8 Force and Laws of Motion

Fastrack Revision

- **Force:** It is a push or hit or pull on a body. Force cannot be seen, tasted or felt but we can see or feel the effect of a force. It is a vector quantity.

  Effects of Force
  - A force can change the magnitude of velocity of an object.
  - A force can change the direction of motion of an object.
  - A force can change the shape or size of objects.

  Types of Force: Forces are of two types:
  - **Balanced Forces:** These are the forces which do not change the state of rest or motion of an object. Also, the forces are balanced if the resultant of applied forces is equal to zero.
  - **Unbalanced Forces:** If the resultant of applied forces is non-zero, the forces are unbalanced. In this case, the object would move in the direction of the greater force. An object in rest can be moved because of applying unbalanced forces.
- **Newton's Laws of Motion:** Newton has given three laws to define the motion of bodies. These laws are called Newton's laws of motion.
- **Newton's First Law of Motion:** An object continues to be in a state of rest or of uniform motion along a straight line unless acted upon by an unbalanced force.
- **Inertia:** The natural tendency of objects to resist a change in their state of rest or of uniform motion is called inertia.

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Inertia is the inherent property of all bodies and Newton's first law of motion is also known as the law of inertia.

- **Types of Inertia**
  - **Inertia of Rest:** It is the tendency of a body to oppose any change in its state of rest.
  - **Inertia of Motion:** It is the tendency of a body to oppose any change in its state of uniform motion.
  - **Inertia of Direction:** It is the tendency of a body to oppose any change in its direction of motion.
- **Mass:** It is a measure of inertia of an object. Its SI unit is **kilogram (kg).** Inertia increases with increase in mass and decreases with decrease in mass.
- **Friction:** Force of friction always opposes motion of objects. It arises between two surfaces in contact. It acts opposite to the direction of motion.
- **Momentum:** It measures the quantity of motion possessed by a body and is defined as the product of mass and velocity of the body. It is a vector quantity and its SI unit is Newton-second (N-s) or kg-m s^{-1}.

  Momentum (p) = mass (m) × velocity (v)

  or $p = mv$

  Its direction is the same as that of velocity v.

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If the body is at rest, its velocity, $v = 0$ and so momentum, $p = 0$.

- **Newton's Second Law of Motion:** The rate of change of momentum of an object is directly proportional to the applied unbalanced force in the direction of the force.

$$\therefore \quad \text{Force} = \frac{\text{Change in momentum}}{\text{Time taken}} = \frac{mv - mu}{t}$$

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

Thus, force is also defined as the product of mass and acceleration. Its SI unit is Newton or $kg\text{-}ms^{-2}$ and is represented by the symbol N.

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The force necessary to change the momentum of an object depends on the time rate at which the momentum is changed.

- A force of one Newton produces an acceleration of 1 m s^{-2} on an object of mass 1 kg.
- **Newton's Third Law of Motion:** When one object exerts a force on another object, then the second object instantaneously exerts an equal and opposite force on the first object. These forces are known as action and reaction forces which are always equal in magnitude but opposite in direction.

  This law can also be stated as to every action, there is an equal and opposite reaction and they act on two different bodies.

Practice Exercise

Multiple Choice Questions

Q 1. There will be a change in the speed or in the direction of motion of a body when it is acted upon by:

a. zero force b. balanced force
c. unbalanced force d. uniform force

Q 2. Identify the correct statement(s).

(i) To accelerate the motion of an object, a balanced force is required.
(ii) Balanced forces do not change the state of rest or of motion of an object.
(iii) Balanced forces do not produce any acceleration, they can change the shape or size or the body.

a. (i) and (ii) b. (ii) and (iii)
c. (i) and (iii) d. None of these

Q 3. A number of forces acting on a body changes velocity of the body. The forces cannot be:

a. paralleled b. unbalanced
c. balanced d. inclined

Q 4. A body is accelerating in a straight line. The unbalanced force acts:

a. in the direction of motion of the body.
b. in a direction opposite to the direction of motion.
c. in a direction perpendicular to the direction of motion of the body.
d. None of the above

Q 5. A hockey player pushes the ball on the ground. It comes to rest after travelling certain distance because:

a. the player stops pushing the ball
b. balanced force acts on the ball
c. the opposing force acts on the ball
d. None of the above

Q 6. Which of the following statement is not correct for an object moving along a straight path in an accelerated motion? *(NCERT EXEMPLAR)*

a. Its speed keeps changing
b. Its velocity always changes
c. It always goes away from the earth
d. A force is always acting on it

Q 7. A passenger in a moving bus tosses a coin which falls behind him. It means that, motion of the bus is: *(NCERT EXEMPLAR)*

a. uniform b. accelerated
c. retarded d. along circular motion

Q 8. A rider on horse falls back when horse starts running, all of a sudden because:

a. rider is taken back
b. rider is suddenly afraid of falling
c. inertia of rest keeps the upper part of body at rest while lower part of the body moves forward with the horse
d. None of the above

Q 9. A man getting down a running bus, falls forward because:

a. due to inertia of rest, road is left behind and man reaches forward
b. due to inertia of motion, upper part of body continues to be in motion in forward direction while feet come to rest as soon as they touch the road
c. he leans forward as a matter of habit
d. of the combined effect of all the three factors stated in a., b. and c..

Q 10. A water tanker filled up to $\frac{2}{3}$ of its height is moving with a uniform speed. On sudden application of the brake, the water in the tank would: *(NCERT EXEMPLAR)*

a. move backward b. move forward
c. be unaffected d. rise upwards

Q 11. The inertia of an object tends to cause the object: *(NCERT EXEMPLAR)*

a. to increase its speed
b. to decrease its speed
c. to resist any change in its state of motion
d. to decelerate due to friction

Q 12. What is the SI unit of momentum?

a. g-m s^{-1} b. g-m^2 s^{-1}
c. kg-m s^{-1} d. kg-m s^{-2}

Q 13. Inertia of a body is quantitative measure of its:

a. velocity b. acceleration
c. mass d. force

Q 14. If *A* and *B* are two objects with masses 13 kg and 25 kg respectively, then

a. *A* has more inertia than *B*
b. *B* has more inertia than *A*
c. *A* and *B* have same inertia
d. None of the two has inertia

Q 15. Which of the following has the largest inertia?

a. Needle b. A water bottle
c. Pen d. Our body

Q 16. Newton's second law of motion gives us a measure of:

a. force b. inertia
c. mass d. acceleration

Q 17. Which of the expression to find the force is correct?

a. $F = m/a$ b. $F = ma$
c. $F = a/m$ d. $F = ma/m$

Q 18. An object will continue to accelerate until the:

a. velocity changes direction
b. resultant force on it is increased continuously
c. resultant force begins to decrease
d. resultant force on it is zero

