the law of conservation of linear momentum. Give its examples.

A. **Momentum:**

The product of mass and velocity of a body is called the momentum.

Momentum ( $P$ ) =  $mv$

**Impulse:**

The product of force and time of action of force is called impulse.

Impulse ( $I$ ) = Force  $\times$  Time

**Law of Conservation of Linear Momentum:**

The total momentum of an isolated system of interacting particles remains constant if there is no resultant external force acting on it.

**Explanation:**

If no external force acts on the system, then momentum of the system remains constant.



$$\text{If } F_{\text{ext}} = 0 \Rightarrow \frac{dp}{dt} = 0 \Rightarrow dp = 0 \text{ or } p = \text{constant}$$

### Examples:

#### i) Motion of a Rocket:

When a rocket is fired, the gases are ejected downward and as a result the rocket moves upward.

#### ii) Explosion of a Shell:

For a shell exploding in mid air the vector sum of the momenta of different fragments is equal to the initial momentum of the shell.

### 3. Why are shock absorbers used in motor cycles and cars?

A. When motor cycle travels on an uneven road, shock absorbers increase the time of impulse and thereby reduces the force.

### 4. Explain the terms limiting friction, dynamic friction and rolling friction?

#### A. Limiting Friction:

The maximum static frictional force between the bodies in contact at rest is called limiting friction.

#### Dynamic Friction:

Frictional force between bodies in motion is called dynamic friction.

#### Rolling Friction:

When one body rolls on the surface of the other body, then the friction in between the surfaces is called rolling friction.

### 5. Explain advantages and disadvantages of Friction?

#### A. Advantages:

- i) Walking on the floor, motion of vehicle etc. is possible due to friction.
- ii) Nails, screws etc. are driven into walls due to friction.

iii) A match stick is lightened due to friction.

iv) Holding the objects with hands, writing with pens or pencils etc. is possible due to friction.

**Disadvantages:**

i) Wear and tear of machine parts are due to friction.

ii) Energy losses as heat is due to friction.

**6. Mention the methods used to decrease friction?**

**A. Methods to Reduce Friction:**

**a) Polishing:**

Polishing the surfaces in contact decreases the inter locking and there by friction can be reduced.

**b) Ball Bearings:**

Ball bearings can reduce the friction, since rolling friction is less than the sliding friction.

**c) Lubricants:**

Lubricants like grease fill the irregularities between the surfaces in contact. Thus friction is reduced.

**d) Streamlining:**

Automobiles and aero planes are streamlined to reduce the air friction.

**7. State the laws of rolling Friction?**

- A.**
- 1) The smaller the area of contact, lesser will be the rolling friction.
  - 2) The larger the radius of the rolling body, the lesser will be the rolling friction.
  - 3) The rolling friction ( $F_r$ ) is directly proportional to the normal reaction ( $N$ ).

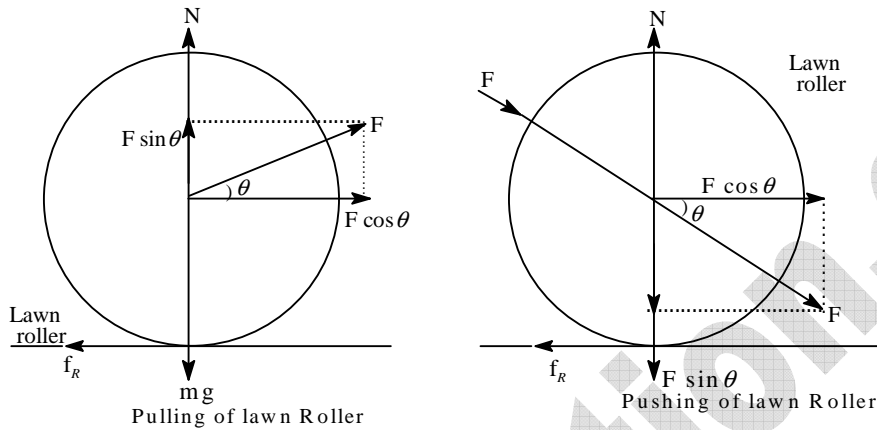
i.e.  $F_r \propto N$  or  $\mu_r = \frac{F_r}{N}$ , Where  $\mu_r$  is the co-efficient of rolling friction.

## 8. Why is pulling the lawn roller is preferred to pushing it?

### A. Pulling:

Let a pulling force  $F$  is applied on the lawn roller as shown.

Normal reaction  $N = mg - F \sin \theta$



Frictional force is given by,

$$f_R = \mu_R N \Rightarrow f_R = \mu_R (mg - F \sin \theta) \text{-----(1)}$$

### Pushing:

Let a pushing force  $F$  is applied on the lawn roller as shown.

