NEWTON'S LAWS OF MOTION

Learning Objectives :

- ♦ Newton's first law of motion.
- ♦ Force and Concept of inertia.
- ♦ Linear momentum.
- ♦ Newton's second law of motion.
- ♦ Impulse.
- ♦ Newton's third law of motion.
- ♦ Law of Conservation of linear momentum.

Real time Applications:

- Φ Importance of seatbelts headrests and airbags in vehicles is the application of I law only
- Φ Inertia explains what happens when a car takes sudden turn or stops suddenly.
- Φ second law is useful in industries to know how much force the machine has to apply in order to move a body.
- Φ In space field newton's third law and law of conservation of energy playing a wide role in sending a rocket to it's target

Important Formulae:

1. P= mv
2. F= ma
3. $F = \frac{mv - mu}{t}$
4. $F = m\frac{dv}{dt}$
5. $F = v\frac{dm}{dt}$
6. $F = u\frac{dm}{dt}$
7. $\left(\frac{dm}{dt}\right)u$ = Mg,
8. $\left(\frac{dm}{dt}\right)u$ = Mg + Ma
9. $m_1u_1+m_2u_2 = m_1v_1+m_2v_2$
10. If $\vec{F} = 0$ then $\vec{p} =$ constant
11. $\vec{V} = \frac{-m\vec{v}}{M}$
12. $\frac{V_1}{V_2} = \frac{-m_2}{m_1}$.

§§ ***Newton's Laws of Motion :***

Newton has given three laws to describe the motion of bodies. These laws are known as Newton's laws of motion.

¶¶ **Newton's First law:**

If no external force acts, a body continues to be in its state of rest or of uniform motion along a straight line.

(OR)

If no external force acts, we can also say that "bodies" go on doing what they are doing.

¶¶ **Inertia:**

In the above law it is clear that a body at rest and a body in uniform motion continue to do what they are doing. Thus, a body cannot change its state of rest or of uniform motion by itself.

The inability of a body to change by itself its state of rest or of uniform motion is called inertia of the body

Inertia can also be defined as the tendency of a body to remain in the state of rest or uniform motion.

¶¶ **Measure of inertia:**

It is more difficult to move a heavier body than a lighter body from the state of rest. Similarly, it is more difficult to stop a heavier moving body than a lighter body. Thus, the more the mass, the more the inability of the bodies to change their present state and hence they have more inertia. So we can conclude that mass is the measure of inertia.

§§ **Types of Inertia:**

There are three different types of inertia. They are:

(i) Inertia of rest

(ii) Inertia of motion

(iii) Inertia of direction

(i) Inertia of rest: The tendency of a body to continue in its state of rest is called inertia of rest.

Examples:

a) The passengers standing in a bus fall backwards when the bus suddenly starts because the feet of the passengers start moving along with the bus as it is in contact with the floor of the bus. Whereas, the upper part of the body, due to inertia of rest, tries to remain stationary. Thus the lower portion of the body (foot) moves forward and the upper portion remains at rest due to inertia of rest, and thus the standing passengers fall back.

b) When a paper on which a pile of books are placed is suddenly pulled with a jerk, we expect the books also to move, but this does not happen. This is because the books, stay where they were due to inertia of rest when the paper is pulled out.

(ii) Inertia of motion: The tendency of a body to continue in its state of motion is called inertia of motion.

Examples:

a) When a fan is switched off, it continues to move due to inertia of motion.

b) A running boy falls in the forward direction if he is tripped by a stone because the stone stops his foot, whereas the rest of the body continues moving forward due to inertia of motion and hence the boy falls in the forward direction.

c) A rider falls forward when a galloping horse stops suddenly because when a horse stops, the rider due to inertia of motion, continues moving and hence falls in forward direction.

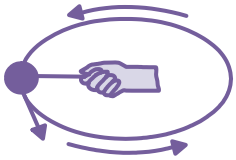
d) Before taking a long jump, an athlete runs a certain distance. In doing so, he picks up inertia of motion which helps in taking a longer leap.

(iii) Inertia of direction:

The tendency of a body to maintain its direction of motion is known as inertia of direction.

Example 1: A stone tied to a string is whirled. If the string is released, the stone flies away tangentially.

Reason: If a stone tied to a string is whirled, the direction of motion, at any instant is the tangential direction as shown below:



Due to inertia of direction, the stone tries to maintain its direction every moment. This can be confirmed, when the stone flies tangentially on release of the string as shown below:

Example 2: When a knife is sharpened by placing it on a rotating iron disc, the sparks move tangentially to the disc due to inertia of direction.

TEACHING TASK

I) Single correct option questions:

1. When a train suddenly start moving forward , a passenger standing in the compartment tends to fall backwards due to
A) inertia of rest of passenger B) inertia of motion of passenger
C) inertia of direction of passenger D) none of these

2. A ball is moving on a perfectly smooth horizontal surface. if no force is applied on it then its speed.....
A) decrease B) increse C) remains same D) can't say

3. To keep a particle (body) moving with a constant velocity on a frictional horizontal surface an external force...
A) should act continuesly B) should be a variable force

C) should not act D) should act opposite to the direction of motion.

4. When a bus is suddenly taken a turn,the passengers are thrown outward because of..
A) inertia of motion of passenger B) acceleration of motion
C) speed of motion D) both A and C

5. When a body is stationary,
A) there is no force acting on it
B) the forces acting on it are not in contact with it
C) the body is in vaccum
D) the combination of forces acting on it balance each other

6. When the driver of a fast moving car suddenly applies breaks, the passengers in the car
A) fall forward B) fall backward C) are not affected D) none of the above

7. Which of the following has more inertia,a rubber ball or a stone of same size?
A) rubber ball B) stone C) both A and B D) neither the ball nor the stone

II) *More than one correct option questions :*

- *This section contains multiple choice questions. Each question has 4 choices (A), (B), (C),(D), out of which **ONE or MORE** is correct. Choose the correct options*

8. Choose the correct option;
a) Newton's first law of motion is also called Galileo's law of inertia
b) Inertia of a body may be defined as the tendency of a body to oppose any change in its state of rest or uniform motion
c) The quantity of motion of the moving body is proportional to mass of the body
d) The tendency of a body to oppose any change in its direction of motion by itself is known as inertia of rest
A) a,b,c B) a,b C) a,b,d D) all

9. Choose the correct option
a) first law of motion defines both inertia and force
b) mass is measure of inertia
c) inertia of a body is directly proportional to the mass of the body
d)inertia of a body is inversely proportional to the mass of the body
A) a,b,c B) a,b C) a,b,d D) all

III) Assertion - A and Reason - R:

- *This section contains certain number of questions. Each question contains Statement – 1 (Assertion) and Statement – 2 (Reason). Each question has 4 choices (A), (B), (C) and (D) out of which **ONLY ONE** is correct Choose the correct option.*

A) Both A and R are true and R is the correct explanation for A.
B) Both A and R are true and R is not correct explanation of A.
C) A is true but R is false. D) A is false but R is true

10. A: When a fan is switched off,it continues to move due to inertia of motion.
R: The inability of a body to change its state of rest is called inertia of motion.

11. A: A table cloth can be pulled from a table without dislodging the dishes.
R: The inability of a body to change its state of rest is called inertia of rest.

IV) Match the following :

- *This section contains Matrix-Match Type questions. Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in **Column–I** have to be matched with statements (p, q, r, s) in **Column–II**. The answers to these questions have to be appropriately bubbled as illustrated in the following example.*

*If the correct matches are A-p,A-s,B-r,B-r,C-p,C-q and D-s,then the correct bubbled 4*4 matrix should be as follows:*

	Column -I	Column - II
12.	a) Newton's first law of motion	1) defines inertia & Force
	b) Fruits fall down when the branches of a tree are shaken	2) Inertia of rest
	c)The swirling of milk in a glass continues even after the stirring is stopped.	3) Inertia of motion
	d) A person jumping out of a moving train falls down	4) Inertia of direction

A) a-1,b-2,c-3,d-4 B) a-3,b-1,c-2,d-4

C) a-2,b-1,c-4,d-3 D) a-4,b-1,c-3,d-2

V) Comprehension type questions :

♦ *This section contains paragraph. Based upon each paragraph multiple choice questions have to be answered. Each question has 4 choices (A) , (B) ,(C) and (D) out of which **ONLY ONE i**s correct. Choose the correct option.*

13. Newton's first law of motion gives the concepts of force and inertia. Force may be defined as that physical cause which changes or tends to change the state of rest or the state of motion of a body.

i) Net force need to

A) keep the body in motion B) keep the body stationary

C) change the speed only

D) change the state of motion or state of rest of the body

ii) Two equal and opposite forces act on a stationary body. will the body move?