Q 19. How much force acts on a body whose momentum (*P*) is constant with time (*t*)?

a. Zero b. $p/2t$
c. $2p/t$ d. None of these

Q 20. A body, whose momentum is constant, must have constant:

a. force b. velocity
c. acceleration d. All of these

Q 21. The momentum of an object at a given instant is independent of its:

a. inertia b. mass
c. velocity d. acceleration

Q 22. A goalkeeper in a game of football pulls his hands backwards after holding the ball shot at the goal. This enables the goalkeeper to: *(NCERT EXEMPLAR)*

a. exert larger force on the ball
b. reduce the force exerted by the ball on hands
c. increase the rate of change of momentum
d. decrease the rate of change of momentum

Q 23. An object of mass 6 kg is sliding on horizontal surface, with a uniform velocity of 8 m/s. Assuming force of friction offered by the surface to be zero, the force required to maintain the motion of object with the same uniform velocity is:

a. Zero b. 2 N
c. 8 N d. 32 N

Q 24. Force required in accelerating a 3 kg mass at 5 m/s^2 and a 4 kg mass at 4 m/s^2, will be:

a. zero in both the cases
b. same in both the cases
c. greater for 3 kg mass at 5 m/s^2
d. greater for 4 kg mass at 4 m/s^2

Q 25. According to the third law of motion, action and reaction: *(NCERT EXEMPLAR)*

a. always act on the same body
b. always act on different bodies in opposite directions
c. have same magnitude and directions
d. act on either body at normal to each other

Q 26. The net force acting on a book placed on a table is:

a. force of gravity
b. force exerted by table on the book
c. frictional force
d. zero

Q 27. A cannon after firing recoils due to:

a. conservation of energy
b. backward thrust of gases produced
c. Newton's third law of motion
d. Newton's first law of motion

Q 28. A man is standing on a boat in still water. If he walks towards the shore, the boat will:

a. move away from the shore
b. remain stationary
c. move towards the shore
d. sink

Assertion & Reason Type Questions

Directions (Q. Nos. 29-37): *Each of the following questions consists of two statements, one is Assertion (A) and the other is Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:*

a. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
b. Both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A).
c. Assertion (A) is true but Reason (R) is false.
d. Assertion (A) is false but Reason (R) is true.

Q 29. Assertion (A): Balanced forces do not change the state of rest or of motion of an object.
Reason (R): If a number of forces acting on a body produce an acceleration in the body, then the forces acting are called unbalanced forces.

Q 30. Assertion (A): When we stop pedalling, the bicycle begins to slow down.
Reason (R): Force of friction always opposes motion of objects.

Q 31. Assertion (A): An object maintains its motion under the continuous application of an unbalanced force.
Reason (R): The change in the direction of motion would continue as long as this unbalanced force is applied.

Q 32. Assertion (A): When a motorcar makes a sharp turn at a high speed, we tend to get thrown to one side.
Reason (R): Inertia is the tendency of undisturbed objects to stay at rest or to keep moving with the same velocity.

Q 33. Assertion (A): A five-rupee coin has more inertia than one-rupee coin.
Reason (R): The mass of an object is a measure of its inertia.

Q 34. Assertion (A): Newton's second law of motion gives the measurement of force.
Reason (R): According to Newton's second law of motion, force is directly proportional to the rate of change of momentum.

Q 35. Assertion (A): The force necessary to change the momentum of an object depends on the time rate at which the momentum is changed.
Reason (R): Rate of change of momentum of a body is directly proportional to the applied unbalanced force.

Q 36. Assertion (A): If the net external force on the body is zero, then its acceleration is zero.
Reason (R): Acceleration does not depend on force.

Q 37. Assertion (A): When a bullet is fired from a gun, the force sending the bullet forward is equal to the force sending the gun backward.
Reason (R): Every action has an equal and opposite reaction.

Answers

1. (c) unbalanced force
   If an unbalanced force is applied on the object, there will be a change either in its speed or in the direction of its motion.
2. (b) (ii) and (iii)
   To accelerate the motion of an object, an unbalanced force is required.
3. (c) balanced
4. (a) in the direction of motion of the body.
5. (c) the opposing force acts on the ball.
   The ball comes to rest because frictional force (opposing force) acts on the ball.
6. (c) It always goes away from the earth
7. (b) accelerated
8. (c) Inertia of rest keeps the upper part of body at rest while lower part of the body moves forward with the horse
9. (b) due to inertia of motion, upper part of body continues to be in motion in forward direction while feet come to rest as soon as they touch the road
10. (b) move forward
    Due to Newton's first law of motion or law of inertia, tanker will stop but water will continue moving forward on sudden application of the brake.
11. (c) to resist any change in its state of motion
12. (c) kg-m s^{-1}
13. (c) mass
14. (b) *B* has more inertia than *A*.
    Heavier objects offer larger inertia.
15. (d) Our body
    Our body out of the four choices, our body is the heaviest. Hence, it has the largest inertia.
16. (a) force
17. (b) $F = ma$
18. (d) resultant force on it is zero
    We know that, $F = ma$
    $\Rightarrow \quad a = \frac{F}{m}$
    As mass is constant and cannot be zero. So, we can say an object will continue accelerating until the resultant force on it is zero.
19. (a) Zero
    Force is the rate of change of momentum.
    So, momentum is constant when force is zero.
20. (b) velocity
    For a given mass, $p \propto v$, if momentum is constant, then its velocity must be constant.
21. (d) acceleration
22. (d) decrease the rate of change of momentum
23. (a) Zero
    Given, $a = 0$
    [Since, object is moving with uniform velocity]
    We know that, $F = ma = 6 \times 0 = 0$ N
24. (c) greater for 3 kg mass at 5 m/s^2
    $F_1 = m_1 a_1 = 3 \times 5 = 15$ N
    $F_2 = m_2 a_2 = 4 \times 4 = 16$ N
    $\Rightarrow \quad F_2 > F_1$
25. (b) always act on different bodies in opposite directions.
26. (d) zero
    According to Newton's third law, the table exerts the same force on the book as the force that the book applies on the table. Thus, net force acting on the book is zero and hence the book remains at rest on the table.
27. (c) Newton's third law of motion
28. (a) move away from the shore
29. (b) Both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A).
30. (a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
31. (d) Assertion (A) is false but Reason (R) is true.
32. (a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
33. (a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
34. (a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
35. (b) Both Assertion (A) and R are true but R is not the correct explanation of Assertion (A).
36. (c) Assertion (A) is true but Reason (R) is false.
    According to Newton's second law of motion,
    $F = ma$
    Clearly, acceleration depends on force acting on the body.
    Also, if net external force is zero, *i.e.*,
    $0 = ma$
    $\Rightarrow \quad a = 0$, *i.e.*, no acceleration in the body.
37. (a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).

