GRAVITY CLASSES

"Come Gravity Feel Success"

11th & 12th BOARD (NEET & JEE)

5th - 10th (All Subject)

NOTES PHYSICS

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FORCE AND LAWS OF MOTION

➢ **Introduction:-**
→ Definition of Force.
→ Types of Force (Balanced, Unbalanced).
→ Newton's First Law of Motion. (Move to Stop)
→ Inertia.
→ Momentum. (Mass × Velocity)
→ Newton's Second Law of Motion. (Bikejerk can jerk)
→ Newton's Third Law of Motion. (Rocket, Swim, Walk)
→ Conservation of Momentum.
→ Numericals.

➢ **Force:-** There is no clear definition of force.

- Pushing, Pulling, Lifting, Stretching, Twisting and Pressing are effects.
- Froce is an external agent or cause capable of changing the state of rest or motion of a particular body once applied. Ex. Weightlifter lifting a weight, pushing a Box, Pulling a Door, Stretching a Rubber Band.
- Effects of Force:- Ex. Football

→ Can change the Direction.
→ Can change the Motion.
→ Can Accelerate the body.
→ Can make a motion object at Rest.
→ Can change the shape and size.

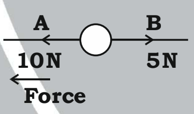
- Force:- Force is a Vector Quantity (Mag. and Direction).
  Ex. Opening Bottle cap, Two Boy pulling 10 N of Force.
- Force a Magnitude.

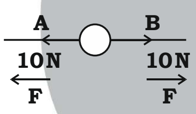
➢ **Types of Forces:-**

(i) Balanced Forces:- If the resultant/wet force of all the forces acting on a body is zero the forces are called balanced force.

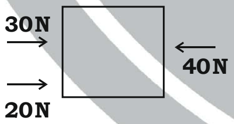
(ii) Unbalanced Forces:- If the resultant forces acting on the is not zero, the forces are called unbalanced force.

Ex.-





Q. Find the resultant force.

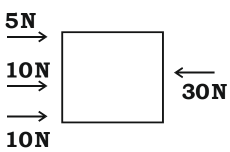


Sol. Resultant Force

$(R_f) = 50N + (-40N)$

$= 10N$

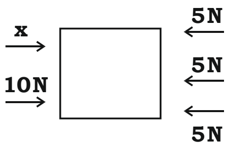
Q.



Sol. $(R_f) = 25N + (-30N)$

$= -5N$ (-ve indicates that force is exerted toward left side)

Q. Find the value of x in the balanced force system.



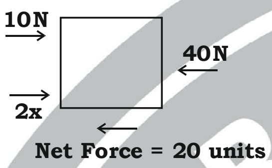
Sol. A/Q Balanced force, So $R_f = 0$

So, L.H.S = R.H.S

$x + 10 = 5 + 5 + 5$

$\boxed{x = +5N}$

Q. Find the value of x if system is an unbalanced force system with resultant force equals to 20 units towards left.

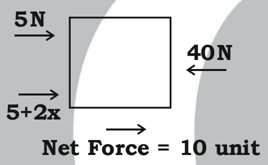


(Unbalanced Force)

Sol. $10 + 2x + (-40) = 20$

$\boxed{x = 25}$

Q. Find the value of x in an unbalanced force system, if resultant force is 10 units towards right.



Sol. $5 + 5 + 2x + (-40) = 10$

$\boxed{x = 20}$

- **Newton's First 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 force to change its state of rest or of uniform motion. Ex.- Ball in Rest (Unless we kick), Car moving continuously (unless rought surface).
- **Inertia:-** The tendency of a body due to which it resists a change in its state of rest or of uniform motion is called Inertia.

  Ex.- Bus on Rest and Start.

- Bus is running and suddenly stop.
- A coin on a card on a glass suddenly pull the card.
- Make to and fro motion with tree (fruits and leaf dettached from tree).
- Hit hanging doormat with Rod dust remove from mat.
- When we not use Seatbelt.

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

→ Mass is a quantitative measure of the inertia of a body.

→ Heavier the body more will be its inertia. Ex.- We can easily move the trolly but not Elephant or Rock.

- **Momentum:-** From Elephant and Trolly we can say.

$\boxed{F \propto m}$

Hitting Ball through Racket and the Same Ball (100g) through free Hand.

So, Velocity with Racket is ↑

Velocity with Free Hand is ↓

So,

$$\boxed{F\uparrow \propto v\uparrow}$$

Now,

$F \propto V$

$F \propto m$

So, $\boxed{F \propto m \times V}$

- Both the quantities are required for the force to be applied.

$$\boxed{F \propto p(\text{momentum})}$$
↓
Force

Momentum:-

→ Momentum is defined of a body as the product of its mass and velocity.

