CH # 04 FORCE AND MOTION

DYNAMICS:

"The branch of physics that deals with the study of moving object with causes or reference of force is known as dynamics."

FORCE:

"Force is that agent which changes or tends to change the state of rest or of uniform motion of a body."

- Force is a vector quantity.

Unit:

S.I or M.K.S Unit of force is Newton (N).

INERTIA:

"The property of all material objects to oppose any change in their state of rest or of uniform motion is known as inertia."

NEWTON'S FIRST LAW OF MOTION OR LAW OF INERTIA:

STATEMENT:

"Everybody continues it's of rest or of uniform motion in a straight line unless it is acted upon by an external unbalanced force."

EXPLANATION:

From our daily life experience we know that if a body is moved it comes to rest after covering some distance.

Newton's first law predicts that the body must continue its motion along a straight line, but our observation seems to contradict Newton's law.

Actually the body comes to rest because of force of friction and air resistance etc. If there was no force of friction or air resistance then the body would have continued its motion along straight path with a constant velocity.

First law of Newton's also known as law of INERTIA.

EXAMPLE:

We know that book lying on a table remains at rest until someone picks it up (by applying some force).This is an accordance of Newton's first law.

NEWTON'S SECOND LAW OF MOTION:

STATEMENT:

"When an unbalanced force acts on an object it produced acceleration in its own direction which is directly proportional to the magnitude of the force and inversely proportional to the mass of the object."

MATHEMATICALLY:

If "F" is the magnitude of the force "a" is the acceleration produced in a body of constant mass in the direction of the applied force then the relationship between acceleration and force can be mathematically expressed as:

$$a \alpha F \_\_\_\_\_ \text{Eq (i}$$

$$a \alpha \frac{1}{m} \_\_\_\_\_ \text{Equ (ii}$$

By combining the above equations we get:

$$a \propto \frac{F}{m}$$

$$a = k.\frac{F}{m}$$

Where k is known as constant of proportionality and its value is 1.

$$a = \frac{F}{m}$$

$$F = ma$$

The direction of "a" and "F" is same.

UNIT OF FORCE:

The S.I or M.K.S Unit of force is NEWTON (N).

$$N = Kg\text{-}m/s^2$$

In C.G.S system Unit of force is DYNE.

$$10^5 Dyne = 1N$$

NEWTON'S THIRD LAW OF MOTION:

STATEMENT:

"For every action (force) there is an equal and opposite reaction (force)."

EXPLANATION:

Action and reaction are two forces exchanged between two bodies when they interact with each other.

EXAMPLE:

- Motion of a rocket.
- Our walking.
- Kicking of a football.
- Firing on a bullet, gun, and throwing a shell etc.

MASS:

"Mass is the quantity of matter present in a body."

- Mass is a scalar quantity.
- Mass is represent by "m".
- Mass is only scalar quantity which remains constant everywhere.

UNIT:

In S.I or M.K.S system unit of mass is Kilogram (Kg)

WEIGHT:

"The force with which earth attracts body towards its centre is called weight."

$$W = mg$$

- Weight is a vector quantity.
- It is directed towards the center of the earth.
- Weight is represented by "W".

UNIT:

In S.I or M.K.S system unit of Weight is Newton (N)

TENSION IN A STRING:

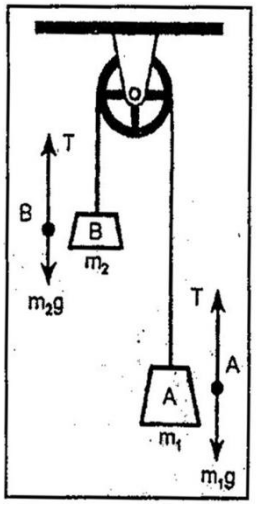
"The force exerted by a string when it is subjected to a pull is known as tension in a string."

MOTION OF BODIES CONNECTED TO STRING:

CASE NO 1: WHEN BOTH THE BODIES ARE MOVE VERTICALLY:

Consider two bodies of masses m_1 and m_2 connected with the ends of a string that passes over a frictionless and light pulley, such that both the bodies hang freely and can move vertically without touching anything.

Let m_1 be greater than m_2, hence the body of mass m_1 will move vertically downward with a certain acceleration "a" whereas the other body will move vertically upward with the same acceleration.



FORCES ACTING ON m_1 ARE:

i. Its weight $W_1 = m_1g$, acting vertically downward.
ii. Tension 'T' in the string acting vertically upward.

