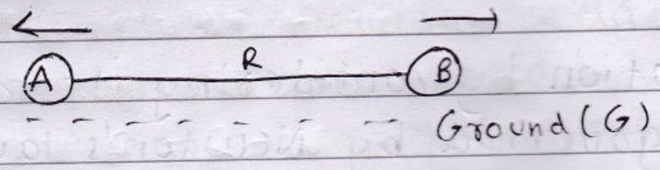
Tug of war



(i) $F_{RA} - F_{AR}$ (iii) $F_{AG} - F_{GA}$
(ii) $F_{RB} - F_{BR}$ (iv) $F_{BG} - F_{GA}$

Linear Momentum

- $p = mv$
- It is a vector quantity.
- Unit is $kgms^{-1}$ or NS.
- It is the total quantity of motion.
- Explains amount of force a body can apply (in motion) when it collides.

$p = mv$, where mass is constant
Thus change in momentum is due to change in velocity.
~~veto~~ change in velocity is due to change in force.

Newton's second law

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

$\therefore F = dp/dt$
$= dmv/dt$
$= m\, dv/dt$ [m is constant]
$= ma$

$\therefore$ Force is the rate of change of linear momentum.

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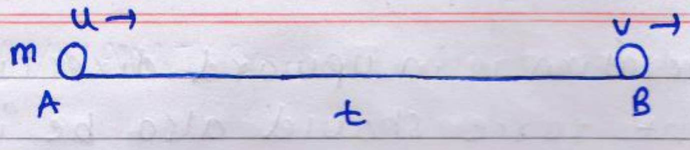


$$F = \frac{mv - mu}{t} = m.\frac{v-u}{t} = ma$$

∴ The product $Ft = mv - mu$, is called the impulse of the force.

∴ SI unit of linear momentum is also Ns (Ft).

$$F = dp/dt$$

∴ $dp = F dt$

∴ For constant change in momentum, when change in time is high; force is less. Thus cricketers lower hand increasing time of impact when catching a ball.

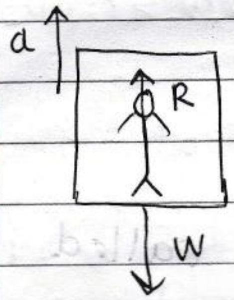
Use of $F = ma$

- F is resultant force in N, m is in kg and a is in m/s^2
- F, p and dp are all in same direction.
- Concept of free body diagrams where we consider a single body at a time and show forces acting on a body.

\# Lift moves with $2 m/s^2$ acceleration. Calculate reaction of floor on man of 50 kg mass standing in lift when lift is

(i) moving upwards

- Forces acting ÷ weight of man downwards
  Reaction force / normal contact force due to lift upwards (R)

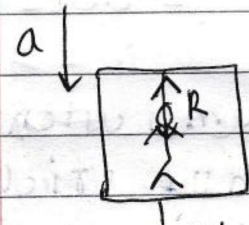


As acceleration is in upward direction, resultant force should also be in upward direction. For this $R > W$.

$F = R - W$

or, $R = F + W = mg + ma = 50(2 + 9.81) = 590.5 \approx 590\,N$

(ii) moving down

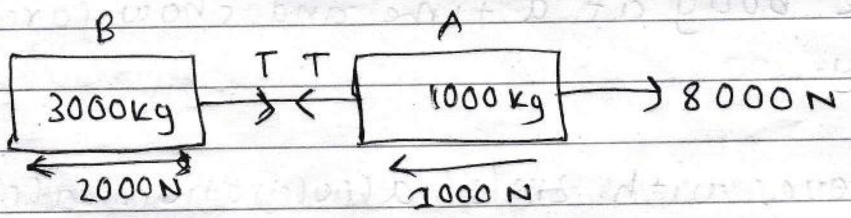


As acceleration is in downward direction, resultant force must also be in same direction. For this $W > R$

$F = W - R$

or, $R = W - F = 50(9.81 - 2) = 390.5 \approx 390\,N$

\# A truck A of mass 1000kg is pulling trailer of mass 3000 kg on a road. Frictional force on A is 1000N and on B is 2000 N, engine exerts 8000N force. Calculate a on truck & trailer and tension on tow bar,



\#Note :- Tension on A is towards trailer B, while tension on B is towards A.

Considering both bodies as one.

$m = 4000\,kg$

$F = 8000 - 2000 - 1000 = 5000\,N$

$F = ma$

or, $a = 5000/4000$

$\therefore a = 1.25\,m/s^2$

Now considering B

$F = T - 2000$

$m = 3000$

$a = 1.25\,m/s^2$

$F = ma$

$T - 2000 = 3000 \times 1.25$

$T = 5750\,N$

21st Nov 2021

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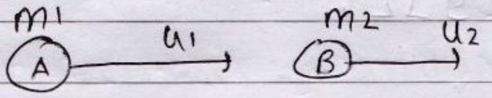
Principle of conservation of linear momentum.

If no resultant (unbalanced) force acts on a system, the total linear momentum of the system remains constant.

If $F = 0$, $dp/dt = 0$, [$dp = 0$, $dt = \infty (\times)$]

$\therefore$ p is constant (Derivative is 0).

For coliding objects



Force on A due to B

$$F_{AB} = \frac{dp_A}{dt} = \frac{m_1 v_1 - m_1 u_1}{t}$$

$$F_{BA} = \frac{dp_B}{dt} = \frac{m_2 v_2 - m_2 u_2}{t}$$

From third law, $F_{AB} = -F_{BA}$

$m_1 v_1 - m_1 u_1 = m_2 u_2 - m_2 v_2$

$\therefore$ $m_1 v_1 + m_2 v_2 = m_1 u_1 + m_2 u_2$

$\therefore$ Total momentum after collision = Total momentum before collision

Vector sum of momentum

29th Nov 2021

Collision

- Interaction between objects for a short interval of time.
- There are forces (normally large) acting between objects.
- There is change in velocity, momentum & Kinetic energy.

Inelastic collision : Total linear momentum is conserved but kinetic energy is not conserved, it is converted.

Elastic collision : Both linear momentum and kinetic energy are conserved.

Relative velocity, elastic collision

$\overrightarrow{V_{AB}} = \overrightarrow{V_A} - \overrightarrow{V_B}$

where $\overrightarrow{V_{AB}}$ is the relative velocity of A with respect to B

$m_1v_1 + m_2v_2 = m_1u_1 + m_2u_2$

$\therefore m_1(v_1 - u_1) = m_2(u_2 - v_2)$ --- (i)

$\frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 = \frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2$

$\therefore m_1(v_1^2 - u_1^2) = m_2(u_2^2 - v_2^2)$ ---(ii)

$$\frac{\cancel{m_1}(v_1^2 - u_1^2)}{\cancel{m_1}(v_1 - u_1)} = \frac{\cancel{m_2}(u_2^2 - v_2^2)}{\cancel{m_2}(u_2 - v_2)}$$

a. $v_1 + u_1 = u_2 + v_2$

$\therefore u_1 + v_1 = u_2 + v_2$

$u_1 - u_2 = v_2 - v_1$

$\therefore u_{12} = v_{21}$

$\therefore$ Relative velocities are equal.