→ It is a vector quantity.

→ S.I. unit $= kg.ms^{-}$

$p = m \times V$

$kg \times ms^{-}$

Q. What is the p (momentum) of a man of mass 75 kg when he walks with a uniform velocity of 2 m/s.

Sol. We know,

$p = m \times V$

$= 75 \times 2$ $\quad [\because m \rightarrow kg, v \rightarrow ms^{-}]$

$p = 150\, kg\, ms^{-}$

Q. An object's momentum is 80 kg m/s and its mass is 1600 G. Find the velocity of the object.

Sol. Given Data V = ?

$p = 80\, kg\, m/s$

$m = 16000\, g$

$m = \frac{16\cancel{000}}{1\cancel{000}} kg = 16\, kg$

We know,

$p = m \times V$

$80 = 16 \times V$

$$\boxed{V = 5\, m/s}$$

Q. Calculate the momentum of the following.

(a) An elephant of mass 2000 kg moving at 5 m/s.

(b) A bullet of mass 0.02 kg moving at 400 m/s.

Sol.(a) $p = m \times V$

$p = 2000 \times 5$

$$\boxed{p = 10000\, kg\, m/s}$$

(b) $p = m \times V$

$= 0.02 \times 400$

$\boxed{p = 8 \text{kg m/s}}$

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

Sol. We know, $\Delta V = V_f - V_i$

In the same fashion

$\Delta p = p_f - p_i$

$\Delta p = mV_f - mV_i$

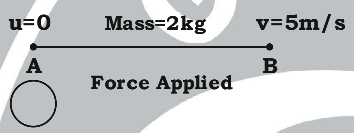
$= m(V_f - V_i)$ $[\because \text{m is constant}]$

$= 1500(20 - 10)$

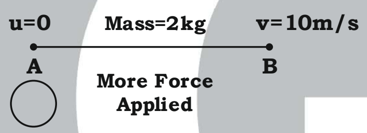
$\boxed{\Delta p = 15000 \text{kg m/s}}$

- **Newton's Second Law of Motion:-**

Case-I



Case-II



Change in momentum can be calculated as:

→ Case-I → As we know,

$\Delta V = V_f - V_i$

So, (Change in momentum)

$\Delta p = p_f - p_i$

$= mV_f - mV_i$ $[\text{Case} - \text{I} \rightarrow V_i = 0,\ V_f = 5 \text{m/s}]$

$= m(5 - 0)$

$\boxed{\Delta p = 10 \text{kg ms}^{-1}}$ or 10kg m/s

→ Case-II

$\Delta p = p_f - p_i$

$= mV_f - mV_i$

$= m(10 - 0)$

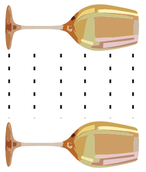
$\boxed{\Delta p = 20 \text{kg ms}^{-1}}$ or 20kg m/s

- Hence Proved

$\boxed{\text{Force} \propto \text{Change in Momentum}}$

Note:- More the force more will be change in momentum.

→ **Case-I- Glass Falling on ground.**



So, Change in momentum

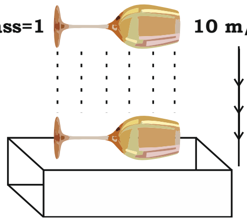
$$\Delta p = m(V_f - V_i)$$

$$= 1(0-10)$$

$$\boxed{\Delta p = 10 kg\, m/s}$$

• Less ↓ time taken more ↑ force exerted.

→ **Case-II-Glass falling on Cusion/Foam.**



So,

$$\Delta p = m(V_f - V_i)$$

$$= 1(2-10)$$

$$\boxed{\Delta p = 8 kg\, m/s}$$

• More ↑ time taken Less ↓ Force exerted.

Note:- We can easily compare the change in momentum in both the cases. In case-II the velocity glass in gradually decreasing the resultant Δp also decreases and finally force will be zero. As we know $\boxed{F \propto \Delta p}$ above.

More Example:-

→ Cricketer take their hand back at the time catching a Ball.

→ Atheletes lands on the sand because gradually velocity decrease so the change in momentum (Δp) also decreases and finally force will also be decreased.

So, from previous glass cases we can say.

$$\boxed{\text{Force} \propto \frac{1}{t(\text{time})}}$$

Where,

t = time at which momentum velocity changes.