Normal reaction  $N = mg + F \sin \theta$

The frictional force is given by,

$$f_R^1 = \mu_R N \Rightarrow f_R^1 = \mu_R (mg + F \sin \theta) \text{-----(2)}$$

From equations (1) and (2)  $f_R < f_R^1$  ..

Hence pulling is easier than pushing the lawn roller.

## Long Answer Questions

1. a) State Newton's second law of motion. Hence derive the equation of motion

$F = ma$  from it.

b) A body is moving along a circular path such that its speed always remains constant. Should there be force acting on the body?

A. a) Newton's second law of motion:

The rate of change of momentum of a body is directly proportional to the net force acting on the body and it takes place in the direction of force.

**To derive  $F = ma$ :**

Consider a body of mass 'm' moving with velocity 'v'. Let its velocity be increased by 'dv' in a time interval dt due to an external force F.

From second law of motion  $F \propto \frac{dp}{dt}$ ,

$$\text{Or } F \propto \frac{d(mv)}{dt} \quad (\because p = mv)$$

$$F = k \frac{d}{dt}(mv)$$

Since the mass of the body is constant,

$$F = k m \frac{dv}{dt} = k m a \quad \left( \because \frac{dv}{dt} = a \right)$$

Where k is proportionality constant

**Unit Force:**

A force which produces a unit acceleration in a body of unit mass is called a unit force.

If m = 1 unit and a = 1unit, then k = 1unit

$$\therefore F = ma$$

## b) Motion in a Circular Path:

A body is moving along a circular path with constant speed experiences centripetal force towards the center of the circular path.

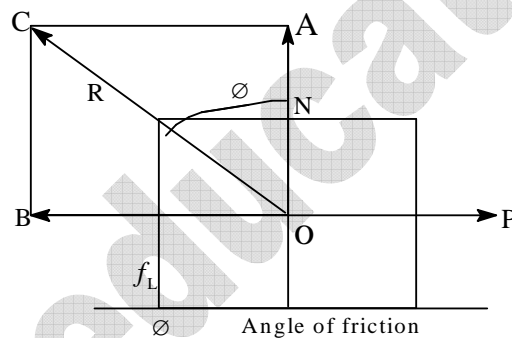
## 2. Define angle of friction and angle of repose.

Show that angle of friction is equal to angle of repose for a rough inclined plane.

A block of mass 4kg is resting on a rough horizontal plane and is about to move when a horizontal force of 30 N is applied on it. If  $g = 10 \text{ ms}^{-2}$  find the total contact force exerted by the plane on the block.

### A. Angle of Friction ( $\theta$ ):

The angle made by the resultant of the normal reaction and the limiting frictional force with normal reaction is called angle of friction.

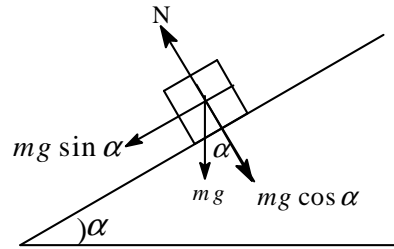


### Angle of Repose ( $\alpha$ ):

When the body is ready to slide down rough inclined plane, the angle of inclination is equal to the angle of repose.

From the figure,  $\tan \alpha = \frac{f_s}{N}$  and  $\mu_s = \frac{f_s}{N}$ .

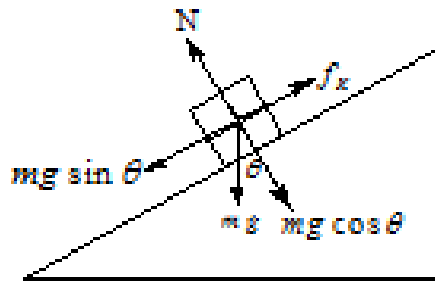
Hence  $\mu_s = \tan \alpha$



### Angle of repose and angle of Friction:

Consider a body of mass 'm' placed on a rough inclined plane of inclination ' $\theta$ '

When the body is ready to slide down the plane, the friction on the block is called limiting friction  $f_s$ . At equilibrium,  $f_s = mg \sin \theta$  and  $N = mg \cos \theta$



$$\therefore \text{Coefficient of static friction } \mu_s = \frac{f}{N} = \frac{mg \sin \theta}{mg \cos \theta} = \tan \theta$$

Here  $\theta$  is the angle of repose.

Hence the angle of repose of a rough inclined plane is equal to the angle of friction of horizontal plane.

### Problem:

$$m = 4 \text{ kg}; \quad F = 30 \text{ N} \quad ; \quad g = 10 \text{ ms}^{-2} \quad ; \quad N = mg = 40 = 40 \text{ N}$$

$$R^2 = N^2 + F^2 \Rightarrow R = \sqrt{30^2 + 40^2} = 50 \text{ N}$$

## Problems

1. The linear momentum of a particle as a function of time  $t$  is given by  $p = a + bt$ , where  $a$  and  $b$  are positive constants. What is the force acting on the particle?