Case Study Based Questions

Case Study 1

If the resultant of all the forces acting on a body is zero, the forces are called balanced forces. A body under the action of balanced forces does not change its position of rest (or of uniform motion) and it appears as if no force is acting on it. They can, however, change the shape of the body.

On the other hand, if the resultant of all the forces acting on a body is not zero, the forces are called unbalanced forces. When unbalanced forces act on a body, they produce a change in its state of rest or of uniform motion.

Read the given passage carefully and give the answer of the following questions:

Q 1. Mark the incorrect option:

a. Balanced forces cannot set any stationary body into motion.
b. Balanced forces cannot change the speed of a moving body.
c. Balanced forces can change the shape and size of a body.
d. None of the above

Q 2. Which is correct for unbalanced forces?

a. When unbalanced forces act on an object at rest, the object will move.
b. Unbalanced forces are necessary to cause a non-moving object to start moving.
c. Unbalanced forces produces change in motion (acceleration).
d. All of the above

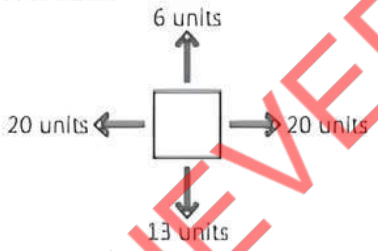
Q 3. If the force acting on an object are balanced, then the object:

a. must be at rest
b. must be moving
c. must not be accelerating
d. must lose energy

Q 4. A batsman hits a sweep short in the game of cricket. What is the nature of force experienced by the ball during the impact?

a. Balanced force
b. Unbalanced force
c. Both balanced and unbalanced forces
d. Neither balanced nor unbalanced forces

Q 5. Find net force on the object shown in the figure and answer if the forces are balanced or unbalanced.



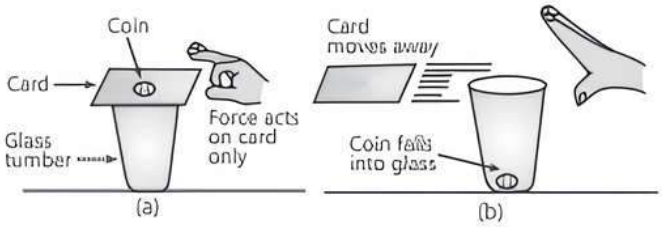
a. $(F_{net}) = 0$; Balanced forces
b. $(F_{net}) \neq 0$; Balanced forces
c. $(F_{net}) = 0$; Unbalanced forces
d. $(F_{net}) \neq 0$; Unbalanced forces

Answers

1. (d) None of the above
2. (d) All of the above
3. (c) must not be accelerating
4. (b) Unbalanced force
   During impact, the direction of the ball and speed changes. Thus, an unbalanced force is applied on the ball.
5. (d) $(F_{net}) \neq 0$; Unbalanced forces
   According to given figure,
   Net horizontal force = 20 – 20 = 0 unit
   Net vertical force = 13 – 6 = 7 units
   So, net force = 7 units (downward)
   Hence, $F_{net} \neq 0$, *i.e.*, forces are unbalanced.

Case Study 2

Varshney Sir was demonstrating an experiment in his class with the setup as shown in the figure below.



A five-rupee coin is set on a stiff card covering an empty glass tumbler standing on a table. He then flicks the card hard with his fingers.

Read the given passage carefully and give the answer of the following questions:

Q 1. Give reason for the above observation.

a. The coin possesses inertia of rest, it resists the change and hence falls in the glass.
b. The coin possesses inertia of motion, it resists the change and hence falls in the glass.
c. The coin possesses inertia of rest, it accepts the change and hence falls in the glass.
d. The coin possesses inertia of motion, it accepts the change and hence falls in the glass.

Q 2. Name the law involved in this case.

a. Newton's second law of motion
b. Newton's first law of motion
c. Newton's third law of motion
d. Law of conservation of energy

Q 3. If the above coin is replaced by a heavy ten rupee coin, what will be your observation? Give reason.

a. Heavy coin will possess more inertia and lesser force is required to perform the activity.
b. Heavy coin will possess less inertia and more force is required to perform the activity.
c. Heavy coin will possess more inertia and more force is required to perform the activity.
d. Heavy coin will possess less inertia and lesser force is required to perform the activity.

Q 4. Complete the statement of the first law of motion:

'A body at rest stays at ..... and a body in motion stays in ..... unless an ..... is applied'.

a. motion; rest; external force
b. rest; motion; external force
c. rest; motion; internal force
d. None of the above

Q 5. Observe the diagram carefully. A car braked suddenly near a cliff. Explain the motion of the driver.

a. The driver is pushed backwards.
b. Due to inertia of motion, driver was thrown forward as he continues to be in motion in the forward direction.
c. Due to inertia of rest, the road is left behind and the driver reaches forward.
d. Due to inertia of motion, the driver moved in the backward direction.

Answers

1. (a) The coin possesses inertia of rest, it resists the change and hence falls in the glass.
2. (b) Newton's first law of motion
3. (c) Heavy coin will possess more inertia and more force is required to perform the activity.
4. (b) rest; motion; external force
5. (b) Due to inertia of motion, driver was thrown forward as he continues to be in motion in the forward direction.

Case Study 3

Newton's second law of motion gives us a relationship between 'force' and 'acceleration'. The acceleration produced in a body is directly proportional to the force acting on it and inversely proportional to the mass of the body. Therefore, if the mass of a body is doubled, its acceleration will be halved. And if the mass is halved, then acceleration will get doubled (provided the force remains the same).