A) no B) yes C) net force on the body is zero D) Both A and C

KEY

ΦΦ TEACHING TASK :

1)A 2) C 3) C 4)A 5) D 6)A 7) B 8) B 9)A 10) C
11)A 12)A 13 i) D ii) D

LEARNER'S TASK

BEGINNERS (Level - I)

I) Single correct option questions:

1. Which of following has the largest inertia

A) pencil B) a book C) a car D) a lorry

2. Newton's first law defines the following

A) mass B) acceleration C) Force D) area

3. The inertia of a body tends to cause the body to

A) speed up B) slow down C) resist any change in its motion

4. A rider on a horse falls backwards when the horse suddenly starts, this is due to A)

Inertia of rider B) Losing of the balance
C) Inertia of horse D) Large weight of horse

5. A body is moving with constant velocity on a frictionless horizontal surface, if it want to continues with the same then an external force
A) Should act continuously B) Should be a variable force
C) Should not act D) Should act opposite to the direction of motion

6. Inertia of an object is measured in terms of
A) velocity B) acceleration C) force D) mass

7. The dust on a carpet can be removed by giving a suddent jerk with a stick because
A) inertia of rest keeps the dust in its position
B) inertia of motion removes dust C) dust particles are very light
D) jerk compensates for the force of adhesion between dust and carpet

8. Which law of motion is called law of Inertia
A) Newton's First law B) Newton's 2nd law C) Newton's 3rd law D) None.

9. If no force acts on a body, it will
A) change its shape B) move with an increased speed
C) either remain at rest or move in a straight line D) break up

10. If the resulting external force on a particle is zero then
A) its momentum is zero B) its velocity is zero
C) its change in velocity is zero D) its change in displacement is zero

ACHIEVERS (Level - II)

Descripitive questions

1. Define Newton's first law of motion.

2. Write a note on inertia and it's types.

EXPLORERS (Level - III)

I) More than one correct option questions :

- *This section contains multiple choice questions. Each question has 4 choices (A), (B), (C),(D), out of which **ONE or MORE** is correct. Choose the correct options*

1. Which of the following statements are 'true' ?
a) The mass of an object is a measure of Inertia.
b) A net force produces change in momentum.
c) Newton's first law of motion gives the defination of volume.
d) inertia is nothing but the mass of a body.
A) a,b,c B) a,b C) a,b,d D) all

2. Inertia is the property of a body by virtue of which the body is unable to change
a) by itself the state of rest b) by itself the state of uniform motion
c) by itself the direction of motion
A) a,b,c B) a,b C) a,c D) b,c

3. Newton's first law gives the concept of
a) Force b) Inertia c) Momentum d) velocity
A) b,c B) a,b C) a,c D) all

II) Assertion - A and Reason - R:

- *This section contains certain number of questions. Each question contains Statement – 1 (Assertion) and Statement – 2 (Reason). Each question has 4 choices (A), (B), (C) and (D) out*

*of which **ONLY ONE** is correct Choose the correct option.*

A) Both A and R are true and R is the correct explanation for A.
B) Both A and R are true and R is not correct explanation of A.
C) A is true but R is false. D) A is false but R is true

4. A: Mass is a measure of inertia of a body in translatory motion
R: Smaller the mass of a body, smaller is the force required to change it's state of rest or of uniform motion in a straight line.

III) Match the following :

- *This section contains Matrix-Match Type questions. Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in **Column–I** have to be matched with statements (p, q, r, s) in **Column–II**. The answers to these questions have to be appropriately bubbled as illustrated in the following example.*

*If the correct matches are A-p,A-s,B-r,B-r,C-p,C-q and D-s,then the correct bubbled 4*4 matrix should be as follows:*

5.

Set-A	Set-B
a) Newton's first law of motion	1) Defines inertia & Force
b) A passenger standing in a bus falls backward, when the bus starts suddenly due to	2) Inertia of rest
c) While dusting a carpet we suddenly jerk or beat it with a stick, it is an example of	3) Inertia of motion
d) When a bus suddenly takes a left turn the passengers are thrown right because of	4) Inertia of direction

A) a-1,b-3,c-2,d-4 B) a-3,b-1,c-2,d-4
C) a-2,b-1,c-4,d-3 D) a-4,b-1,c-3,d-2

IV) Comprehension type questions:

- *This section contains paragraph. Based upon each paragraph multiple choice questions have to be answered. Each question has 4 choices (A) , (B) ,(C) and (D) out of which **ONLY ONE i**s correct. Choose the correct option.*

6. Inertia of a body may be defined as the tendency of a body to oppose any change in its state of rest or uniform motion.

i) A passenger sitting in a bus gets a backward jerk when the bus starts suddenly due to the
a) inertia of rest b) inertia of motion
c) inertia of direction d) none of these

ii) While dusting a carpet we suddenly jerk or beat it with a stick because
a) Inertia of rest keeps the dust in its position and the dust is removed by moment of the carpet away
b) Inertia of motion removes the dirt
c) no inertia is involved it is due to practical experience
d) none of these

iii) A player run some distance before taking a long jump because
a) it helps him to gain energy b) it helps to apply large force
c) it gives himself large amount of inertia d) none of these.

KEY

ΦΦ TEACHING TASK :

- **BEGINNERS :** 1) D 2) C 3) C 4) A 5) C 6) D 7) A 8) A 9) C 10) A
- **EXPLORERS :** I) 1) B 2) A 3) B **II)** 14) A **III)** 15) A **IV)** 16) i) A ii) A iii) C

§§ Linear momentum :-

Consider two balls A and B. Let ball A be heavier than the ball B. i.e. mass (m_1) of ball A is greater than the mass (m_2) of the ball B. Suppose both balls are moving with same velocity $\vec{v}$. The force require to stop ball A is more than the force required to stop ball B. This shows that the heavier ball has more quantity of motion than the lighter ball. **Thus, quantity of motion of a body is directly proportional to the mass of the body.**

Now consider two balls of same mass moving with different velocities. The force required to stop the fast moving ball is more than the force required to stop the slow moving ball. So the quantity of motion of the body is directly proportional to the velocity of the ball.

Conclusion : The quantity of motion of the moving body is proportional to

(i) mass of the body

(ii) velocity of the body.

This quantity of motion possessed by a moving body is known as momentum of the body. (or) The total quantity of motion contained in a body is called momentum.

Mathematical expression : Momentum of a body is equal to the product of the mass (m) of the body and the velocity $(\vec{v})$ of the body. It is denoted by $\vec{p}$.

Thus, momentum = mass × velocity

$$\vec{p} = m\vec{v}$$

* momentum is a vector quantity

Note :- The direction of momentum of a body is same as that of the direction of the velocity of the body.

Units of momentum : S.I. unit of momentum = S.I unit of mass × S.I unit of velocity = kg × m/s = kg m/s. Similarly C. G. S. unit of momentum is **g cms^{-1}.**

Change of momentum : If 'u' and 'v' are the initial and final velocity of a body then its, initial momentum = mu final momentum = mv

Now change of momentum = final momentum – initial momentum = mv – mu

§§ CHANGE IN MOMENTUM OF A BODY IN DIFFERENT CASES

Consider a body of mass m moving with velocity $\vec{V}_i$ and momentum $\vec{P}_i$. Due to a collision (or) due to the action of a force on it suppose its velocity changes to $\vec{V}_f$ and momentum changes to $\vec{P}_f$ in a small time interval Δt.

Change in momentum of body = $\Delta\vec{P} = \vec{P}_f - \vec{P}_i$

$= m\vec{V}_f - m\vec{V}_i$ $\left|\Delta\vec{P}\right| = \left|\vec{P}_f - \vec{P}_i\right| = \sqrt{P_f^2 + P_1^2 - 2P_fP_i\cos\theta}$

where θ = angle between $\vec{P}_f$ and $\vec{P}_i$

Case (i) : Consider a body of mass m moving with velocity $V\hat{i}$. If it hits a rigid surface (or) a wall and comes to rest. Change in momentum of the body =

$\overrightarrow{\Delta P} = \vec{P}_f - \vec{P}_i = 0 - (mv)\hat{i}$

$= -(mv)\hat{i} \quad \left|\overrightarrow{\Delta P}\right| = mv$

Note : From law of conservation of linear momentum, theoretically, Change in momentum of surface / wall = $+(mv)\hat{i}$

Case(ii) : In the above case if the body rebounds with same speed V then $\theta = 180^0$

$\overrightarrow{\Delta P} = \vec{P}_f - \vec{P}_i = \left[-(mv)\hat{i}\right] - \left[(mv)\hat{i}\right] = -(2mv)\hat{i}$

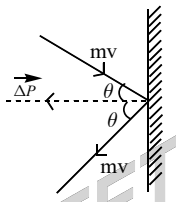
$\therefore \left|\overrightarrow{\Delta P}\right| = 2mv$

Case (iii) : If a body of mass m moving with velocity $V_1\hat{i}$ hits a rigid wall and rebounds with speed V_2 then $\theta = 180^0$, $\overrightarrow{\Delta P} = \vec{P}_f - \vec{P}_i$

$= \left[-(mv_2)\hat{i}\right] - \left[(mv_1)\hat{i}\right] \quad \left|\overrightarrow{\Delta P}\right| = m(V_2 + V_1)$

Case (iv) : A body of mass m moving with speed V hits a rigid wall at an angle of incidence θ and reflects with same speed V $\overrightarrow{\Delta P}$ of body is along the normal, away from the wall

$\left|\overrightarrow{\Delta P}\right| = 2mv\cos\theta$



Case(v) : In the above case if θ is the angle made by $\vec{V}_i$ with wall then $\left|\overrightarrow{\Delta P}\right| = 2mv\sin\theta$

§§ NEWTON'S SECOND LAW OF MOTION

1. The rate of change of momentum of a body is directly proportional to the external force and the change in momentum takes place in the direction of the force.