Now come to conclusion.

$$F \propto \Delta p$$

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

So, $\boxed{F \propto \frac{\Delta p}{t}}$

$$F \propto \frac{mV_f - V_i}{t}$$

$$F \propto \frac{m(V_f - V_i)}{t} \qquad \left[\text{We know from Motion Equation } v = u + at, \boxed{a = \frac{v-u}{t}}\right]$$

$$F \propto \frac{m(V_f - V_i)}{t}$$

$$F \propto \frac{m(v-u)}{t} \qquad [v = \text{final velocity}, u = \text{initial velocity}]$$

$$F \propto m\left[\frac{v-u}{t}\right]$$

$$F \propto m.a$$

$$F = kma$$

Where, K = Proportionality constant i.e. value of K in S.I. unit is 1.

Now,

$$F = 1ma$$

$$\boxed{F = m \times a}$$

Where,

F = Force (Newton)

m = Mass (kg)

a = Acceleration (m/s^2)

- **Newton's Second Law of Motion:-** 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.

i.e. $\boxed{F \propto \frac{\Delta p}{t}}$

- **Numerical:-**

Q. What forces would be needed to produce an acceleration of 4 m/s^2 in a ball of mass 6 kg?

Sol. Given Data a = 4 m/s, m = 6 kg.

We know, Newton's 2nd Law of Motion.

$$F = m \times a$$

$$\boxed{F = 6 \times 4}$$

$$\boxed{F = 24 N}$$

Q. What is the acceleration produced by a force of 12 Newton's exerted on an object of mass 3 kg?

Sol. Here,

Force (F) = 12 N

Mass (m) = 3 kg

Acceleration (a) = ?

We know that,

$$F = ma$$

$$12 = 3 \times a$$

$$\boxed{a = 4 m/s^2}$$

Q. Two objects of mass 5 kg and 8 kg are at rest F_1 and F_2 are the forces applied on both the respectively. If the speed of both objects after 10 second become 10 m/s and 20 m/s. Find the value of F_1 and F_2.

Sol.

1	**2**
F_1	F_2
$m_1 = 5 kg$	$m_2 = 8 kg$
$u_1 = 0$	$u_2 = 0$
$t = 10 sec$	$t = 10 sec$
$V_1 = 10 m/s$	$V_2 = 20 m/s$

We know,

$$F_1 = m_1\left(\frac{V_f - V_i}{t}\right) \qquad F_2 = \frac{m_2(V_f - V_i)}{t}$$

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

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

$$\boxed{F_1 = 5\,N} \qquad\qquad \boxed{F_2 = 16\,N}$$

- We can also find acceleration in both case from Motion Equation.

$$v_1 = u_1 + a_1 t \qquad\qquad v_2 = u_2 + a_2 t$$

$$10 = 0 + a \times 10 \qquad\qquad 20 = 0 + a_2 \times 10$$

$$10 = 10\,a \qquad\qquad 20 = 10\,a_2$$

$$\boxed{a = 1\,m/s^2} \qquad\qquad \boxed{a_2 = 2\,m/s^2}$$

Q. Calculate the force required to impart to car a velocity of 30 m/s in 10 seconds, starting from rest. The mass of the car is 1500 kg.

Sol. Given

Mass (m) = 1500 kg

Initial Velocity (u) = 0 (Car starts from Rest)

Final Velocity (v) = 30 m/s

Time (t) = 10 sec.

We know,

~~$v = u + at$~~

$$F = m \times a$$

$$v = u + at$$

$$30 = 0 + a \times 10$$

$$a = 3\,m/s^2$$

Now, putting $a = 3\,m/s^2$ in force.

$$F = m \times a$$

$$= 1500 \times 3$$

$$\boxed{F = 4500\,N}$$

➢ **Newton's Third Law of Motion:-** Whenever one body exerts a force on another body the second body exerts an equal and opposite force on the first body.

- Force exerted by the first body is action.
- Force exerted by the second body is reaction.

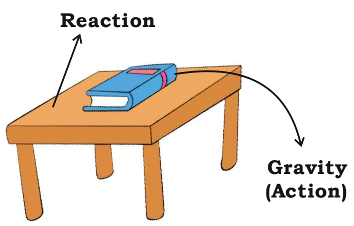
→ Every action has an equal and opposite reaction.

Ex.- Walking on earth, Land (Action Force).

→ Walking on treadmill. (Reaction Force).

→ Swimming.

→ Jumping from boat to land. Boat went backward and person body moved to land. (Person applied action force on Boat and same amount of force applied reaction force to the person by Boat).