Since m_1 moves vertically downward with an acceleration 'a' therefore, $W_1 > T$.

Net force on m_1	=	$W_1 - T$
F	=	$W_1 - T$
m_1a	=	$W_1 - T$ = (2^{nd} law of motion)
m_1a	=	$m_1g - T$ (W = mg) _____ (1)

FORCES ACTING ON m_2 ARE:

i. Its weight $W_2 = m_2g$, acting vertically downward.
ii. Tension 'T' in the string acting vertically upward.

Since m_2 moves in the upward direction with an acceleration 'a', therefore $T > W_2$.

Net force on m_2	=	$T - W_2$
F	=	$T - W_2$
m_1a	=	$T - W_2$ (2^{nd} law of motion)
m_2a	=	$T - m_2g$(W = mg) _____ (2)

DERIVATION FOR ACCELERATION:

In order to drive a formula for acceleration 'a' with which m_1 moves vertically downward, add equation (1) & (2).

m_1a	=	m_1g	–	T
m_2a	=	$-m_2g$	+	T
$m_1a + m_2a$	=	m_1g	–	m_2g
$(m_1 + m_2)a$	=	$(m_1 + m_2)g$		

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

DERIVATION FOR 'TENSION':

Now dividing equation (1) and (2),

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

$m_2 (m_1 g - T) = m_1 (T - m_2 g)$

$m_1 m_2 g - m_2 T = m_1 T - m_1 m_2 g$

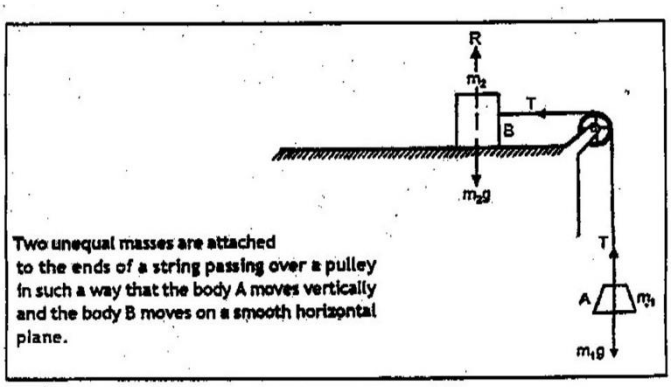
$m_1 m_2 g + m_1 m_2 g = m_1 T + m_2 T$

$2 m_1 m_2 g = T (m_1 + m_2)$

$$\boxed{T = \left(\frac{2 m_1 m_2}{m_1 + m_2}\right) g}$$

CASE NO 2: WHEN ONE OF THE BODY MOVES VERTICALLY DOWNWARD AND THE OTHERMOVES HORIZONTALLY:

Consider two bodies of masses m_1 and m_2 connected t the end of the string which passes over a frictionless pulley, such that 'm_1' hangs freely whereas 'm_2' is placed on smooth horizontal surface.



Two unequal masses are attached to the ends of a string passing over a pulley in such a way that the body A moves vertically and the body B moves on a smooth horizontal plane.

FORCES ACTING ON M_1 ARE:

i. Its weight $W_1 = m_1 g$, acting vertically downward.

ii. Tension 'T' in the string acting vertically upward.

Since m_1 moves vertically downward with an acceleration 'a' therefore, $W_1 > T$.

Net force on m_1 = $W_1 - T_1$

F = $W_1 - T_1$

$m_1 a$ (2^{nd} law of motion) = $W_1 - T$

$m_1 a$ = $m_1 g - T$ ($W = mg$) _____(1)

FORCES ACTING ON M_2 ARE:

i. Its weight $W_2 = m_2 g$, acting vertically downward.

ii. Tension 'T' in the string acting towards the pulley.

Since m_2 does not move vertically, therefore forces in vertical direction balances each other.

Net force on m_2 = Tension

F = T

T = $m_2 a$ (2^{nd} law of motion)_____(2)

DERIVATION OF 'ACCELEARTION':

Adding equation (1) and (2) we get:

$m_1 g - T = m_1 a$

$T = m_2 a$

$m_1 g = m_1 a + m_2 a$

$m_1 g = a (m_1 + m_2)$

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

DERIVATION OF 'TENSION':

Substituting the expression for 'a' in equation (2)

$T = m_2 a$

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

$$\boxed{T = \left(\frac{m_1 m_2}{m_1 + m_2}\right) g}$$

MOMENTUM:

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

OR

"The quantity of motion present in a body is called momentum"

FORMULA:

Momentum = mass x Velocity

$$\boxed{\vec{P} = m\vec{V}}$$

- Momentum is a vector quantity.
- Momentum is represented by "P.