2. Newton's second law of motion leads to a formula useful for measuring force. $\bar{F} = m\,\bar{a}$.

3. Force is a vector. It is always in the direction of change in momentum. Force is also always in the direction of acceleration.

4. SI unit of force is *newton* (N). If a force acting on a mass of 1 kg produces in it an acceleration of 1 m s^{-2} in its direction, it is called a *newton*.

5. CGS unit of force is dyne. If a force acting on a mass of 1 gm produces in it an acceleration of 1 cm s^{-2} in its direction, it is called a *dyne*.

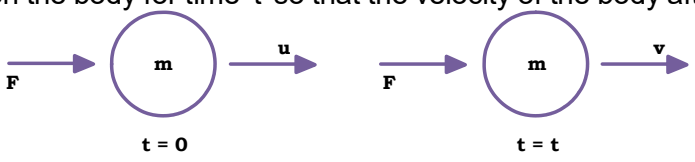
6. One *newton* = 10^5 *dyne*.

7. **Gravitational units of force:** kilogram weight (kg.wt) and gram weight (gm.wt) are called the gravitational units of force. 1 kg.wt or kg. f = 9.8 N,
1 gm.wt or gm.f = 980 dyne.

8. To calculate a force '*F*', there are several useful variants of the formula $\bar{F} = m\,\bar{a}$.

9. $F = \frac{mv - mu}{t}$, 10. $F = m\frac{dv}{dt}$s , 11. $F = v\frac{dm}{dt}$

¶¶ **Derivation of F = ma :** Consider a body of mass 'm' moving with initial velocity u. Let a force F acts on the body for time 't' so that the velocity of the body after time 't' is v.



Initial momentum of the body (P_i) = m u

Final momentum of the body (P_f) = m v

Now, change in momentum of the body = $P_f - P_i$ = mv – mu = m (v – u)

Time taken for this change in momentum = (t – 0) = t

$\therefore$ Rate of change of momentum = $\frac{\text{change of momentum}}{\text{time taken}} = \frac{m\,(v-u)}{t}$

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

EXAMPLE

√ **Ex-1:** Two forces having magnitude 3F and 2F, when act in the same direction simulataneously on a body gives a net force equal to 25 N. Find the value of F.

Sol : Net force = sum of the two forces = 3F + 2F = 5F

$\Rightarrow F = \frac{25}{5} = 5N$

√ **Ex-2:** A car changes its speed from 20 km h^{-1} to 50km h^{-1} of mass 3600 kg in 5s. Determine the net external force applied on the car.

Sol: $F = m\left(\frac{v-u}{t}\right) = 3600\left(\frac{50-60}{5}\right)\times\frac{15}{18}$

= 600 x 30 = 1800 N.

√ **Ex-3:** If a force of 50 N is applied on a body and it is still at rest then find the magnitude of static fricational force acting on it.

Sol : The magnitude of the force acting on the body (f) = 50 N.

Due to application of this force, the body tends to move but is not set in motion.

and hence, the applied force is equal in magnitude and opposite in direction to static firctional force.

$\therefore$ The magnitude of static frictional force = 50 N.

√ **Ex-4:**The speed of a car weighing 1000 kg increases from 36 km/h to 108 km/h. Calculate the change in momentum.

Sol: Mass of the car (m) = 1000 kg

initial velocity (v) = 36 km / h (1 km/h = 5 /18 m/s)

= 36 x 5/ 18 m/s

= 10 m/s

Final Velocity (v) = 108 km/h = 108 x 5 / 18 m/s

= 6 x 5

= 30 m/s

Change in momentum = mv -mu

= m(v - u)

= 1000 (30 - 10)

= 1000 x 20

=20000

√ **Ex-5:**An object requries the force of 100 N to gain an acceleration 'a'. If the mass of the object is 500 kg what will be the value of 'a'?

Sol : According to the question,

mass (m) = 500 kg,

Force (F) = 100 N,

Acceleration (a) = ?

We know that, Force = Mass x Acceleration

Or F = m x a

Therefore, 100 N = 500 kg x a

a = 100 N / 500 kg

a = 100 kg ms^{-2} / 500 kg

a = 0.2 ms^{-2}

Thus, acceleration of the vehicle = 0.2 ms^{-2}

√ **Ex-6:** A Hockey player hits a ball (m = 100 g) lying on ground with his stick. It is found that the ball starts moving with a velocity of 40 ms^{-1}. Find

a) The impluse of the force exerted by the stick on the ball.

b) If the stick was in contact with the ball for 1 ms then find the magnitude of the force acting on the ball

Sol : a) Impulse = F x t

= ma x t

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

=0.1 kg (40 ms^{-1} - 0)

= 4 kg ms^{-1}

b) I = F x t

4 kg ms^{-1} = F x 1 x 10^{-3} s

$F = \frac{4\,kgms^{-1}}{1\times10^{-3}\,s}$

= 4 x 10^3 $kgms^{-2}$

F = 4 x 10^3 N

√ **Ex 7:** When a car weighing 800 kg was moving on a horizontal road with 30 ms^{-1} velocity its breaks stopped working. The car came to rest after travelling a distance of 150 m. Find i) the retardation of the car ii) frictional force exerted by the ground on the car .

sol : i) Given u = 30 ms-1

v = 0

s = 150 m a = ?

We know that $v^2 = u^2 + 2as$

$\Rightarrow$ 0 = $(30)^2$ + 2 x a x 150

$\therefore$ -300 a = 900

$\therefore$ a = -3 ms^{-2}

ii) We know that F = ma

= 800 x -3

F = -2400 N

Negative sign implies that it is a retardation force. This force which opposes the motion of a car on the ground is a frictional force.

$\therefore$ Frictional force exerted by ground on car = 2400 N.

√ **Ex-8:** If a bullet of mass 5 g moving with a velocity of 100m/s penetrates a wooden block upto 6cm. Find the average force imposed.

Sol:

u = 100 m/s, v = 0

S = 6×10^{-2} m , a = ?

$v^2 - u^2 = 2as$

$0^2 - (100)^2 = 2 \times a \times 6 \times 10^{-2}$

$$a = \frac{-100 \times 100}{2 \times 6 \times 10^{-2}}$$

$$\boxed{a = \frac{-1}{12} \times 10^6 \ \text{m/s}}$$

$$F = ma = 5 \times 10^{-3} \times \left[\frac{-1}{12} \times 10^6\right]$$

$$F = \frac{-5000}{12} = -417 \text{ N}$$

Retarding force F = 417 N

√ ***Ex-9:*** Batsman hits 150 gm ball moving horizontally at 20m/s back to bowler at 12m/s. If contact of cricket ball lasts for $\frac{1}{25}$ sec with the bat, find the average force that the bats man exerts

Sol. The change in momentum of ball

$\Delta p = m(v-u) = 150 \times 10^{-3}$ [20 – (– 12)]

= $32 \times 15 \times 10^{-2} = 4.8N \times S$

given, $\Delta t = \frac{1}{25}\text{sec}$ $\therefore$ $F = \frac{\Delta p}{\Delta t} = 120N$

√ ***Ex-10:*** A force produces acceleration 16 m/s² in a mass 0.5 kg and an acceleration 4.0 m/s² in an unknown mass when applied seperately. If both masses are tied together, what will be the acceleration under same force?

Sol. Force is, F = ma = $0.5 \times 16 = 8$ N when both masses are joined and same force act, acceleration is $a' = \frac{F}{m+m'} = \frac{8}{0.5+8/4} = \frac{8}{2.5} = 3.2 m/s^2$

√ ***Ex-11:*** A force of 100 dyne acts on a mass of 5 grams for 10 sec. Find the velocity produced.?

