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SOLUTIONS BOOK

CLASS 9

Science · Exploration

CHAPTER 6

How Forces Affect Motion

Complete Questions, Examples and Activities Solutions

In-text Questions | Examples | Revise, Reflect, Refine | The Journey Beyond

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Every question is followed by its answer. Question numbers above are clickable and the PDF bookmarks panel lets you jump to any exercise set or question. Figures are reproduced from the NCERT textbook (© NCERT) for educational use.

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6.1

CLASS 9 SCIENCE · CHAPTER 6

In-text Questions

Solutions · 26 questions

Directions (Questions 1–26): These are the questions that appear inside the chapter (Think It Over, Pause and Ponder, What if …, Think as a Scientist, the Activities and the questions asked in the text), numbered in the order in which they appear. Model answers based on the chapter are given; observations for activities show the expected trend.

QUESTION 1 *Think It Over · p. 94*

Why does a canoe move forward when the canoeist pushes water backwards with their paddle and why does it move faster when they push harder?

ANSWER

The canoe moves because of Newton’s third law of motion: forces always occur in pairs, and the two forces of a pair act on two different objects.

a Why the canoe moves forward

- The canoeist pushes the water backwards with the paddle (action).
- At the same time the water pushes the paddle forward with an equal and opposite force (reaction).
- These two forces act on different objects (the paddle and the water), so they do not cancel each other. The forward force on the paddle moves the paddle and the canoe forward.

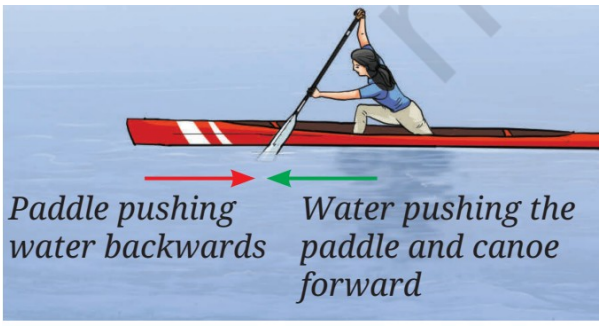

Fig. 6.28: Rowing a canoe

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b Why it moves faster when the canoeist pushes harder

- A harder push on the water gives an equal but larger forward force on the paddle.
- A larger net force on the canoe gives a larger acceleration (a = F/m), so its velocity increases more quickly.

Therefore, the canoe moves forward because the water pushes the paddle forward (third law), and a harder push gives a larger forward force and a greater acceleration (second law).

QUESTION 2 *Think It Over · p. 94*

Suppose the same canoeist uses the same paddle force in two different canoes, one empty and one carrying another passenger. In which case will the canoe move faster?

ANSWER

By Newton's second law, a = F/m. When the force is the same, the acceleration depends only on the mass that is being moved.

a Comparison for the same paddle force F

Case	Mass moved	Acceleration
Empty canoe	Smaller (m_1)	Larger
Canoe with a passenger	Larger ($m_2 > m_1$)	Smaller

b Working

Empty canoe: $a_1 = F/m_1$

Canoe with passenger: $a_2 = F/m_2$

Since $m_2 > m_1$, $a_1 > a_2$

Therefore, the empty canoe will move faster, because for the same force a smaller mass has a larger acceleration.

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QUESTION 3 *Balanced and Unbalanced Forces · p. 95*

In such cases, what is the effect of forces when more than one force is acting on an object at rest or in motion?

ANSWER

When several forces act, what matters is their combined effect, called the net force. The motion depends only on the net force.

a Balanced forces

Two forces equal in magnitude but opposite in direction are balanced forces. The net force is zero, so the object at rest stays at rest (the rope in tug of war does not move, Fig. 6.4a).

b Unbalanced forces

If the forces are not balanced, a non-zero net force acts and the object's motion changes (the rope moves in the direction of the larger force, Fig. 6.4b).

c Finding the net force

Situation	Magnitude of net force	Direction
Two forces in opposite directions	Difference of the two magnitudes	Along the larger force
Two forces in the same direction (Fig. 6.5)	Sum of the two magnitudes	Same as the individual forces

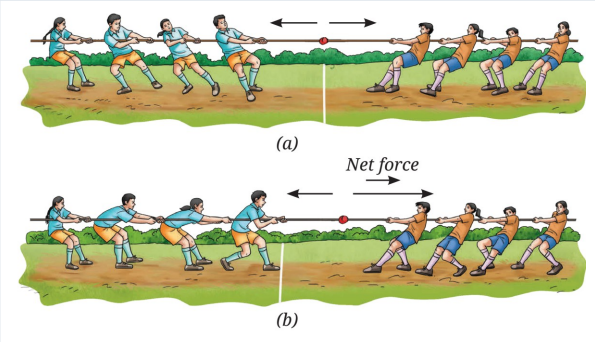

Fig. 6.4: Two forces in opposite directions of (a) equal magnitudes, (b) unequal magnitudes

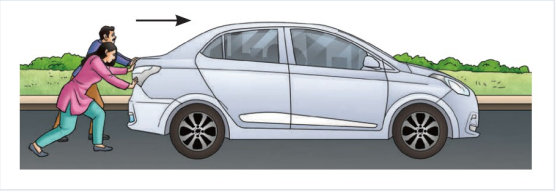

Fig. 6.5: Two forces applied in the same direction

Therefore, balanced forces leave the state of the object unchanged, while unbalanced forces produce a net force that changes its motion.

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QUESTION 4 *Pause and Ponder 1 · p. 97*

A weightlifter lifts a barbell (Fig. 6.8). List two forces that are acting on the barbell. Are these forces balanced if the weightlifter keeps the barbell steady?