Read the given passage carefully and give the answer of the following questions:

Q 1. Newton's second law of motion tells us that:
a. all forces in the universe occur in equal but oppositely directed pairs.
b. an object will remain at rest or in uniform motion in a straight line unless acted upon by an external force.
c. the rate of change of linear momentum is equal to force acting on the body.
d. None of the above

Q 2. The incorrect statement about Newton's second law of motion is that:
a. it provides a measure of inertia
b. it provides a measure of force
c. it relates force and acceleration
d. it relates momentum and force

Q 3. Which of the following situations involves the Newton's second law of motion?
a. A force can stop a lighter vehicle as well as a heavier vehicle which are moving
b. A force can accelerate a lighter vehicle more easily than a heavier vehicle which are moving
c. A force exerted by a lighter vehicle on collision with a heavier vehicle results in both the vehicles coming to a standstill
d. A force exerted by the escaping air from a balloon in the downward direction makes the balloon to go upwards

Q 4. During athletics meet, a high jumping athlete is provided either a cushion or a heap of sand on the group to fall upon. Which law is used to explain it?
a. Law of inertia
b. Newton's first law of motion
c. Newton's second law of motion
d. Newton's third law of motion

Q 5. Two bodies have masses in the ratio 3 : 4. When a force is applied on the first body, it moves with an acceleration of 6 m s^{-2}. How much acceleration will the same force produce in the other body?
a. 1.5 m s^{-2} b. 3 m s^{-2}
c. 45 m s^{-2} d. 4.5 m s^{-2}

Answers

1. (c) the rate of change of linear momentum is equal to force acting on the body.
2. (a) it provides a measure of inertia
3. (b) A force can accelerate a lighter vehicle more easily than a heavier vehicle which are moving
4. (c) Newton's second law of motion
5. (d) 4.5 m s^{-2}

   Let the masses of the bodies be $3x$ and $4x$ respectively.

   Given acceleration = 6 m s^{-2}

   We know that, $F = m \times a$

   $\therefore$ $F = 3x \times 6 = 18x$

   As we are applying same force for the second body,

   $\therefore$ $18x = 4x \times a$

   $\Rightarrow$ $a = 18/4 = 4.5\ m/s^2$.

   Hence, acceleration is 4.5 m/s^2 or 4.5 ms^{-2}.

Case Study 4

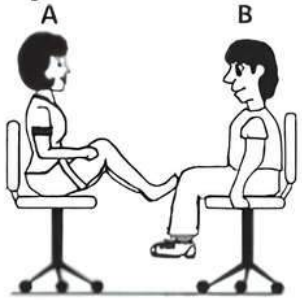
According to Newton's third law of motion, whenever one body exerts a force on another body, the second body exerts an equal and opposite force on the first body. The force exerted by the first body on the second body is known as 'action' and the force exerted by the second body on the first body is known as 'reaction'.

Read the given passage carefully and give the answer of the following questions:

Q 1. 'The action and reaction are equal in magnitude'. Is this statement true and which law is related with it?
a. Yes, Newton's second law
b. Yes, Newton's third law
c. No, Newton's third law
d. Yes, Newton's first law

Q 2. Newton's third law of motion can be used to explain:
a. why the passengers in a bus tend to fall backward when its starts suddenly
b. swimming of a man
c. walking
d. Both b. and c.

Q 3. Student *A* and student *B* sit in identical office chairs facing each other, as shown in figure. Student *A* is heavier than student *B*. Student *A* suddenly pushes with his feet. Which of the following occurs?



a. Neither student applies a force on each other
b. A exerts a force that is applied to B, but A experiences no force
c. Each student applies a force to the other, but A exerts the larger force
d. The students exerts the same amount of force on each other

Q 4. According to Newton's third law, action is always equal and opposite to the reaction. A horse can pull a cart because it applies a:

a. force on cart
b. force on ground
c. Both a. and b.
d. None of the above

Q 5. When a fireman directs a powerful stream of water on a fire from a hose pipe, the hose pipe tends to go backward. This is an example of Newton's:

a. law of gravitation
b. first law of motion
c. second law of motion
d. third law of motion

Answers

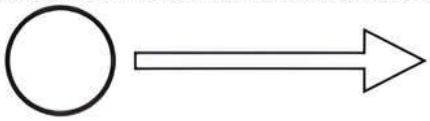
1. (b) Yes, Newton's third law
2. (d) Both b. and c.
3. (d) The students exerts the same amount of force on each other
4. (c) Both a. and b.
5. (d) third law of motion

Case Study 5

Momentum is a vector quantity that is the product of the mass and velocity of an object or particle. Momentum is measured in the standard unit of kilogram-metre per second. The direction of momentum is same as the direction of velocity. Every moving body possesses momentum. Since momentum depends on the mass and velocity of a body, so a body will have a large momentum (a) if its mass is large, or (b) if its velocity (speed) is large, or (c) if both mass and velocity (speed) are large.

Read the given passage carefully and give the answer of the following questions:

Q 1. Define momentum. State its SI unit.
Q 2. Is momentum a scalar or a vector quantity?
Q 3. A ball is moving in the direction as shown. What will be the direction of momentum?



Q 4. A hockey ball of mass 200 g travelling at 10 m s^{-1} is struck by a hockey stick so as to return it along its original path with a velocity of 5 m s^{-1}. Calculate the change of momentum which occurred in the motion of the hockey ball by the force applied by the hockey stick.

Q 5. Represent the following graphically:
(i) Momentum *versus* velocity when mass is fixed.
(ii) Momentum *versus* mass when velocity is fixed.

Answers

1. Momentum is defined as the product of mass and velocity of an object. Its SI unit is kg-m/s.
2. Momentum is a vector quantity.
3. Direction of momentum is same as the direction of velocity. Hence, the direction of momentum of ball in the given case is East.
4. Given, mass of the hockey ball,

$m = 200\ g = 0.2\ kg$

Initial velocity of ball, $u = 10\ m\ s^{-1}$

Final velocity of ball, $v = -5\ m\ s^{-1}$

Initial momentum of the ball $= mu$

$= 0.2\ kg \times 10\ m\ s^{-1}$

$= 2\ kg\text{-}m\ s^{-1}$

Final momentum of the ball $= mv$

$= 0.2\ kg \times (-5\ m\ s^{-1})$

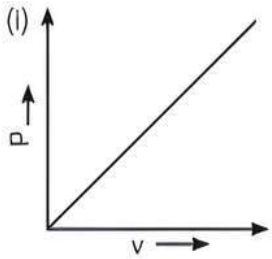
$= -1\ kg\text{-}m\ s^{-1}$

Therefore, the change in momentum $= mv - mu$

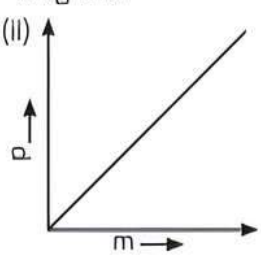
$= -1\ kg\text{-}m\ s^{-1} - 2\ kg\text{-}m\ s^{-1}$

$= -3\ kg\text{-}m\ s^{-1}$

5. (i)



(ii)



Very Short Answer Type Questions

Q 1. Apart from changing the magnitude of velocity of an object or changing the direction of motion of an object, what other changes can force bring on an object?

Ans. Force can change the shape of an object.