Application of 3rd Law:-

Q. Why the gun recoils?

- When bullet is fired from the gun force sending the bullet forward is equal to the force sending the gun backward.

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

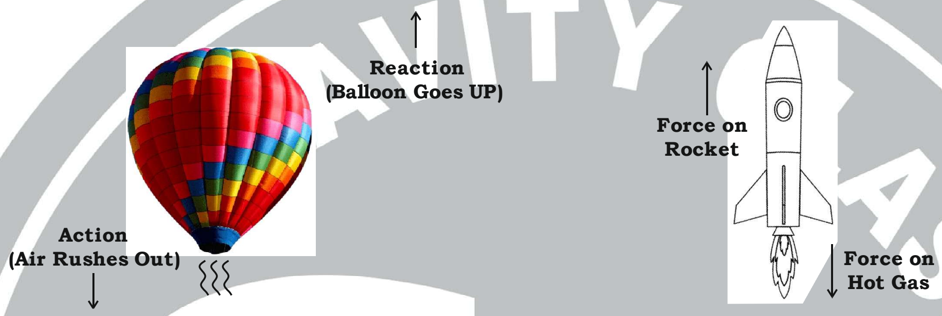
- Amount is same but directions are opposite.

$$\boxed{M_B < M_G} \qquad \left[\because F = ma, m = \frac{F}{a}\right]$$

(Acceleration of gun is less than the acceleration of Bullet).

- Gun moves only a little distance backward and gives a backward jerk to the shoulder/hand of the gunman.

Q. The flying of Jet Aeroplane and Rocket.

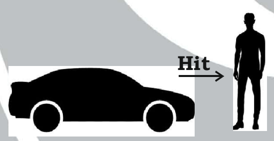


- In jet aircraft the hot gases obtained by buming of fuels, rush out of a jet at rear end of the aircraft at a great speed.
- The equal and opposition reaction of the backward going gases pushes the aircraft forward at a great speed.

➢ **Law of Conservation of Momentum:-** It states that "sum of Total Momenta (plural of momentum) of both the bodies before and after collision remains same".

- In other words total momentum of the two object is conserved even after the collision.

Ex.- Suppose there are two object A and B. Both object collide with each other.

(i) 

(ii) 

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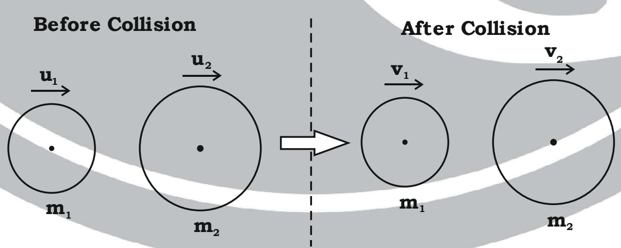
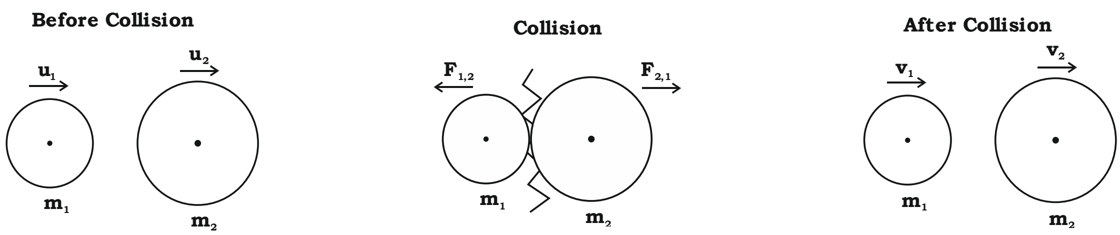




It is originated from Newton's 3rd Law of Motion.

$F_{1,2} = -F_{2,1}$ (−ve because force is a vector Q)

$m_1a_1 = -m_2a_2$ $[\because F = ma]$

$m_1\left(\frac{v_1 - u_1}{t_1}\right) = -m_2\left(\frac{v_2 - u_2}{t_2}\right)$ $\left[\because a = \frac{v-u}{t}\right]$

$m_1\left(\frac{v_1 - u_1}{t_1}\right) = -m_2\left(\frac{v_2 - u_2}{t_2}\right)$ $[\because$ Collision happens in same time$]$

$m_1\left(\frac{v_1 - u_1}{\cancel{t_1}}\right) = -m_2\left(\frac{v_2 - u_2}{\cancel{t_2}}\right)$

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

$m_1v_1 - m_1u_1 = -m_2v_2 + m_2u_2$

$m_1v_1 + m_2v_2 = m_1u_1 + m_2u_2$

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

↓ ↓ ↓ ↓

p_{1i} + p_{2i} + p_{1f} + p_{2f}

$p_{1i} \rightarrow$ Momentum of 1st body at initial.