Sol : $a = \frac{F}{m} = \frac{100}{5} = 20 \ \text{cm/s}^2$

v = u + at

v = 0 + 20 × 10 = 200 cm/sec.

√ ***Ex -12:***

Sol : $F = \left(\frac{dm}{dt}\right) \times v$

F = 0.5 × 2 = 1 N

√ ***Ex -13***

A body of mass 5 kg starts from the origin with an initial velocity of $\bar{U} = (30\hat{i} + 40\hat{j}) \text{ m/s}$. A constant force of $F = (-\hat{i} - 5\hat{j}) \text{ N}$ acts on the body. Find the time in which the y-component of the velocity becomes zero.

Sol : $\bar{u} = 30i + 40j$.....(1)

$u = u_x\hat{i} + u_y\hat{j}$ .....(2)

$F = -i - 5\hat{j}$.....(3)

$F = F_x\hat{i} + F_y\hat{j}$.....(4)

comparing (1) and (2), (3) and (4)

we have

$u_y = 40$ m/s

$F_y = -5N$

$F_y = ma_y$

$\boxed{a_y = -1 \text{ m/s}^2}$

$v_y = u_y + a_y \times t$

$0 = 40 - 1 \times t$

$t = 40$ sec

√ ***Ex -14:*** A satellite in force free space sweeps stationary interplanetary dust at a rate $\frac{dM}{dt} = \alpha v$ where m is mass, v is the velocity of the satellite and α is a constant. What is the deceleration of the satellite.

Sol : $F = \frac{dp}{dt} \Rightarrow F = v.\frac{dM}{dt}$

$F = v(\alpha v) \Rightarrow F = \alpha v^2$

$Ma = \alpha v^2$

$a = \frac{\alpha v^2}{M}$

Ex -15

A particle of mass 0.3 kg is subjected to a force F = kx with k = 15 N/m. What will be its initial acceleration, if it is released from a point 20 cm away from the origin ?

Sol : $a = \frac{F}{M} = \frac{kx}{M} = \frac{15 \times 0.2}{0.3}$ = 10 m/s²

TEACHING TASK

I) Single correct option questions :

1. A force of 100 N acts on a body of mass 2kg fgor 10s . the change in momentum of the body is.....

A) 100 Ns B) 250Ns C) 500Ns D) 1000Ns

2. A mass of 2 kg at rest travels for 4 sec with an acceleratio of 1.5 m/s². The gain of momentum of the body is

A) 5 kgm/s B) 10 kgm/s C) 12 kgm/s D) 14 kgm/s

3. If a constant force acts on a body initially kept at rest, the distance moved by the body in time 't' is proportional to

A) t B) t^2 C) t^3 D) t^4

4. A force produces an acceleration of 0.5 m/s² in a body of mass 3.0 kg. If the same force acts on a body of mass 1.5 kg the acceleration produced in it is

A) 3.0 m/s² B) 1.0 m/s² C) 5.0 m/s² D) 7 m/s

5. The force produces an acceleration of 2.0 m/s^2 in a body A and 5.0 m/s^2 in another body B. The ratio mass of A to the mass of B is
A) 5:2 B) 3:5 C) 2:5 D) 4:5

6. A block of mass 2 kg is moving with an accelertion of 1 m/s^2 under the action of a constant horizontal foce. A similar block of mass 2 kg is gently glued over the moving block and the two blocks are now moving as a single unit. Find the acceleration of the combination if the same force continuous to act
A) 0.2 m/s^2 B) 0.1 m/s^2 C) 0.5 m/s^2 D) 1 m/s^2

7. A block of mass 2 kg is moving on a smooth surface with constant speed. A constant horizontal force F acts on the body for 2 s during which its speed increases by 3 m/s. Find F
A) 2 N B) 4 N C) 3 N D) 1 N

8. A force of 1.0 N acts on a body of mass 10 kg. The body covers 100 cm in 4 seconds moving along a straight line. The initial velocity is
A) 2 cm/s B) 4 cm/s C) 6 cm/s D) 5 cm/s

9. If a force of 15 N acts upon a mass of 20 kg kept on a smooth horizontal surface, what velocity does it generate in 8 s
A) 5 m/s B) 3 m/s C) 1 m/s D) 6 m/s

10. A block of mass 2 kg is lying on a smoth horizontal surface. A constant horizontal force F starts acting on the block and speed of the block becomes 3 m/s over the distance 1 m. Find F
A) 10 N B) 7 N C) 9 N D) 5 N

11. An open carriage in a goods train is moving with a uniform velocity of 5 ms^{-1}. If the rain adds water with zero velocity at the rate of 5 kg s^{-1}, then the additional force applied by the engine to maintain the same velocity of the train is
A) 0.5 N B) 2.0 N C) 50 N D) 25 N

12. A balloon has 8 gram of air. A small hole is pierced into it. The air escapes at a uniform rate of 7cm/s. If the balloon shrinks in 5.6 sec then the average force acting on the balloon is
A) 10^{-4} N B) 10^{-2} dyne C) 56 dyne D) 10^{-6} N

13. Bullets of 0.03 kg mass each hit a plate at the rate of 200 bullets per second with a velocity of 30 m/s. They average force acting on the plate in newton is
A) 120 B) 180 C) 300 D) 480

14. A machine gun fires a bullet of mass 40g with a velocity 1200 ms^{-1}. The man holding it can exert a maximum force of 144 N on the gun. How many bullets can he fire per second at the most?
A) One B) Three C) Two D) Four

II) *More than one correct option questions :*

- *This section contains multiple choice questions. Each question has 4 choices (A), (B), (C),(D), out of which **ONE or MORE** is correct. Choose the correct options*

15. Choose the correct option
a) The acceleration produced in a body is directly proportional to the force acting on it
b)The acceleration produced in a body is inversely proportional to the mass of the body
c) 1 newton = 10^5 dyne d) 1 newton = 1 kg ms^{-2}
A) a,b,c B) a,b C) a,b,d D) all

16. 1 gm weight =

a)980gcm/s^2 b) 980 dyne c)9800gm/s^2 d) 98 dynes

A) a,b,c correct B) a,b correct C) a,b,d correct D) all correct

17. Which of the following are correct?

a) F=ma b) F = $u\frac{dm}{dt}$ c) F=u dm X dt d) P=mv

A) a,b,c B) b,c,d C) a,b,d D) all

III) **Assertion - A and Reason - R :**

- *This section contains certain number of questions. Each question contains Statement – 1 (Assertion) and Statement – 2 (Reason). Each question has 4 choices (A), (B), (C) and (D) out of which **ONLY ONE** is correct Choose the correct option.*

A) Both A and R are true and R is the correct explanation for A.
B) Both A and R are true and R is not correct explanation of A.
C) A is true but R is false. D) A is false but R is true

18. A: If the velocity of a body is zero then it's momentum is equal to zero.
R: Momentum is the product of mass and acceleration of a body.

19. A: Newton's second law gives the measurement of force.
R: Newton's first law gives the defination of force.

20. A: Newton's second law gives the concept of momentum.
R: Newton's second law gives the concept of inertia.

IV) **Match the following :**

- *This section contains Matrix-Match Type questions. Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in **Column–I** have to be matched with statements (p, q, r, s) in **Column–II**. The answers to these questions have to be appropriately bubbled as illustrated in the following example.*

*If the correct matches are A-p,A-s,B-r,B-r,C-p,C-q and D-s,then the correct bubbled 4*4 matrix should be as follows:*

21.

Set-A	Set-B
a) Initial momentum of body	1) mv-mu
b) Rate of change of momentum	2) m(v-u)/t
c) change in momentum of body	3) mv
d) final momentum of body	4) mu

A) a-1,b-4,c-2,d-3 B) a-3,b-1,c-2,d-4
C) a-2,b-1,c-4,d-3 D) a-4,b-2,c-1,d-3

V) **Comprehension type questions :**

- *This section contains paragraph. Based upon each paragraph multiple choice questions have to be answered. Each question has 4 choices (A) , (B) ,(C) and (D) out of which **ONLY ONE i**s correct. Choose the correct option.*

22. A body of mass 10kg is at rest on a smooth horizontal surface. A person applies a force of 20N horizontally. Due to the action of force body moves with avelocity of 30m/s.

i) Final momentum of the body is
A) 0 B) 300 kgm/s C) 30kg m/s D) 2000 kgm/s

ii) Initial momentum of body is
A) 0 B) 200kgm/s C) 300 kgm/s D) 7.5kgm/s.

iii) Acceleration of the body is
A) 1m/s^2 B) 5m/s^2 C) 2m/s^2 D) 10m/s^2

KEY

ΦΦ TEACHING TASK :

1) D, 2) C, 3) B, 4) B, 5) A, 6) C, 7) C, 8) D, 9) D, 10) C,
11) D, 12) A, 13) B, 14) B, 15) D, 16) B, 17) C, 18) C, 19) B, 20) B,
21) D, 22) i) B, ii) A, iii) C

LEARNER'S TASK

BEGINNERS (Level - I)

I) Single correct option questions :

1. A body of mass 10kg moves with a velocity of 2m/s. Its momentum is ..... kgm/s
A) 20 B) 10 C) 5 D) None

2. A body of mass 10kg moves with a velocity of 50cm/s its momentum is ....
A) 5kgm/s B) 7kg/s C) 10kgm/s D) none

3. A force of 100N applied on a body of mass 20kg at rest. What is the acceleration acquired by the body ?
A) $2m/s^2$ B) $4m/s^2$ C) $5m/s^2$ D) $10m/s^2$.