A.  $p = a + bt$

$$F = \frac{dp}{dt} = b$$

2. Calculate the time needed for a net force of 5N to change the velocity of a 10kg mass by 2m/s

**Sol:**  $F = 5\text{N}$ ,  $m = 10\text{kg}$

Change the velocity  $(v - u) = 2\text{m/s}$

$$F = ma = \frac{m(v - u)}{t}, \quad 5 = \frac{10(2)}{t}$$

Or  $t = 4\text{sec}$

3. A ball of mass  $m$  is thrown vertically upward from the ground and reaches a height  $h$  before momentarily coming to rest. If  $g$  is the acceleration due to gravity. What is the impulse received by the ball due to gravity force during its flight? (Neglect air resistance)

A. Impulse  $F t = m a t = m g \frac{2u}{g} = 2m \sqrt{2gh} = \sqrt{8m^2 gh}$

4. A constant force acting on a body of mass 3.0kg changes its speed from  $2.0\text{ms}^{-1}$  to  $3.5\text{ms}^{-1}$  in 25s. The direction of motion of the body remains unchanged. What is the magnitude and direction of the force?

A.  $m = 3\text{kg}$ ,  $u = 2\text{ms}^{-1}$ ,  $v = 3.5\text{ms}^{-1}$   $t = 25\text{s}$

$$F = ma = \frac{m(v - u)}{t}, \quad F = \frac{3(3.5 - 2)}{25} = \frac{3 \times 1.5}{25} = 0.18\text{N}$$

5. A man in a lift feels an apparent weight  $W$ , when the lift is moving up with a uniform acceleration of  $\frac{1}{3}$ rd of the acceleration due to gravity. If the same man were in the same lift now moving down with a uniform acceleration that is  $\frac{1}{2}$  of the acceleration due to gravity, then what is the apparent weight?

A.  $a = \frac{1}{3}g$

When the lift moves up,  $W = (g + a) = m\left(g + \frac{g}{3}\right) = \frac{4mg}{3} \dots (1)$

Now,  $a = \frac{1}{2}g$

When the lift is moving down,  $W' = m(g - a)$

$W' = (g - a) = m\left(g - \frac{g}{2}\right) = \frac{mg}{2} \dots (2)$

From (1) and (2)  $W' = \frac{3W}{8}$

6. A container of mass 200kg rests on the back of an open truck. If the truck accelerate at  $1.5m/s^2$ , what is the minimum coefficient of static friction between the container and the bed of the truck required to prevent the container from sliding off the back of the truck?

Sol:  $m = 200kg$  ;  $a = 1.5m/s^2$

$F = \mu mg$  Or  $ma = \mu mg$  or  $\mu = \frac{a}{g} = \frac{1.5}{9.8} = 0.153$

7. A bomb initially at rest at a height of 40m above the ground suddenly explodes in to two identical fragments. One of them starts moving vertically downwards with an initial speed of 10m/s. If acceleration due to gravity is  $10m/s^2$ . What is the separation between the fragments 2s after the explosion?

Sol: As the bomb explodes into two identical fragments, their velocities after explosion are equal and opposite. As  $u_1 = 10m/s$   $u_2 = -10m/s$  in upward direction.

Displacement of body (1) in 2 sec is



$$s_1 = ut + \frac{1}{2}gt^2 = 10 \times 2 + \frac{1}{2} \times 10 \times 2^2 = 40m$$

Displacement of body (2) in 2sec is

$$s_2 = -ut + \frac{1}{2}gt^2 = -10 \times 2 + \frac{1}{2} \times 10 \times 2^2 = -20 + 20 = 0$$

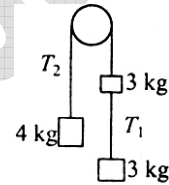
$\therefore$  Separation between two fragments after the explosion =  $40 + 0 = 40m$

8. A fixed pulley with a smooth groove has a light string passing over it with a 4 kg attached on one side and a 3kg on the other side. Another 3kg is hung from the other 3kg as shown with another light string. If the system is released from rest, find the common acceleration? ( $g = 10m/s^2$ )

**Sol:**  $m_1 = 3 + 3 = 6kg$

$$m_2 = 4kg$$

$$a = \frac{(m_1 - m_2)g}{m_1 + m_2} = \frac{(6 - 4)10}{6 + 4} = 2m/s^2$$



9. A block of mass of 2kg slides on an inclined plane that makes an angle of  $30^\circ$  with the horizontal. The coefficient of friction between the block and the surface is  $\sqrt{3}/2$ .
- a) What force should be applied to the block so that it moves down without any acceleration?
- b) What force should be applied to the block so that it moves up without any acceleration?