Q 2. Using a horizontal force of 200 N, we intend to move a wooden cabinet across a floor at a constant velocity. What is the friction force that will be exerted on the cabinet? *(NCERT EXERCISE)*

Ans. The magnitude of frictional force is equal to the force exerted on the cabinet, which is 200 N. Therefore, the force of friction on the cabinet = 200 N, in a direction opposite to the direction of motion of the cabinet.

Q 3. Name the force which is responsible for change in position or state of an object.

Ans. Unbalanced force is responsible for change in position or state of an object.

Q 4. An object experiences a net zero external unbalanced force. Is it possible for the object to be travelling with a non-zero velocity? If yes, state the conditions that must be placed on the magnitude and direction of the velocity. If no, provide a reason. *(NCERT EXERCISE)*

Ans. Yes, an object may travel with a non-zero velocity even when the net external force on it is zero. When external force is zero, then velocity of object remains same both in magnitude and direction.

Q 5. While riding a bicycle, if we stop pedalling, why does the bicycle begin to slow down?

Ans. If we stop pedalling, the applied force becomes lesser than the frictional force between bicycle wheels and the road. The friction force acts opposite to the direction of motion of bicycle, thus slaving down the bicycle.

Q 6. How is the frictional force in Galileo's experiment on an inclined plane be minimised?

Ans. The frictional force can be minimised by using a smooth marble and a smooth plane as well as by providing a lubricant on top of the inclined planes.

Knowledge BOOSTER

Frictional force arises when two rough surfaces in contact tend to be in relative motion.

Q 7. Why are seat belts provided in vehicles?

Ans. Seat belts are provided in vehicles to save the passengers from impact or collision with the panels in front by making the forward motion slower when brakes are applied suddenly.

Q 8. When a carpet is beaten with a stick, dust comes out of it. Explain. *(NCERT EXERCISE)*

Ans. Initially, the dust particles are at rest along with the carpet. Beating the carpet with the stick makes the carpet move but the dust particles remain at rest due to inertia of rest and hence dust comes out of the carpet when beaten.

Q 9. Explain why some of the leaves may get detached from a tree if we vigorously shake its branch. *(NCERT INTEXT)*

Ans. Initially, leaves and tree both are in rest. But when the tree is shaken vigorously, tree comes in motion while leaves tend to remain in rest due to inertia of rest. This results in detaching of leaves from the tree.

Q 10. You are given a heavy object and a light object. Which object will have more inertia?

Ans. A heavy object will have more inertia than the lighter one because inertia depends upon mass.

Q 11. There are three solids made up of aluminium, steel and wood, of the same shape and same volume. Which of them would have highest inertia? *(NCERT EXEMPLAR)*

Ans. Steel has greatest density and greatest mass among the three solids, therefore, it has highest inertia.

Q 12. Define one Newton force.

Ans. One Newton force is defined as the amount that produces an acceleration of 1 m s^{-2} in an object of 1 kg mass.

Q 13. An automobile vehicle has a mass of 1500 kg. What must be the force between the vehicle and road if the vehicle is to be stopped with a negative acceleration of 1.7 m s^{-2}? *(NCERT EXERCISE)*

Ans. Given, mass of the automobile vehicle (m) = 1500 kg
acceleration of the automobile (a) = –1.7 m s^{-2}
Using Newton's second law of motion,
$F = ma = 1500 \times -1.7 = -2550$ N

Q 14. Why does a person gets injured severely when hit by a moving vehicle?

Ans. A person gets injured severely when hit by a moving vehicle because of momentum of the vehicle which is due to its mass and velocity.

Q 15. Two similar trucks are moving with the same velocity on a road. One of them is loaded while the other one is empty. Which of the two will require a larger force to stop it?

Ans. The loaded truck will require a larger force to stop it as its mass is more as compared to the truck which is empty.

Q 16. Athletes in pole jump event fall on cushioned surface and not on floor. Why?

Ans. When athletes fall on cushioned surface, the rate of change of momentum is less. This reduces the force acting on the body of athletes and they do not get hurt.

Q 17. A goalkeeper in a game of football pulls his hands backwards after holding the ball shot at the goal. Explain.

Ans. The goalkeeper pulls his hands backwards after holding the ball so as to decrease the rate of change of momentum by increasing the time. Thus, less force is exerted on his hands.

Q 18. A truck of mass M is moved under a force F. If the truck is then loaded with an object equal to the mass of the truck and the driving force is halved, then how does the acceleration change? *(NCERT EXEMPLAR)*

Ans. We know that, force = mass × acceleration

$\Rightarrow$ $a_1 = F/M$

According to the question, body of same mass is loaded.

$\therefore$ Total mass $= M + M = 2M$ and force $= F/2$

$\Rightarrow$ $a_2 = F/4M = a_1/4$

Hence, acceleration becomes 1/4 times.

Q 19. A runner presses the ground with his feet before he starts his run. Identify action and reaction in this situation.

Ans. The force exerted by runner on the ground is the action force which produces a reaction force from the ground that acts back on the runner and pushes him forward.

Q 20. Do all action and reaction forces produce acceleration of equal magnitudes in both objects? Why/Why not?

Ans. No, though action and reaction are equal in magnitude, they may not produce acceleration of equal magnitudes because each force acts on different objects having different masses.

Q 21. Why a person should hold the rifle tightly on his shoulder before firing a bullet from the rifle?

Ans. When bullet is fired from a gun (action), it pushes the gun in opposite direction (reaction) with equal magnitude of force. Therefore, the person who is firing the bullet must hold the rifle tightly on his shoulder to avoid injury to the shoulder.

Q 22. Explain why is it difficult for a fireman to hold a hose, which ejects large amount of water at a high velocity? *(NCERT INTEXT)*

Ans. Water is ejected from a hose with a large amount of force. So, as per Newton's third law of motion, there will be an equal and opposite force on the hose pipe making it difficult to hold.

Short Answer Type-I Questions

Q 1. Why do you fall in the forward direction when a moving bus brakes to a stop and fall backwards when it accelerates from rest? *(NCERT INTEXT)*

Ans. When the moving bus brakes to a stop, then the passengers who had inertia of motion oppose a change in their state. However, the lower portion of their body in contact with bus comes to rest. So, they fall forward.

When the bus accelerates from rest, then the passengers who had inertia of rest, oppose a change in their state. However, the lower portion of their body starts moving with the bus. Hence, they fall backwards.

Q 2. Why is it advised to tie any luggage kept on the roof of a bus with a rope? *(NCERT EXERCISE)*

Ans. When the bus stops suddenly, then bus comes in the state of rest but the luggage remain in the state of motion. So, due to inertia of motion, the luggage move forward and may fall down from the roof of the bus. Similarly, when the bus starts suddenly, then bus comes in the state of motion but luggage remain in the state of rest. Due to inertia of rest, the luggage does not moves in the forward direction and may fall down. Thus, to avoid falling of luggage, it is tied with a rope.

