Force and Laws of Motion

✓ push & pull, pressing, lifting, stretching are effects

→ Force is an external agent or cause capable of changing the state of rest or motion of a particular body once applied on it

Eg - lifting a weight; stretching a Rubber band; Pressing a button

Force is a vector qty

Types of forces

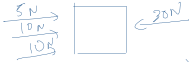
Resultant/net force :- Summation of all the forces being applied on the body.

Balanced forces :- If the resultant of all the forces acting on a body is zero, the forces are called balanced force.

Unbalanced forces :- If the resultant forces acting on the body is not zero, the forces are called unbalanced force.

Q. Type of force resultant acts direction

Rf : 30+20 - 40
= 50 - 40 = 10N



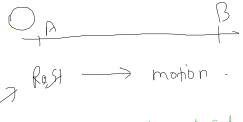
Rf : (5+10+10 - 30) = -5N

2) Find the value of x in the balanced force system.

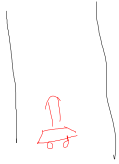
3) Find the value of x if system is an unbalanced force system, with resultant force equal to 23 units towards left

10 + 2x - 46 = -23
2x - 36 = -23
2x = 13
x = 13/2 = 6.5

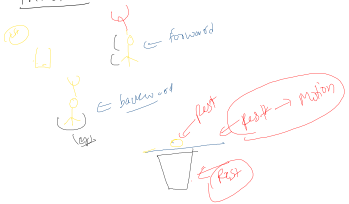
Newton's 1st law of motion



→ A body at rest will remain at rest and a body in motion will continue in motion in a straight line with a uniform speed, unless it is compelled by an external unbalanced forces to change its state of rest or of uniform motion.



Inertia



The tendency of a body due to which it resists a change in its state of rest or of uniform motion.

→ Why it is recommended to wear Seat belt in the car ? & if you wear & if you don't what will be the consequences ?

6.20

✓ Greater the inertia of a body, greater will be the force required to bring a change in its state of rest or of motion.

✓ Heavier the body, the more will be its inertia.

Law: The rate of change of momentum of a body is directly proportional to the applied force, and takes place in the direction in which the force acts.

Momentum

Force required to move bag rock >>> wooden block

$F \propto m$

$m \uparrow$ $F \uparrow$

(cricket ball) → throwing of ball through hand → $v \uparrow$ (mass of the ball remain same)

tennis racket hit the ball → $v \uparrow \uparrow$

$F \propto v$

$F \propto mv$

✓ $F \propto P$ (momentum)

Momentum: Momentum is defined of a body as the product of its mass & velocity.

✓ It is a vector quantity.

✓ SI unit – $kg\,ms^{-1}$

Q) What is the P of a man of m 75000 gm when he walks with a uniform velocity of 18 km/hr.

Velocity = ms^{-1}, momentum = $kg\,ms^{-1}$ (S.I.)

$m = 75000\,gm$

$m = 75\,kg$

$v = 18\,km\,h^{-1} \times \frac{5}{18} = 5\,ms^{-1}$

ms^{-1} : $\frac{18\,km}{1\,hr} = \frac{18 \times 1000\,m}{60 \times 60\,sec}$

$P = 75 \times 5 = 375\,kg\,ms^{-1}$

Q An object's momentum is $80\,kg\,ms^{-1}$ & its mass is 16000 g, Find the velocity of object.

$kg\,ms^{-1} \to P = mv$

$80 = \frac{16000}{1000}\,kg \times v$

$\frac{80}{16} = v$ ($5\,ms^{-1}$)

Q Calculate momentum

i) A truck of mass 2000 kg moving at $5\,ms^{-1}$

ii) A bullet of mass 0.02 kg " at $400\,ms^{-1}$.

$m \times v$

$400 \times 2 / 100$

$= 8\,m$

Q What is the change in momentum of a car weighing 1500 kg when its speed increases from 36 km/hr to 72 km/hr uniformly.

$\Delta V = V_f - V_i$

$72 \times \frac{5}{18} = 20$

$\Delta P = mV_f - mV_i$

$= m(V_f - V_i)$

$= 1500(20 - 10) = 15000\,kg\,ms^{-1}$

Newton's Second law of Motion

$F \propto \frac{1}{t}$

Case I: $u = 0$, 2 kg, $v = 5\,m/s$

$\Delta P = P_f - P_i$

$= mv - mu$

$= m(v - u)$

$= 2(5 - 0)$

$= 10\,kg\,ms^{-1}$

Case II: $u = 0$, 2 kg, $v = 10\,m/s$

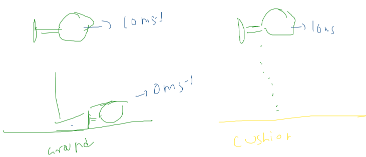
More force applied → $20\,kg\,ms^{-1}$

$2(10 - 0)$

$= 20\,kg\,ms^{-1}$

$F \propto$ change in momentum

More the force more will be change in momentum.



✓ Change in momentum $\propto$ Force.