$p_{2i} \rightarrow$ Momentum of 2nd body at initial.

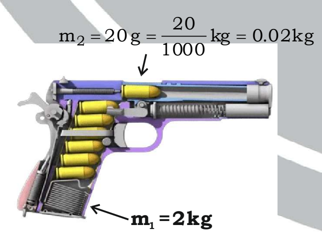
$p_{1f} \rightarrow$ Momentum of 1st body at initial.

$p_{2f} \rightarrow$ Momentum of 2nd body at final.

$p_{i(1)} + p_{i(2)}$	=	$p_{f(1)} + p_{f(2)}$
Sum of Initial Momentum of two bodies.	=	Sum of Final Momenta of both the bodies
(Before Collision)		(After Collision)

➢ **Numerical:-**

Q. A bullet of mass 20 g is horizontally fired with a velocity 150 ms^{-1} from a pistol of mass 2 kg. What is the recoil velocity of the pistol?



Sol. Given,

$u_1 = 0$

$u_2 = 0$

$v_1 = ?$ (Recoil Velocity)

$v_2 = 150\,m/s$

→ There is a collision so we use conservation of momentum.

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

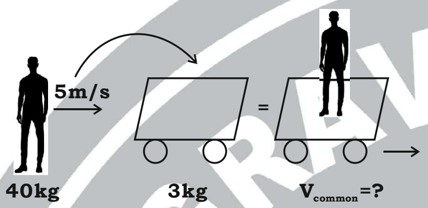
$$2\times 0 + 0.02\times 0 = 2\times v_1 + 0.02\times 150$$

$$0 + 0 = 2\times v_1 + \frac{0.02\times 150}{100}$$

$$v_1 = \frac{-3}{2}$$

$$\boxed{v_1 = -1.5\,m/s}$$ [−ve sign shows −ve x-axis direction]

Q. A girl of mass 40 kg jumps (Common Velocity) with a horizontal velocity of 5 ms^{-1} onto a stationary cart with frictionless wheels. The mass of the cart is 3 kg what is her velocity as the cart start moving?



Sol. $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$m_1u_1 + m_2u_2 = m_cv_c + m_cv_c$ [∵ cart and girl are in same position]

$$40\times 5 + 3\times 0 = v_c(m_1 + m_2)$$

$$200 + 0 = v_c(40 + 3)$$

$$\boxed{v_c = \frac{200}{43} = 4.65\,m/s}$$

Q. From a rifle of mass 4 kg a bullet of mass 50 g is fired with an initial velocity of 35 m/s. Calculate the initial recoil velocity of the rifle.

Sol. When ever, $(u_1 = 0 \text{ and } u_2 = 0)$

So, Given (rifle) $m_1 = 4\,kg$

(Bullet) $m_2 = 50\,kg = \frac{50}{1000}\,kg = 0.05\,kg$

$u_1 = 0$

$u_2 = 0$

$v_1 = ?$

$v_2 = 35\,m/s$

So, $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$$4\times 0 + 0.05\times 0 = 4\times v_1 + 0.05\times 35$$

$$0 + 0 = 4v_1 + \frac{0.05}{100}\times 35$$

$$-\frac{7}{16} = v_1$$

$$\boxed{v_1 = -\frac{7}{16} = -0.43\,m/s}$$

Note:- −ve sign shows direction in opposite.

Q. A bullet of mass 10g moving with a velocity of 400 m/s gets embedded in a freely suspended wooden block of mass 900g. What is the velocity acquired by the block?

$400\,m/s \Rightarrow 10\,g\,(\text{before}) \qquad 900\,g \rightarrow \boxed{\Rightarrow}\,(\text{after})$

$900\,g + 10\,g = 910\,g$

Sol. $\text{Bullet } (m_1) = 10\,g$

$$= \frac{10}{1000}\,kg = 0.01\,kg$$

$\text{Bullet } (v_1) = 400\,m/s\,(\text{Common Velocity})$

$u_1 = 400\,m/s$

$m_2 = 900\,g$

$v_2 = ?$

$u_2 = 0$

From Law of Conservation of Momentum.

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$0.01 \times 400 + 900 \times 0 = m_1v_c + m_2v_c$

$\frac{0.01}{100} \times 400 + 0 = v_c(m_1 + m_2)$ 4

$4 = v_c(0.01 + 0.9)$

$\boxed{v_2 = v_c = 4.39\,m/s}$