Q 3. A pile of carrom coins is hit with a fast sliding striker. What happens to the carrom coins and why?

Ans. The lowest carrom coin leaves the pile and moves forward by the impact of striker. The rest of the coins do not move forward due to their inertia of rest. They resist any change in their state of rest and fall vertically on the carrom board.

Q 4. An object of mass 100 kg is accelerated uniformly from a velocity of 5 m/s to 8 m/s in 6 s. Calculate the initial and final momentum of the object. Also, find the magnitude of the force exerted on the object. *(NCERT EXERCISE)*

Sol. Given, mass of the object, $m = 100$ kg

Initial velocity, $u = 5$ m/s

Final velocity, $v = 8$ m/s

Time, $t = 6$ s

$\therefore$ Initial momentum $= mu$

$= 100 \times 5 = 500$ kg-m/s

and final momentum $= mv$

$= 100 \times 8 = 800$ kg-m/s

From Newton's second law, force exerted on the object = rate of change of momentum

$$= \frac{\text{Change in momentum}}{\text{Time}}$$

$$= \frac{\text{Final momentum} - \text{Initial momentum}}{\text{Time}}$$

$$= \frac{800 - 500}{6} = \frac{300}{6} = 50\,\text{N}$$

Q 5. Two balls A and B of masses 'm' and '$2m$' are in motion with velocities '$2v$' and 'v' respectively. Compare:

(i) their inertia,

(ii) their momentum, and

(iii) the force needed to stop them in the same time.

Ans. (i) Inertia of ball A : Inertia of ball B

$= m : 2m = 1 : 2.$

(ii) $\because$ $p_A = m(2v) = 2mv$

$p_B = (2m)v = 2mv$

$\therefore$ $p_A = p_B$

Or

Momentum of ball A : Momentum of ball B = $2mv : 2mv = 1:1$

(iii) $F_A = \frac{m(2v-0)}{t}$

$F_B = \frac{2m(v-0)}{t}$

Force needed to stop A : Force needed to stop $B = F_A : F_B = \frac{2mv}{t} / \frac{2mv}{t} = 1:1$

Q 6. Define SI unit of force. A force of 2 N acting on a body changes its velocity uniformly from 2 m/s to 5 m/s in 10 s. Calculate the mass of the body.

Ans. SI unit of force is newton (N). A force of one Newton produces an acceleration of 1 m s^{-2} in an object of mass 1 kg.

Given, $F = 2N$, $t = 10$ s, $u = 2$ m s^{-1}, $v = 5$ m s^{-1}.

We know that, $F = ma$ or $F = m\left(\frac{v-u}{t}\right)$

$\Rightarrow \quad m = \frac{Ft}{v-u} = \frac{2 \times 10}{5-2} = \frac{20}{3} = 6.67$ kg

Q 7. A hammer of mass 500 g moving at 50 m/s strikes a nail. The nail stops the hammer in a very short time of 0.01 s. What is the force of the nail on the hammer? *(NCERT EXERCISE)*

Sol. Given, mass of the hammer = 500 g = 0.5 kg

Initial velocity of hammer, $u = 50$ m/s

Final velocity of hammer, $v = 0$

(because the hammer stops)

Time, $t = 0.01$ s

According to Newton's second law of motion,

Force of the nail on the hammer

= Rate of change of momentum of hammer

$= \frac{m(v-u)}{t} = \frac{0.5 \times (0-50)}{0.01} = -\frac{25}{0.01} = -2500$ N

Negative sign indicates that the force of the nail on the hammer is acting in the direction opposite to that of motion of hammer.

Q 8. Why does a person hit harder when he falls on a concrete floor than when he falls on a heap of sand from the same height?

Ans. When a person falls from a height on to a concrete floor, then he comes to rest in a short interval of time and the rate of change of momentum is very large, thus large opposing force is acted on the person. While, when a person falls on a heap of sand, the rate of change of momentum is less due to which a smaller stopping force acts on the person.

Q 9. A swimmer is able to swim in a forward direction in a swimming pool only when he is pushing the water in the backward direction. Give reason for the above mentioned statement and justify the same.

Ans. A swimmer pushes the water backwards (or applies force on water backwards) with his hands and feet to move in the forward direction in water. It is the equal and opposite reaction to this force which pushes the swimmer forward. This is in accordance with Newton's third law of motion.

Short Answer Type-II Questions

Q 1. (i) What do you understand by the terms 'balanced forces' and 'unbalanced forces'?

(ii) What type of forces – balanced or unbalanced – act on a rubber ball when we press it between our hands? What effect is produced in the ball?

Ans. (i) If the resultant of all the forces acting on a body is zero, then forces are called balanced forces. These forces do not change the state of rest or of uniform motion of body but can change the shape of the body.

If the resultant of all the forces acting on a body is not zero, the forces are called unbalanced forces. These forces change the state of rest or of uniform motion of a body.

(ii) When we press a rubber ball between our two hands, balanced forces acts on it and hence the shape changes from spherical to oblong.

Q 2. (i) State Newton's first law of motion. If first law holds good, why does a rolling football come to rest on its own.

(ii) Derive Newton's first law of motion from the second law.

Ans. (i) It states that an object continues to be in a state of rest or of uniform motion along a straight line unless acted upon by an unbalanced force.

A rolling football comes to rest on its own because of the unbalanced external force of ground or by force of friction which always opposes motion of objects.

(ii) From Newton's second law, $F = ma$

If $F = 0$, then $a = 0$

This implies that when force is not applied on a body, the acceleration will be zero. Hence, a body not acted upon by an external force does not change its state of rest or motion which is the statement of Newton's first law of motion.

Q 3. Define inertia. Give two examples exhibiting inertia in our daily life.

Ans. Inertia: The natural tendency of objects to resist a change in their state of rest or of uniform motion is called inertia.

Following are the two examples exhibiting inertia in our daily life:

(i) When a running car or bus stops suddenly, the passengers are jerked forward.

(ii) When a hanging carpet is beaten with a stick, the dust particles start coming out of it.

Q 4. State reason why

(i) Glasswares are wrapped in straw during their transportation?

(ii) When a motorcar makes a sharp turn at a high speed, passengers tend to get thrown to one side?

Ans. (i) The glasswares are wrapped in straw, so that at the time of any jerk during transport, the force of jerk is transmitted to them from pieces of straw in a longer period of time. Hence, the change in momentum of glasswares takes place in a longer period of time. So, they experience a smaller force in the event of jerks and they do not break.