4. What will be the force required to accelerate rocket of mass of 50kg by $15m/s^2$?
A) 750 N B) 0.3 N C) 65 N D) 35 N

5. A body of mass 2 kg is sliding with a constant velocity of 4 m/s on a friction less horzontal table. Find the force required to keep the body moving with he same velocity
A) 0 B) 2 N C) 4 N D) 1 N

6. Find the amount of force required to impart an acceleration of 2 m/s^2 in a body of mass 1.5 kg lying on a smooth horizpntal surface
A) 1 N B) 2 N C) 3 N D) 4 N

7. A constant horizontal force F imparts an accelertion of 1 m/s^2 in a block of mass 500 g lynig on a horzontal surface. The force is
A) 0.1 N B) 0.4 N C) 0.2 N D) 0.5 N

8. A force produces an acceleration of 5.0 cm/s^2 when it acts on a body of mass 20 g. The force in netwon is
A) 2×10^{-3} N B) 4×10^{-3} N C) 1.0×10^{-3} N D) 5×10^{-3} N

9. Find the amount of force required to produce an acceleration of 3 cm/s^2 in a body of mass 250 g
A) 75×10^{-4} N B) 25×10^{-4} N C) 50×10^{-4} N D) 15×10^{-4} N

10. If same force is applied on the bodies of masses 2kg and 3kg, what is the ratio of their accelerations ?
A) $a_1 : a_2 = 1 : 2$ B) $a_1 : a_2 = 3 : 2$ C) $a_1 : a_2 = 2 : 3$ D) $a_1 : a_2 = 2 : 1$

11. A force acts on a particle of mass 200 g. The velocity of the particle changes from 15 m/s to 25 m/s in 2.5 sec. Assuming the force to be constant, it magnitude is
A) 0.4 N B) 0.6 N C) 0.8 N D) 0.5 N

12. A force acting on a particle of mass 200 g displaces it through 400 cm in 2 sec. The magnitude of the force if the initial velocity of the particle is zero is
A) 0.1 N B) 0.3 N C) 0.4 N D) 0.5 N.

13. A block of metal weighing 2 kg is resting on a frictionless plane. It is struck by a jet releasing water at a rate of 1 kg s^{-1} and at a speed of 5 ms^{-1}. The initial acceleration of the block will be

A) 2.5 ms^{-2} B) 5.0 ms^{-2} C) 10 ms^{-2} D) 10^3 km h^{-2}

14. An open carriage in a goods train is moving with a uniform velocity of 10 ms^{-1}. If the rain adds water with zero velocity at the rate of 5 kg s^{-1}, then the additional force applied by the engine to maintain the same velocity of the train is

A) 0.5 N B) 2.0 N C) 50 N D) 25 N

ACHIEVERS (Level - II)

I) Solve the following :

1. A ship of mass 3 x 10^7 kg initially at rest is pulled by a force of 5 x 10^4 N through a distance of 3 m. Assuming the resistance due to water is negligible, find the speed of ship

2. A force of 30 N acted on a block of mass 12 kg at rest for 6 sec and then the direction of the force is reversed.
a) what distance the block moves before coming to rest.
b) after what time the block reaches the starting point and with what velocity

3. A body of mass 2 kg moving on a horizontal surface with an initial velocity of 4 m/ scomes to rest 2 s. If one wants to keep this body moving on same surface with a velocity of 4 m/s find the force required.

4. A body of mass 2 kg on which a constant force is applied, travels 1 m in first second and 3 m in next second, find the magnitude of the force.

5. A mass of m kg is subjected to a constant force of F kg. wt for t sec initial the body is being at rest. Under the action of force the body moves a distance x meters (in t sec)and acquires a velocity of V m/s. Then x is

6. A balloon has 5 gm of air. A small hole is pierced into it. The air escapes at a uniform rate with a velocity of 4 cm s^{-1}. If the balloon shrinks completely in 2.5 second, then the average force acting on the balloon is

EXPLORERS (Level - III)

I) More than one correct option questions :

*This section contains multiple choice questions. Each question has 4 choices (A), (B), (C),(D), out of which **ONE or MORE** is correct. Choose the correct options*

1. 1 Newton =

a) 1 kgm/s^2 b)1000g×100cm/s^2 c) 100000gcm/s^2 d) 10^5gcm

A) a,b,c correct B) a,b correct C) a,b,d correct D) b, c correct

2. The unit of momentum

a) $gcms^{-1}$ b) $gcms^{-2}$ c) $kgms^{-1}$ d) $kgms^{-2}$

A) a,b,c correct B) a,c correct C) a,b,d correct D) b, c correct

3. Choose the correct option

a) P=mv b) $a = \frac{v-u}{t}$ c) v=Pm d) $V = \frac{a-u}{t}$

A) a,b,c B) a,b C) a,b,d D) b, c

4. linear momentum of a body is the product of its

a) velocity b) volume c)mass d)area

A) a,b,c correct B) a,b correct C) a,b,d correct D) a, c correct

II) **Assertion - A and Reason - R :**

- *This section contains certain number of questions. Each question contains Statement – 1 (Assertion) and Statement – 2 (Reason). Each question has 4 choices (A), (B), (C) and (D) out of which* ***ONLY ONE*** *is correct Choose the correct option.*

A) Both A and R are true and R is the correct explanation for A.
B) Both A and R are true and R is not correct explanation of A.
C) A is true but R is false. D) A is false but R is true.

1. A: Momentum is a vector quantity.
R: p=mv.

2. A: Mass is the measure of force.
R: Mass is the measure of inertia.

3. A: Force is the rate of change in momentum.
R: Foce is a vector quantity.

III) ***Match the following :***

- *This section contains Matrix-Match Type questions. Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in* ***Column–I*** *have to be matched with statements (p, q, r, s) in* ***Column–II****. The answers to these questions have to be appropriately bubbled as illustrated in the following example.*

*If the correct matches are A-p,A-s,B-r,B-r,C-p,C-q and D-s,then the correct bubbled 4*4 matrix should be as follows:*

1.

Physical quantity	***S.I unit***
a) Displacement	1) m/s
b) Speed	2) N
c) Force	3) m
d) momentum	4) Ns

A) a-1,b-4,c-2,d-3 B) a-3,b-1,c-2,d-4 C) a-2,b-1,c-4,d-3 D) a-4,b-1,c-3,d-2

Comprehension type questions:

2. A ball of mass 2kg moving with an initial velocity 5m/s is hit by a bat for 0.1s, then the ball velocity becomes 6ms^{-1}.

i) Find the initial momentum of the ball in kgms^{-1}
A) 5 B) 10 C) 1.25 D) 2.5

ii) Find the final momentum of the ball in kgms^{-1}
A) 5 B) 10 C) 12 D) 2.

iii) Find the change in momentum of the ball in kgms^{-1}
A) 0.5 B) 1 C) 2 D) 4

iv) Find the force acted on the ball in newton.
A) 5 B) 10 C) 15 D) 20

KEY

ΦΦ LEARNER'S TASK :

- **BEGINNERS :** 1) A 2) A 3) C 4) A 5) A 6) C 7) D 8) C 9) A 10) B 11) C 12) C 13) A 14) C
- **ACHIEVERS :** 1)0.1m/s 2)90m,12s,0 3)4 N 4) 4 N. 5) $V^2m/2gF$ 6) 8 dyne
- **EXPLORERS : I)** 1) D 2) B 3) B 4) D **II)** 1) B 2) D 3) B 4) B **III)** 23) i) B ii) C iii) C iv) D

§§ **Newton's Third Law :**

To every action there is always an equal and opposite reaction

- Action and reaction do not occur on the same body they act on different bodies at same instant of time.
- Action and reaction, known as pair of forces, equal in magnitude opposite in directions acting on diffrerent bodies in interaction. So they never cancel each other.