✓ $F \propto \frac{1}{t}$

✓

Time ↓ change in momentum ↑ Force ↑

Time ↑ change in momentum ↓ Force ↓

$F \propto \frac{1}{t}$

t = time at which momentum velocity change.

$F \propto \frac{P}{t}$

$F \propto \frac{m(v - u)}{t}$ $\left(a = \frac{v - u}{t}\right)$

$F \propto ma$

$F = kma$ (k = proportionality constant i.e. value 1, of k in SI units)

Force = mass × acc^n

Newton's 2nd law of motion numericals

1) What force would be needed to produce an acc^n of 6 m/s^2 in a ball of mass 1/2 kg ?

$a = 6\ m/s^2$

$m = \frac{1}{2}\ kg$

$F = 3\ N$

2) What is the acc^n produced by a force 34 N exerted on an object of mass 17000 g ?

$F = ma$ (Newton's 2nd law)

$34 = 17 \times a$

$a = \frac{34}{17} = 2\ m/s^2$

Ignoring 1 kg = 1000 g

3) Two objects of mass 5 kg and 8 kg are at rest. F_1 & F_2 are the forces applied on the both, if the speed of both the objects after 10 seconds become 10 m/s & 20 m/s, find the value of $F_1 - F_2$

m_1 (5 kg), m_2 (8 kg)

F_1, F_2

$u_1 = 0$, $u_2 = 0$

$v_1 = 10$, $v_2 = 20$

$t = 10$ sec, $t = 10$ sec

$F_1 - F_2$

$m_1 a_1 - m_2 a_2$

$m_1 \left(\frac{v_1 - u_1}{t}\right) - m_2 \left(\frac{v_2 - u_2}{t}\right)$

$5\left(\frac{10 - 0}{10}\right) - 8\left(\frac{20 - 0}{10}\right)$

$\frac{50}{10} - \frac{160}{10}$

$= -11\ N$

4) Calculate the force required to impart to car a velocity of 30 m/s in 10 sec starting from rest, the mass of the car 15×10^3 g

$u = 0$, $v = 30\ m/s$

$t = 10$ sec

$m = 15 \times 10^3$ g

1000 g = 1 kg

$m = 15000$ kg

$F = ma$

$= m\left(\frac{v - u}{t}\right)$

$= 1500\left(\frac{30 - 0}{10}\right)$

$= 1500\ N$

Newton's 3rd law of motion.

football → motion

force

Q When you are walking ?

Swimming

→ Whenever one body exerts a force on another body, the second body exerts an equal & opposite force on the first body.

→ Force exerted by first body is action

→ Force " " second " " reaction.

→ Every action has an equal & opposite reaction.

Application:

i) Why the gun recoils ?

Gun → bullet ← Rest → motion

Force

$F_{GB} = -F_{BG}$

Gun should recoil with the same velocity as bullet, but it didn't happened ?

Newton's 2nd law

↓ law of motion

$F = ma$

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

$m \uparrow$ $a \downarrow$

Mass of bullet << Mass of gun

Gun recoil velocity ?

Conservation of momentum

→ When two bodies act upon one another their total momentum remains constant provided no external forces are acting on it.

$P = mv$

Let the velocities before collision be u_1 and u_2 respectively.

Let the velocities after collision be v_1 and v_2 respectively.

Masses will remain same after the collision

Initial momentum = $m_1u_1 + m_2u_2$

Final momentum = $m_1v_1 + m_2v_2$

$F_{AB} = F_{BA}$

$m_1a_1 = -m_2a_2$

$m_1\left(\frac{v_1 - u_1}{t}\right) = -m_2\left(\frac{v_2 - u_2}{t}\right)$

$m_1v_1 - m_1u_1 = m_2u_2 - m_2v_2$

$\boxed{m_1v_1 + m_2v_2 = m_2u_2 + m_1u_1}$

Total momentum before Collision = Total Momentum after Collision

Q) Car A of mass 1500 kg, travelling at $25\ ms^{-1}$ collides with another car B of mass 1000 kg travelling at $15\ ms^{-1}$ in the same direction. After collision the velocity of car A becomes $20\ ms^{-1}$. Calculate the velocity of car B after the collision.

✓ ✓ ① $F_{AB} = -F_{BA}$

② $P_i = P_f$

A: $m_1 = 1500kg$, $u_1 = 25ms^{-1}$, $v_1 = 20ms^{-1}$

B: $m_2 = 1000kg$, $u_2 = 15ms^{-1}$, $v_2 = ?$

Q) A bullet of mass 10g is fired from a gun of mass 6 Kg with a velocity of $300\ ms^{-1}$. Calculate the recoil velocity of the gun.

→ Gun ← Bullet

$m_1 = 10g$ $m_2 = 6kg$

$u_1 = 0$ $u_2 = 0$

Law of cons

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$0 = 0.01 \times 300ms^{-1} + 6v_2$

$0 = 3 + 6v_2$

$-3 = 6v_2$

$v_2 = -0.5\ ms^{-1}$