(ii) During sharp turn of motorcar at a high speed, the lower portion of passengers turns suddenly along the motorcar but the upper portion inertia is changed by the new direction. So, this portion moves forward and passengers are thrown to one side.

Q 5. (i) Why is it dangerous to jump out of a moving vehicle? How can the danger be minimised?

(ii) Why does a boatman push the water backward with the oars while rowing a boat?

Ans. (i) If a person jumps out of a moving vehicle, the feet will suddenly come to rest while the rest of the body remains in motion. Hence, he will fall down and may get hurt. This danger can be minimised by running along with moving vehicle in the same direction in which the vehicle is moving for sometime while jumping out of it.

(ii) When the boatman pushes the water backward with an oar while rowing the boat then according to Newton's third law of motion, the water applies reaction force and pushes the boat in forward direction.

Q 6. Which of the following has more inertia?

(i) A rubber ball and a stone of same size

(ii) A bicycle and a train

(iii) A five-rupee coin and a one-rupee coin

Give reasons for your answer. *(NCERT INTEXT)*

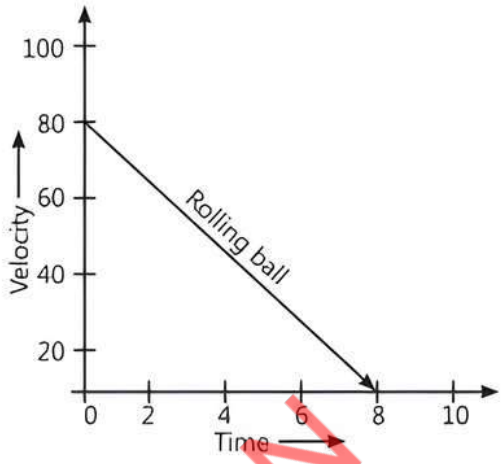
Ans. Inertia of an object is proportional to its mass.

(i) A stone of same size as that of rubber ball will have greater mass, so the stone will have more inertia.

(ii) A train has much greater mass than that of a bicycle, so the train will have more inertia.

(iii) A five-rupee coin has more mass than a one-rupee coin, so five-rupee coin will have greater inertia.

Q 7. (i) Velocity *versus* time graph of a ball of mass 50 g rolling on a concrete floor is shown in figure. Calculate the acceleration and frictional force of the floor on the ball. *(NCERT EXEMPLAR)*



(iii) A bullet of mass 10 g moving with a velocity of 400 m/s or a cricket ball of mass 400 g thrown with the speed of 90 km/h. Which one will have a higher value of momentum?

Sol. (i) Given, $m = 50\ g = 0.05\ kg$, $u = 80\ m\ s^{-1}$, $v = 0\ m\ s^{-1}$, $t = 8\ s$

Acceleration, $a = \frac{v-u}{t} = \frac{0-80}{8} = -10\ m\ s^{-2}$

Force, $F = ma = 0.05 \times (-10) = -0.5\ N$

Hence, acceleration is $-10\ m\ s^{-2}$ and frictional force of the floor on the ball is 0.5 N.

(ii) Mass of bullet, $m_b = 10\ g = 0.01\ kg$

Velocity of bullet, $v_b = 400\ m/s$

Momentum of bullet, $p_b = m_b v_b = 0.01 \times 400 = 4\ kg\text{-}m\ s^{-1}$

Mass of ball, $m_B = 400\ g = 0.4\ kg$

Velocity of ball, $v_B = 90\ km/h = \frac{90 \times 5}{18} = 25\ m/s$

Momentum of ball, $p_B = m_B v_B = 0.4 \times 25 = 10\ kg\text{-}m\ s^{-1}$

Thus, cricket ball has higher momentum.

Q 8. (i) State the law that provides the formula for measuring force and the law which provides the definition of force.

(ii) A man throws a ball of mass 0.4 kg vertically upwards with a velocity of 10 m s^{-1}. What will be its initial momentum? What would be its momentum at the highest point of its reach?

Ans. (i) Newton's second law of motion states that the rate of change of momentum of an object is proportional to the applied unbalanced force in the direction of the force.

(ii) Given, mass of ball, $m = 0.4\ kg$,

Initial velocity, $u = 10\ m\ s^{-1}$

$\therefore$ Initial momentum of the ball $= mu = 0.4 \times 10 = 4\ kg\text{-}m\ s^{-1}$

At the highest point, velocity of ball is zero.

$\therefore$ Momentum of the ball $= 0.4 \times 0 = 0$

Hence, momentum at the highest point of reach is 0.

Q 9. Why do fielders pull their hand gradually backwards while catching a fast cricket ball?

Ans. A fast moving cricket ball has a large momentum. In stopping (or catching) this cricket ball its momentum has to be reduced to zero. When a fielder moves back his hands on catching the fast ball, then the time taken to reduce the momentum of ball to zero is increased. Due to more time taken to stop the ball, the rate of change of momentum of ball is decreased and hence a small force is exerted on the hands of the fielder. Hence, he will not get injured by the ball.

Q 10. A motorcar of mass 1200 kg is moving along a straight line with a uniform velocity of 90 km/h. Its velocity is slowed down to 18 km/h in 4 s by an unbalanced external force. Calculate the acceleration and change in momentum. Also, calculate the magnitude of the force required. *(NCERT EXERCISE)*

Sol. Given, mass, $m = 1200$ kg

Initial velocity, $u = 90$ km/h $= 90 \times \frac{5}{18} = 25$ m/s

Final velocity, $v = 18$ km/h $= 18 \times \frac{5}{18} = 5$ m/s

Time, $t = 4$ s

$\therefore$ Acceleration, $a = \frac{v - u}{t} = \frac{5 - 25}{4}$

$= -\frac{20}{4} = -5$ m/s^2

(here, negative sign indicates that the velocity decreases)

$\therefore$ Change in momentum

= Final momentum – Initial momentum

$= mv - mu = m(v - u)$

$= 1200\ (5 - 25)$

$= 1200 \times (-20) = -24000$ kg-m/s

$\therefore$ Magnitude of the force required

= Rate of change of momentum

$= \frac{\text{Change in momentum}}{\text{Time}}$

$= \frac{-24000}{4} = -6000$ N

Q 11. A 8000 kg engine pulls a train of 5 wagons, each of 2000 kg along a horizontal track. If the engine exerts a force of 40000 N and the track offer a friction force of 5000 N, then calculate

(i) the net accelerating force,

(ii) the acceleration of the train and

(iii) the force of wagon 1 on wagon 2. *(NCERT EXERCISE)*

Ans. (i) Net accelerating force = Force exerted by engine – Friction force

(Here, frictional force is subtracted because it opposes the motion)

$= 40000 - 5000 = 35000 = 3.5 \times 10^4$ N

(ii) From Newton's second law of motion,

accelerating force = mass of the train × acceleration of train

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

Mass of train = 5 × Mass of one wagon + Mass of engine

$= 5 \times 2000 + 8000 = 18000$ kg

$\therefore$ Acceleration $= \frac{35000}{18000} = 1.94$ m/s^2

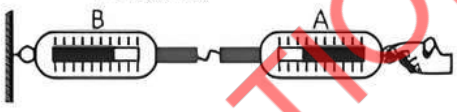
(iii) Force of wagon 1 on wagon 2

$= (35000 - 1.94 \times 2000)$ N

$= (35000 - 3880)$ N

$= 31120$ N

Q 12.