♣ **Limitation of Newton's Third law :**

a) Newtons third law is not strictly applicable for the interaction between two bodies seperated by larger distances, of the order of astronomical units.

b) It does not apply strictly when the objects move with velocity nearer to that of light of light.

c) It does not apply where the gravitational fields are very strong.

¶¶ **Characterstics of action and reaction :**

1) Action and reaction are equal in magnitude and opposite in direction

2) Action and reaction do not act on the same body, therefore they do not cancel each other

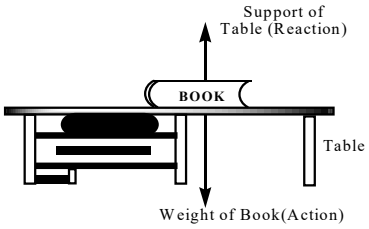
3) Action and reaction are mutual and simultaneous. This means they always exist in pairs and one exists only as long as the other exists.

4) The force of action and reaction may appear due to actual physical contact of the two bodies or even from a distance. But they are always equal and opposite.

5) When taken together action and reaction be come internal forces.

Ψ Some of the **examples** of **Newton's third law of motion** are given below:

1. **Book kept on a table.** A book lying on a table exerts a force on the table, which is equal to the weight of the book.This may be called the force of action. The table supports the book,by exerting an equal force on the book.This is the force of reaction,



Since the book is observed to be at rest, the net external force on it must be zero.This implies that the normal reaction must be equal and opposite to the weight of the book.

2. **Walking :** while walking, a person presses the ground in the backward direction (action)by his feet.The ground pushes the person in forward direction with an equal force (reaction).The component of reaction in the horizontal direction makes the person move forward.
3. **Swimming.** A swimmer pushes the water backwards (action).The water pushes the swimmer forward(reaction) with the same force.Hence the swimmer swims
4. **Firing from a gun.** When a gun is fired, the bullet moves forward (action).The gun recoils backwards (reaction)
5. **Flight of jet planes and rockets.**The burnt fuel which appears in the form of hot and highly compressed gases escapes through the nozzle (action) in the backward direction.

The escaping gases push the jet plane or rocket forward (reaction)with the same force.Hence the jet or rocket moves.

6. **Rebounding of a rubber ball**. When a rubber ball is struck against a wall or floor, it exerts a force on wall (action).The ball rebonds with an equal force (reaction) exerted by the wall or floor on the ball.

7. **It is difficult to walk on sand or ice**. This is because on pushing sand gets displaced and reaction from sandy ground is very little.In case of ice, force of reaction is again small,because friction between our feet and ice is very little.

§§ ***Law of conservation of linear momentum :***

Collision: If a number of bodies collide with one another then total momentum of the bodies, just before collision is equal to the total momentum just after collision.

i.e. $m_1u_1+m_2u_2 = m_1v_1+m_2v_2$

i) In the absence of an external force, the linear momentum of a particle or a body remains constant i.e. if $\overrightarrow{F} = 0$ then $\overrightarrow{p} =$ constant

ii) In the absence of external force, the linear momenta of individual particles can change but the total linear momentum of the whole system remains constant.

iii) The law of conservation of linear momentum is based on the Newton's third law of motion. This is the fundamental law of nature and there is no exception to it.

iv) This law is valid only for linear motion.

v) Internal forces cannot change the total momentum of the system, however they may change the momentum of each particle of the system.

vi) Motion of a rocket, firing of a bullet from a gun and explosion of a shell fired from a cannon are some examples where we can apply the law of conservation of linear momentum

§§ **Applications of the principle of conservation of linear momentum :**

1) Recoiling of a gun : When a bullet is fired from a gun, the gun recoils i.e. moves in

a direction opposite to the direction of motion of the bullet. The recoil velocity of the gun can be calculated from the principle of conservation of linear momentum.

Suppose m_1 = mass of bullet,

m_2 = mass of gun,

$\vec{v}_1$ = velocity of the bullet,

$\vec{v}_2$ = velocity of recoil of the gun.

Before firing, the gun and the bullet both, are at rest. Therefore , total linear momentum before firing = 0. Therefore, total linear momentum before firing = 0. The vector sum of linear momenta on firing $m_1\vec{v}_1 + m_2\vec{v}_2 = 0$. According to the principle of conservation of linear momentum, total linear momentum after firing should also be zero.

$\therefore m_1\vec{v}_1 + m_2\vec{v}_2 = 0$

or $m_2\vec{v}_2 = -m_1\vec{v}_1$ ..... (25)

or $\vec{v}_2 = -\frac{m_1\vec{v}_1}{m_2}$ ..... (26)

The negative sign shows that direction of $\vec{v}_2$ is opposite to the direction of $\vec{v}_1$ i.e. the

gun recoils. Further, as $m_2 >> m_1$ therefore , $\vec{v}_2 << \vec{v}_1$ i.e. velocity of recoil of the gun is much smaller than the velocity of the bullet .

From eq. (26) , $v_2 \propto \frac{1}{m_2}$

It means that a heavier gun will recoil with a smaller velocity and vice-versa.

Initial K.E of the system is zero, as both the gun and the bullet are at rest. Final K.E. of the system = $\left(\frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2\right) > 0$. Thus K.E of the system increases (and is not constant).

If P.E. is assumed to be constant, mechanical energy(=K.E = P.E) will also increase.

As M.E. is conserved, therefore, chemical energy of gun powder must have been converted into K.E.

While firing the gun must be held tightly to the shoulder. This would save hurting the shoulder. When the gun is held tightly, the body of the shooter and the gun behave as one body. Total mass becomes large and therefore, recoil velocity of the body and the gun becomes too small.

2) Flight of rockets and jet planes. In rockets and jet planes,the fuel is burnt in the presence of some oxidising agent in combustion chamber. The hot and highly compressed gases escape through the narrow opening (i.e., exhaust nozzle) with large velocity. As a result of it, the escaping gases acquire a large backward momentum. This in turn, imparts an equal forward momentum to the rocket in accordance with the law of conservation of linear momentum.

3) When a man jumps out of a boat to the shore, the boat is pushed slightly away from the shore. The momentum of the boat is equal and opposite to that of the man in accordance with the law of conservation of linear momentum.

4) Explosion of bomb. When a bomb falls vertically downwards its horizontal velocity is zero and hence its horizontal momentum is zero. When bomb explodes, its pieces are scattered horizontally in different directions so that the vector sum of momenta of these pieces becomes zero in accordance with the law of conservation of linear momentum.

EXAMPLES

√ **Ex-1:**A man weighing 60 kg runs along the rails with the velocity of 18 km hr-1 and jump in to a car of the mass 1 quintal standing on the rails. calculate the velocity with which the car will start travelling along the rails.

Sol : Here, mass of man, m_1 = 60 kg.

initial velocity of man, u_{-1} 18 km/ 1 h = 18 x 1000 m / 60 x 60 s = 5 ms-1

Mass of a car , m_2 = 1 quintal = 100 kg.

Initial velocity of a car, u_{-2} = 0

After a man jumps into a car, let their common velocity be v

Applying the principle of conservation of momentum

Total momentum after jump = Total momentum before jump

$(m_1 + m_2)\, v = m_1 u_1 + m_2 u_2$

$(60 \times 100)\, v = 60 \times 5 + 100 \times 0$

OR $v = \frac{300}{160} = 1.8$

√ **Ex-2:** A toy rocket weighing 500 g is standing vertically on ground .How much force should act on it so that it starts ascending with a uniform acceleration of 5 ms^{-2} (Take g = 10 ms^{-2})

Sol : To go up, the upwards force should acting on the rocket must be greater than its weight 'mg'.

Net force acting on rocket

$F_{net} = F_{up} - mg$ (i)

By Newton's II law,

$F_{net} = ma$ (ii)

From equation (i) and (ii),

$F_{up} - mg = ma$

$F_{up} = mg + ma$

$= m(g + a) = 0.5\ kg\ (10 + 5)\ ms^{-1} = 0.5 \times 15\ kgms^{-2}$

$= 7.5\ N$

√ **Ex-3:** Two body s of mass 4 kg , 8kg are traveling in the same direction with a speed of 4 m/s and 2m/s they collide as a result of their collision 8 kg object start moveing with 8 m/s in the same direction so the speed of 6 kg mass of the body after collision

Sol: $m_1 = 6$ kg, $m_2 = 8$ kg, $u_1 = 4$ m/s

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$6 \times 4 + 8 \times 2 = 6 \times v_1 + 8 \times 8$

$24 + 16 = 6v_1 + 64$

$= 40 - 64 = 6v_1$

$v_1 = -24/6 = -4$m/s

√ **Ex- 4:** A gun fires a bullet of mass 100 g with a velocity of 60 m/s becauseof this gunpush back with a velocity of 2 m/s then the mass of the gun is ?