**Sol:**  $m = 2kg$ ,  $\theta = 30^\circ$ ,  $g = 9.8$ ,  $\mu = \frac{\sqrt{3}}{2}$

i)  $F = mg(\sin \theta - \mu_k \cos \theta) = 2 \times 9.8 \left( \sin 30^\circ - \frac{\sqrt{3}}{2} \times \cos 30^\circ \right) = 4.9N$

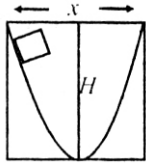
ii)  $F = mg(\sin \theta + \mu_k \cos \theta) = 2 \times 9.8 \left( \sin 30^\circ + \frac{\sqrt{3}}{2} \times \cos 30^\circ \right) = 24.5N$

10. A block is placed on a ramp of parabolic shape given by the equation  $y = x^2 / 20$ .

If  $\mu_s = 0.5$ , what is the maximum height above the ground at which the block can be

placed without slipping?  $\left( \tan \theta = \mu_s = \frac{dy}{dx} \right)$

Sol:



$$y = \frac{x^2}{20}$$

$$\frac{dy}{dx} = \frac{2}{20} \times x$$

$$\frac{dy}{dx} = \frac{x}{10} \left( \tan \theta = \mu_s = \frac{dy}{dx} \right)$$

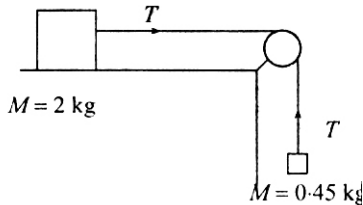
$$0.5 = \frac{x}{10} (\mu_s = 0.5)$$

$$x = 5\text{m}$$

$$\text{Max. Height (H)} = \frac{R}{4} = \frac{5}{4} = 1.25\text{m}.$$

Here x is equal to range (R)

11. A block is metal of mass 2kg on a horizontal table is attached to a mass of 0.45kg by a light string passing over a frictionless pulley at the edge of the table. The block is subjected to a horizontal force by allowing the 0.45kg mass to fall. The coefficient of sliding friction between the block and table is 0.2. Calculate a) The Initial acceleration b) The Tension in the string c) The Distance the block would continue to move if, after 2s of motion, the string should break



**Sol:**  $M_1 = 2\text{kg}$ ,  $M_2 = 0.45\text{kg}$ ,  $\mu = 0.2$

i) For  $M_1$ ,  $T - \mu M_1 g = M_1 a \rightarrow (1)$

For  $M_2$ ,  $M_2 g - T = M_2 a \rightarrow (2)$

$$a = \frac{(M_2 - \mu M_1)g}{M_1 + M_2} = \frac{(0.45 - 0.2 \times 2)9.8}{2.45}$$

$$a = \frac{0.05 \times 9.8}{2.45} \quad \text{Or} \quad a = 0.2 \text{ m/s}^2$$

ii) Tension (T) =  $M_1(a + \mu g) = 2(0.2 + 0.2 \times 9.8)$   
 $= 0.4(1 + 9.8) = 0.4(10.8)$  T = 4.32N

iii)  $a = 0.2 \text{ m/s}^2$ ,  $t = 2\text{s}$

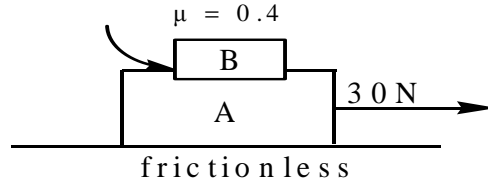
The velocity of the block before the string breaks,  $v = u + at$

$v = 0 + 0.2 \times 2 = 0.4 \text{ m/s}$ , after break if the block travels a distance  $s$ , then

$$K.E \Rightarrow \mu m g \cdot s = \frac{1}{2} m u^2$$

$$0.2 \times 2 \times 9.8 \cdot s = \frac{1}{2} \times 2 \times (0.4)^2 \Rightarrow s = \frac{(0.4)^2}{0.4 \times 9.8} = 0.041 \text{ m} = 4.1 \text{ cm}$$

12. On a smooth horizontal surface a block A of mass 10kg is kept. On this block a second block B of mass 5kg is kept. The coefficient of friction between the two blocks is 0.4. A horizontal force of 30N is applied on the lower block as shown. The force of friction between the blocks is (Taking  $g = 10 \text{ m/s}^2$ ).



A. Applied force  $F = (m_1 + m_2)a = (10 + 5)a \Rightarrow a = 2 \text{ m/s}^2$

Frictional force between two blocks is  $f = m_2 a = 5 \times 2 = 10 \text{ N}$