UNIT:

In S.I system unit of Momentum is Kilogram meter per second (Kg-m/s) or Newton Second (N-S)

EXAMPLES OF MOMENTUM:

1. **Loaded Cart:**
   It is more difficult to stop loaded cart than the unloaded cart moving with the same velocity. Thus the heavier body possess greater quantity of motion.

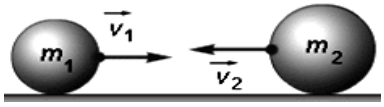
2. **Balls moving with different velocities:**
   We want to stop two identical balls moving with different velocities. We have to apply greater force to the ball moving with greater velocity than the ball moving with lesser velocity. Thus the ball moving with greater velocity posses greater quantity of motion.

LAW OF CONSERVATION OF MOMENTUM:

STATEMENT:

"The total momentums of an isolated system of bodies always remain constant."

EXPLANATION:



Consider a system of bodies consisting of two balls A and B of mass m_1 and m_2 moving in a straight line, with velocities U_1 and U_2. On colliding with each other they move with velocities V_1 and V_2 respectively as shown in figure.

Momentum of the system before collision = $m_1U_1+m_2U_2$
Momentum of the system after collision = $m_1V_1+m_2V_2$

According to law of conservation of momentum:
Total momentum before collision = Total momentum after collision

$$\boxed{m_1U_1+m_2U_2 = m_1V_1+m_2V_2}$$

APPLICATIONS/EXAMPLES OF LAW OF CONSERVATION OF MOMENTUM:

1. **Balloon:**
   If a balloon is blown up and released it flies around the room. During the flight, air escape from the balloon in one direction while it move in the opposite direction. This is due to the law of conservation of momentum of the system of the air and balloon.

2. **Recoil of gun:**
   When a bullet fired from the recoil of the gun is due to the conservation of momentum of the system consisting of the gun and the bullet.

3. **Molecules of a gas:**
   Molecules of a gas at constant temperature obey the law of conservation of momentum.

FRICTION:

"The force which opposes the motion of one surface over another is known as the force of friction"

TYPES OF FRICTION:

There are two major types of friction.

1. STATIC FRICTION:

"The force of friction between the stationary body and the surface is called static friction."

- **LIMITING FRICTION:**

  "The maximum value of force of friction is called limiting friction."

Limiting friction "F" is directly proportional to the normal reaction "R".

$$F \propto R$$

$$F = \mu R$$

Where μ (meu) is known as co-efficient of friction.

- **CO-EFFICIENT OF FRICTION:**

"The ratio between Friction and normal reaction is known as co-efficient of friction."

$$\mu = \frac{F}{R}$$

2. KINETIC FRICTION:

"The force of friction between the moving body and the surface on with its move is called kinetic or sliding friction."

TYPES OF KINETIC FRICTION:

i) SLIDING FRICTION:

"The force of friction between the moving body and the surface on with its move is called sliding friction."

ii) ROLLING FRICTION:

"When a body rolls on a surface its experience an opposition. This opposition is called rolling friction."

ADVANTAGES OF FRICTION:

i. Friction helps us in walking.
ii. Force of friction between the road and the tires provide the necessary propelling force.
iii. To stop a moving car it brakes are applied which produce a large force of friction.
iv. Proper friction between our joints helps us in many ways.

DISADVANTAGES OF FRICTION:

i. Friction between different moving parts of a machine wastes lots of useful energy.
ii. Friction between parts of machines raises its temperature which may be harmful if necessary precautions are not taken.
iii. Friction causes wear and tear of different parts of machine, thus reducing its life.

METHOD OF REDUCING FRICTION:

There are two different ways of reducing friction.

a) Use of ball or roller bearings:

- In machines, the sliding of various parts is usually replaced by rolling and this is done by using ball bearings. Rolling friction is less than the sliding friction.

b) Use of lubricants:

- The various parts of the machine which are moving one another are properly lubricated.
- The presence of dust of liquid keep the sliding surfaces separated from each other which reduces the friction.

c) Oblong front:

- The front of the fast moving object e.g. cars, aeroplanes, are made oblong to minimize friction.

d) By Use of Chalk powder:

The friction in different sliding surface can be reduced by putting fine chalk powder or any powder between them.