Sol: M = ?

m = 100g = 100 x 10^{-3} kg

V = 2 m/s

v = 60 m/s

M V = - m v

M = - mv /V = $60 \times 100 \times 10^{-3} kg$ /2 = 3 k g

√ **Ex 5:** Bullet of mass of 40 g is fired from a Riffle of mass 16 kg with a velocity

200m/SSs the recoli velcity of gun ?

Sol : M = 16kg, m=40g =40 x 10^{-3}kg, V=?

v = 200ms^{-1}

MV= -mv

V= $\frac{-mv}{M} = -\frac{40\times10^{-3}\times200}{16} \Rightarrow \frac{1}{4} \Rightarrow 0.25ms^{-1}$

TEACHING TASK

I) Single correct option questions :

1. A base ball of mass 150 gm travelling at 20 m/s is caught by a fielder and brought to rest in 0.04s. the force applied to the ball and the distance over which this force acts are respectively

A) 75 N, 0.8 m B) 37.5 N, 0.4 m C) 75 N, 0.4 m D) 37.5 N, 0.8 m

2. A ball of mass 0.05 kg travelling at 4 ms^{-1} hits a wall and rebounds without any change in its speed. If the ball remains in contact with the wall for 0.01 s, then the force exerted by the ball on the wall is

A) 0.05N B) 0.01N C) 50 N D) 40 N

3. A 6 kg mass 'A' moving with a velocity of 2 m/s collids with a 4 kg mass 'B' moving with a velocity of 1.5 m/s in the opposite direction in a straight line. If the two mass get stuck, then the velocity of the combination is

A) 0.4 m/s B) 0.2 m/s C) 0.1 m/s D) 0.6 m/s

4. A 6kg mass collides with a body at rest. After collision they travel together with a velocity one third the velocity of 6 kg mass. The mass of the second body is

A) 6 kg B) 3 kg C) 12 kg D) 18 kg

5. A shot moving with a velocity 140 ms^{-1} collides a wooden block and comes to rest in it. If mass of the block is 13 times the mass of the shot, velocity of the block is

A) 14ms^{-1} B) 10 ms^{-1} C) 4 ms^{-1} D) 2.5ms^{-1}

6. Two bodies of masses 2kg and 4kg travelling in same direction with speed 6m/s and 2m/s collide. As a result of this collision 4kg object starts moving with 4m/s in same direction. Speed of 2kg body after collision is

A) 1m/s B) 2m/s C) 3m/s D) 4m/s

II) More than one correct option questions :

- *This section contains multiple choice questions. Each question has 4 choices (A), (B), (C),(D), out of which **ONE or MORE** is correct. Choose the correct options*

7. The change in momentum per unit time of a body represents

a) Force b) massxacceleration c) Impulse d) velocity.

A) a,b correct B) b,c,d correct C) a,b,d correct D) all correct

8. Regarding linear momentum of a body

a. It is a measure of quantity of motion contained by the body

b. Change in momentum is the measure of impulse

c. Impulse and acceleration act in opposite direction to the change in momentum

d. In the case of uniform circular motion the linear momentum is conserved.
A) a,b,c correct B) a,b correct C) a,b,d correct D) all correct

9. Which of rthe following is correct?
a) Action reaction pairs acts on a same body.
b) Rocket works on the principle of newton's third law and law of conservation of linear momentum.
c) Action reaction pairs acts on different bodies.
d) Rocket works on the principle of newton's second law and law of conservation of energy.
A) a,b,c B) a,b C) a,b,d D) all

III) **Assertion - A and Reason - R :**

- *This section contains certain number of questions. Each question contains Statement – 1 (Assertion) and Statement – 2 (Reason). Each question has 4 choices (A), (B), (C) and (D) out of which* ***ONLY ONE*** *is correct Choose the correct option.*

A) Both A and R are true and R is the correct explanation for A.
B) Both A and R are true and R is not correct explanation of A.
C) A is true but R is false. D) A is false but R is true

10. A: If the force varies with time in a complicated way then the net force is measured by the total change inmomentum of the body
R: Change in momentum and force are numerically equal.

11. A: For every action there is an equal and opposite reaction.
R: In the absence of external force the linear momentum of a body remains constant.

IV) ***Match the followin :***

- *This section contains Matrix-Match Type questions. Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in* ***Column–I*** *have to be matched with statements (p, q, r, s) in* ***Column–II****. The answers to these questions have to be appropriately bubbled as illustrated in the following example.*

*If the correct matches are A-p,A-s,B-r,B-r,C-p,C-q and D-s,then the correct bubbled 4*4 matrix should be as follows:*

12.

Set-A	***Set-B***
a) momentum	1)Ns
b) Force	2) N
c) Rocket	3) Variable mass system.
d) Table fan	4) Isolated mass system.

A) a-1,b-4,c-2,d-3 B) a-3,b-1,c-2,d-4
C) a-2,b-1,c-4,d-3 D) a-1,b-2,c-3,d-4

V) **Comprehension type questions:**

- *This section contains paragraph. Based upon each paragraph multiple choice questions have to be answered. Each question has 4 choices (A) , (B) ,(C) and (D) out of which* ***ONLY ONE i****s correct. Choose the correct option.*

13. If a number of bodies collide with one another then total momentum of the bodies, just before collision is equal to the total momentum just after collision.
If Two bodies of masses 1 kg and 3kg travelling in same direction with speed 9m/s and 3m/s collide. As a result of this collision 3kg object starts moving with 2m/s in same direction.
i) Total momentum of the two bodies, just before collision is...
A) 18 Ns B) 3 Ns C) 27Ns D) 32 Ns
ii) Speed of 1kg body after collision is
A) 10m/s B) 12m/s C) 13m/s D) 4m/s

KEY

ΦΦ TEACHING TASK :

1) C 2) D 3) D 4) C 5) B 6) B 7) A 8) A 9) B 10) C
11) B 12) D 13. i) A ii) B.

LEARNER'S TASK

BEGINNERS (Level - I)

I) Single correct option questions :

1. A body of mass 300 g is kept at rest breaks into two parts due to internal forces. One part of mass 200 g is found to move at a speed of 12 m/s towards west. The velocity of other part is
A) 24 m/s towards the east B) 14 m/s towards the west
C) 34 m/s towards the noth D) 54 m/s towards the south

2. A 2kg shot is fired from a cannon of mass 198 kg with a velocity 50 ms^{-1} w.r.t. the gun. Then the velocity of recoil of the gun is
A) $-0.5ms^{-1}$ B) $0.1ms^{-1}$ C) $0.25ms^{-1}$ D) 1 ms^{-1}

3. A shell of mass M moving with a velocity v explodes into two parts and one of the part of mass m is left stationary after explosion. The velocity of the other part is
A) $\frac{mv}{M}$ B) $\frac{Mv}{m}$ C) $\frac{Mv}{M-m}$ D) $\frac{Mv}{M+m}$

4. A truck of mass 1200 kg is moving with a speed of 7 ms^{-1} when it collides with a second truck of mass 1600kg which is stationary. If the two trucks are automatically coupled together on impact, the speed with which combination moves is
A) 2 m/s B) 3 m/s C) 1.5 m/s D) 6 m/s

ACHIEVERS (Level - II)

I) Solve the following :

1. A 1.5kg hammer moving with velocity 10ms^{-1} strikes a nail for 0.005, seconds. Average force exerted on the nail is

2. A space craft of mass 2000 kg moving with a velocity of 600m/s suddenly explodes into two pieces. One piece of mass 500 kg is left stationary. The velocity of the other part must be

3. A bullet of mass 20gm is fired from a riffle of mass 8 kg with a velocity of 100m/s. The velocity of recoil of the refle is

4. A ball of mass 10 gm hits vertically a hard surface with a speed of 5 ms^{-1} and rebounds with the same speed. The ball remains in contact with the surface for 1/100 sec. The average force exerted by the surface on the ball is

5. A person weighing 60 kg in a small boat of mass 140 kg that is at rest, throws a 5 kg stone in the horizontal direction with a velocity of $14\,ms^{-1}$. The velocity of the boat

immediately after the throw is

6. A man and a cart move towards each other. The man weighs 64 kg and the cart 32kg. The velocity of the man is 5.4 km/hr and that of the cart is 1.8 km/hr. When the man approaches the cart, he jumps on to it. The velocity of the cart carrying the man will be

EXPLORERS (Level - III)

I) More than one correct option questions :

- *This section contains multiple choice questions. Each question has 4 choices (A), (B), (C),(D), out of which **ONE or MORE** is correct. Choose the correct options*

1. Which of rthe following are correct?
a) Both action and reaction are forces.b) Action and reaction act simultaneously
c) Action and reaction acts on different bodies.
d) Action and reaction forces occur in pairs only.
A) a,b,c B) a,b C) a,b,d D) all

2. Which of the following works on the principle of Newton's III law
a) Jet aeroplane b) rockets c) gun d) Rowing of a boat
A) a,b,c B) a,b C) a,b,d D) all

II) Assertion - A and Reason - R :

- *This section contains certain number of questions. Each question contains Statement – 1 (Assertion) and Statement – 2 (Reason). Each question has 4 choices (A), (B), (C) and (D) out of which **ONLY ONE** is correct Choose the correct option.*

A) Both A and R are true and R is the correct explanation for A.
B) Both A and R are true and R is not correct explanation of A.
C) A is true but R is false. D) A is false but R is true

3. A: newton-sec is the unit of momentum.
R: momentum is the product of mass and velocity.

4. A: Both impulse and change in momentum have the same units.
R: The dimensional formula for momentum is MLT^{-1}.

5. A: Newton's third law gives the concept of linear momentum.
R: When a stationary shell breaks into two fragments the two fragments will have same magnitude of linear momentum.