Look at the diagram above and answer the following questions:

(i) When a force is applied through the free end of the spring balance *A*, the reading on the spring balance *A* is 15 g wt. What will be the reading of spring balance *B*?

(ii) Write reasons for your answer.

(iii) Name the force which balance *A* exerts on balance *B* and the force of balance *B* on balance *A*.

Ans. (i) 15 g wt.

(ii) Force exerted by spring balance *A* on balance *B* is equal but opposite in direction to the force exerted by balance *B* on balance *A*.

(iii) Force exerted by spring balance *A* on balance *B* is called action and force exerted by balance *B* on balance *A* is called reaction.

Long Answer Type Questions

Q 1. Explain the following:

(i) Why do we jerk wet clothes before spreading them on line?

(ii) Why fruits fall off the branches in strong wind?

(iii) Why a pillion rider falls forward, when the driver of a two wheeler suddenly applies brakes?

(iv) How a karate player can break a pile of tiles with a single blow of his hand?

(v) A greater force is required to impart a greater velocity to an object.

Ans. (i) Initially, water and clothes both are in the state of rest. When the wet clothes are jerked, the particles of water tend to continue in their state of rest because of inertia of rest. Therefore, the removal of water helps wet clothes to dry up quickly because the droplets of water fall off from the clothes.

(ii) Initially, the fruits on the branches are in the state of rest. Because of inertia of rest, the fruits tend to continue in their state of rest, but due to strong wind, they fall off the branches.

(iii) The pillion rider and driver are in a state of motion during the ride. But when the driver applies brakes, the body of pillion rider continues to move forward due to inertia of motion. So, a pillion rider falls forward.

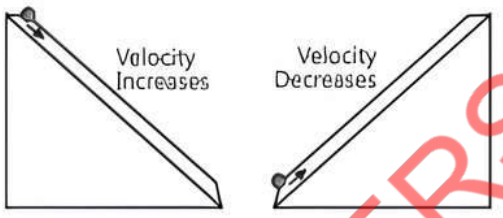
(iv) The karate player strikes the pile of tiles with his hand very fast. Hence, the large momentum of fast moving hand is reduced to zero in a very short time. This exerts a very large force on the pile of tiles which is sufficient to break them.

(v) Force produces an acceleration in an object on which it acts. If a larger change in velocity is required, then more force needs to be applied.

Q 2. Describe Galileo's experiment to demonstrate motion of objects on an inclined plane.

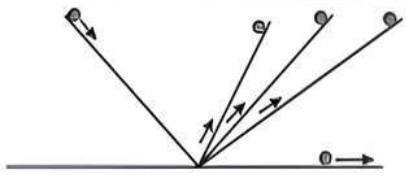
Ans. Galileo deduced that objects move with constant speed when no force acts on them by studying the motion of objects on an inclined plane.

Galileo took a marble, a frictionless inclined plane and started the experiment by rolling it down the inclined plane. He observed that when a marble rolls down an inclined plane, its velocity increases. Here, the marble falls under the unbalanced force of gravity as it rolls down and attains a definite velocity by the time it reaches the bottom and its velocity decreases when it climbs up.



From these observations, Galileo argued that when the marble is released from left, it would roll down the slope and go up on the opposite side to the same height from which it was released. If the inclinations of the planes on both sides are equal, then the marble will climb the same distance that it covered while rolling down.

If the angle of inclination of the right-side plane were gradually decreased, then the marble would travel further distances till it reaches the original height. If the right-side plane were ultimately made horizontal (that is, the slope is reduced to zero), the marble would continue to travel forever trying to reach the same height that it was released from.



Thus, it suggests that an unbalanced (external) force is required to change the motion of the marble but no net force is needed to sustain the uniform motion of the marble.

Q 3. Derive the unit of force using the second law of motion. A force of 5 N produces an acceleration of 8 m s^{-2} on a mass m_1 and an acceleration of 24 m s^{-2} on a mass m_2. What acceleration would the same force provide if both the masses are tied together?

(NCERT EXEMPLAR)

Sol. The SI unit of force is Newton (N).

Since, Force = Mass × Acceleration

Therefore, 1 Newton (N) = 1 kg × 1 m s^{-2}

= 1 kg-m s^{-2}

Given, $F = 5$ N, $a_1 = 8$ m s^{-2} and $a_2 = 24$ m s^{-2}

$$\therefore \quad m_1 = \frac{F}{a_1} = \frac{5}{8} = 0.625 \text{ kg}$$

and $$m_2 = \frac{F}{a_2} = \frac{5}{24} = 0.208 \text{ kg}$$

Total mass, $M = m_1 + m_2 = (0.625 + 0.208)$ kg

= 0.833 kg

Acceleration produced in the combined mass M,

$$a = \frac{F}{M} = \frac{5}{0.833} = 6 \text{ ms}^{-2}$$

Hence, if both the masses are tied together, the acceleration provided is 6 m s^{-2}.

Q 4. Explain the following:

(i) Why are the wheels of vehicle provided with mud guards?

(ii) Why does a boat tend to leave the shore, when passengers are alighting from it? How does boatman overcome the above difficulty?

(iii) Why does a gun recoil, when fixed?

(iv) How do the rockets operate in space?

Ans. (i) Due to inertia of motion, wheels rotate at high speed and mud sticking to the wheel flies off tangentially. To prevent this, wheels are provided with mud guards.

(ii) The passengers push the boat in backward direction while alighting from it. As a result, the boat has a tendency to slip back into water. This difficulty is overcome by the boatman by binding the boat to some rigid support on the bank.

(iii) When a bullet is fired, a gun recoils in accordance with Newton's third law because the force sending the bullet forward is equal to the force sending the gun backward (or recoiled).

(iv) When the rocket is fired, the burnt gases come out from the bottom of the rocket with a tremendous force which, in turn, applies a force on the rocket in the opposite direction.