6. A: Action and reaction forces are equal in magnitude but opposite in direction
R: Newton's third law defines the force.

7. A: According to Newton's third law, the sum of action and reaction will becomes zero
R: For every action there is an equal and opposite reaction.

IIII) Match the following :

- *This section contains Matrix-Match Type questions. Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D) in **Column–I** have to be matched with statements (p, q, r, s) in **Column–II**. The answers to these questions have to be appropriately bubbled as illustrated in the following example.*

*If the correct matches are A-p,A-s,B-r,B-r,C-p,C-q and D-s,then the correct bubbled 4*4 matrix should be as follows:*

8.

Physical quantity	*S.I unit*
a) velocity	1) kgs^{-1}
b) dm/dt	2) kg
c) mass	3) ms^{-1}
d) acceleration	4) ms^{-2}

A) a-1,b-4,c-2,d-3 B) a-3,b-1,c-2,d-4
C) a-2,b-1,c-4,d-3 D) a-1,b-2,c-3,d-4

9.

Set-A	***Set-B***
a) action= - reaction	1) Newtons first law
b) F=0	2) Newton's second law
c) Definition of force	3) Conservation of linear momentum.
d) Measurement of force	4) Newton's third law.

A) a-1,b-4,c-2,d-3 B) a-3,b-1,c-2,d-4
C) a-2,b-1,c-4,d-3 D) a-4,b-3,c-1,d-2

10.

Set-A	**Set-B**
a) W	1) law of conservation of momentum
b) F	2) ma
c) mv-mu	3) change in momentum
d) Newton's third law	4) mg

A) a-1,b-4,c-2,d-3 B) a-3,b-1,c-2,d-4
C) a-2,b-1,c-4,d-3 D) a-4,b-2,c-3,d-1

IV) Comprehension type questions :

♦ *This section contains paragraph. Based upon each paragraph multiple choice questions have to be answered. Each question has 4 choices (A) , (B) ,(C) and (D) out of which* ***ONLY ONE i****s correct. Choose the correct option.*

11. In the absence of any external force the total linear momentum of a body remains constant is called law of conservation of linear momentum.

i) A gun fires a bullet of mass 50 gm with a velocity of 30 ms^{-1}. Because of this the gun is pushed back with a velocity of 1 ms^{-1}. Mass of the gun is

A) 1.5 Kg B) 30 Kg C) 15 Kg D) 20 Kg

ii) A machine gun of mass 10 kg, fires 10 gm bullets with a velocity of 400m/s at the rate of one every second. The velocity of recoil of the gun after four bullets are fired is

A) 0.4 m/s B) 0.8 m/s C) 1.6 m/s D) 3.2 m/s

RESEARCHERS (Level - IV)

Single correct option questions :

1. A retardating force of 150 N is applied to a body of mass 50 kg .which is moving with a speed of 30 m/s.the time taken by the body to com to rest is... **[NTSE 2016]**

A) 20s B)30s C) 5s D)10s

2. Which of the following statement is INCORRECT ? **(NSEJS 2010-11)**

A) If the net force on a body is zero, its velocity is constant or zero.
B) If the net force on a body is zero, its acceleration is constant and nonzero.
C) If the velcoity of a body is constant, its acceleration is zero

D) A body may have a varying velocity yet a constant speed.

3. A certain force applied to a body A gives it an acceleration of 10 m/s^2. The same force is applied to body B gives it an acceleration of 15 m/s^2. If the two bodies are joined together and the same force is applied to the combination, the acceleration will be **(NSEJS 2011-12)**

A) 6 ms^{-2} B) 25 ms^{-2} C) 12.5 ms^{-2} D) 9 ms^{-2}

4. What is the reading of the spring balance shown in the figure below? **(NSEJS 2012-13)**

A) 0 B)2N C) 4N D)6N

5. When a car turns on a curved road, you are pushed against one of the doors of the car because of **(NSEJS 2012-13)**

A) inertia B) the centripetal force C) the centrifugal force D) the frictional force

6. If two bodies of different masses, initially at rest, are acted upon by the same force for the same time, then both bodies acquire the same **(NSEJS 2014-15)**

A) Velocity B) momentum C) acceleration D) kinetic energy

7. The "reaction" force does not cancel the "action" force because **(NSEJS 2015-16)**

A) the action force is greater than the reaction force

B) the reaction force exists only after the action force is removed

C) the reaction force is greater than the action force

D) they act on different bodies

8. A body is in equilibrium under the combined action of several forces then

A) all the forces must be applied at the same point **(NSEJS 2015-16)**

B) all the forces form pairs of equal and opposite forces

C) the sum of the torques about any point must always be equal to zero

D) the lines of action of all the forces must pass through the centre of gravity of the body.

9. The object at rest suddenly explodes into three parts with the mass ratio 2:1:1. The parts of equal masses move at right angles to each other with equal speed V. The speed of the third part after the explosion will be **(2008 M)**

A) 2V B) $V/\sqrt{2}$ C) V/2 D) $\sqrt{2}V$

10. A rifle of 20kg mass can fire 4 bullets per second. The mass of each bullet is $35\times10^{-3}kg$ and its final velocity is $400ms^{-1}$. Then what force must be applied on the rifle so that it does not move backwards while firing the bullets ? **(2007 E)**

A) 80 N B) 28 N C) -112 N D) -56 N

11. A bullet of mass 10gm of fired horizontally with a velocity $1000ms^{-1}$ from a rifle situated at a height 50 m above the ground. If the bullet reaches the ground with a velocity $500ms^{-1}$, the work done against air resistance in the trajectory of the bullet is (in joules) $\left(g=10ms^{-2}\right)$ **(2006 E)**

A) 5005 B) 3755 C) 3750 D) 17.5

12. A gravel is dropped into a conveyor belt at a rate of 0.5 kg/s.The extra force required in N to keep the belt moving at 2 m/s is

A) 2 B) 1 C) 4 D) 5 **(1983 E)**

13. A boat of mass 3000 kg,initially at rest is pulled by a force of 1.8 x 10^4 N through a distance of 3m.Assuming that the velocity of air resistance as zero,velocity of boat is

A) 2 m/s B) 4m/s C) 3 m/s D) 6 m/s **(1983 E)**

14. A machine gun fires a bullewt of mass 40g with a velocity of 1200m/s.A man holding it

can exert a maximum force of 144 N on the gun.How many bullets can he fire per sec atmost. **(AIEEE-2004)**

A) 2 B) 4 C) 1 D) 3

15. A bomb of mass 16kg at rest explodes into 2 pieces of masses 4kg and 12kg.The velocity of 12kg mass is 4m/s.The K.E. of other mass is **(AIEEE-2006)**

A) 144J B) 288J C) 192J D) 96J

KEY

ΦΦ TEACHING TASK :

- **BEGINNERS :** 1) A , 2) A, 3) C, 4) B,
- **ACHIEVERS :** 1)3000N 2)800 m/s 3)0.25 m/s 4) 10 N, 5) $0.35\ ms^{-1}$, 6) 3 km/hr
- **EXPLORERS : I)** 1) D 2) D **II)** 3) A 4) B 5) B 6)C 7) A **III)** 8) B 9) D 10) D **IV)** 11) i) A, ii) C.
- **RESEARCHERS :** 1) D, 2) B, 3) A, 4) C, 5) A, 6) B 7) D, 8) B, 9) A, 10) D, 11) D, 12) B, 13) D, 14) D, 15)B