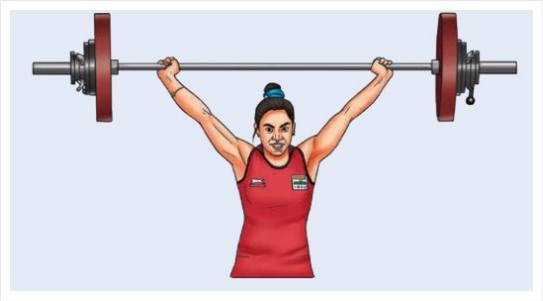

Fig. 6.8: A weightlifter lifting barbell

ANSWER

Two forces act on the barbell along the same vertical line, one downwards and one upwards.

a The two forces

- Gravitational force (weight) of the Earth on the barbell, acting downwards.
- The upward force applied by the weightlifter on the barbell.

b Are they balanced?

When the barbell is kept steady its velocity does not change, so the net force on it is zero (Newton's first law). Hence the upward force applied by the weightlifter is equal in magnitude and opposite in direction to the weight. The two forces are balanced.

Therefore, the weight (downwards) and the lifter's force (upwards) are balanced when the barbell is steady.

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QUESTION 5 *Pause and Ponder 2 · p. 97*

Two players R and S are participating in an arm-wrestling match (Fig. 6.9). At the instant, when the arms tilt to the front direction (out of the page towards you), are the forces exerted by the players balanced? If not, which player exerted the larger force?

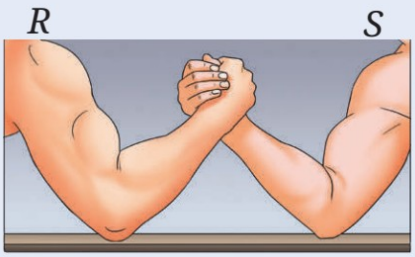

Fig. 6.9: Arm-wrestling match

ANSWER

If the two players' forces were equal and opposite, the net force would be zero and the clasped hands would not move.

a Are the forces balanced?

At that instant the arms are tilting, i.e. the clasped hands are changing their position. A change in motion needs a non-zero net force (Newton's first law). So the forces exerted by the two players are not balanced.

b Which player exerted the larger force?

The net force acts along the larger of the two forces. In Fig. 6.9 the hands are being pushed over towards S's side, so the net force is in the direction of the push by R. Hence player R exerted the larger force.

Therefore, the forces are not balanced, and R exerted the larger force.

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QUESTION 6 *Section 6.3 · pp. 97–98*

Does it mean that you need to continuously apply a force to keep it moving?

ANSWER

The question follows the examples of a box that stops after the push ends, a bicycle that stops after pedalling stops, and a ball that stops after it is no longer pushed.

a Why such objects stop

- Friction acts opposite to the direction of motion and gradually decreases the velocity until the object comes to rest.
- To keep a moving object going, we have to apply a force that counters (balances) the force of friction.

b Is a force needed for motion itself?

No. If the applied force equals the force of friction, the net force is zero and the object continues with constant velocity (Newton’s first law). The force is needed only to overcome friction, not to maintain the motion.

Therefore, we apply a continuous force on a moving object only to counter friction; without friction no force is needed to keep it moving.

QUESTION 7 *What if … · p. 98*

What if the force of friction disappears in the world? How will the motion of objects be impacted?

ANSWER

Friction always acts against motion, but it also makes many everyday actions possible. Without it, the motion of objects would change in several ways.

a Possible effects

- A moving object would never slow down or stop by itself. It would keep moving with constant velocity until some other force acts on it.

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- We could not walk or run, because the forward push that moves us is the force of friction (Section 6.6). Our feet would slip backwards.
- Vehicles could not start, stop or turn, because the tyres would not grip the road.
- Objects would not stay at rest on slightly inclined surfaces and would slide easily.

Therefore, without friction objects once set in motion would keep moving, and activities like walking and driving would not be possible.

QUESTION 8 *Activity 6.1 · p. 98*

Do you find that after losing contact with the rubber band, the velocity of the stack of coins decreases gradually and it comes to rest after travelling some distance?
Does the stack of coins travel a larger distance than it did on the wooden table top before coming to rest? Does its velocity decrease more slowly now?
Does the stack of coins travel an even larger distance and its velocity decrease even more slowly? What conclusion do you draw from your observations?

ANSWER

Activity 6.1 compares the motion of a released stack of four ₹10 coins on a wooden table top, a laminated table top and a polished marble or tiled floor. The rubber band is stretched to the same mark C each time.

a Observations (expected trend)

Surface	Distance travelled	Decrease in velocity	Friction
Wooden table top	Smallest of the three	Fastest	Largest
Laminated table top	Larger than on wood	Slower than on wood	Smaller than on wood
Polished marble / tiled floor	Largest	Slowest	Smallest

Yes, on every surface the velocity decreases gradually and the stack comes to rest after travelling some distance. Measure the distances yourself and record them; the order is what matters.

b Explanation

- Before release the stack is stationary, so the forces on it are balanced.

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- After release the force of the stretched rubber band is larger than friction, so a net force acts forward and the stack accelerates from zero velocity.
- As soon as the stack loses contact with the band, only the force of friction acts on it, opposite to its motion. It gradually decreases the velocity and finally brings the stack to rest.

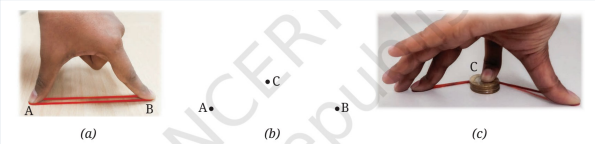

Fig. 6.12: (a) rubber band stretched between forefinger and thumb, (b) marks A, B, C, (c) band stretched back to C with the stack of coins

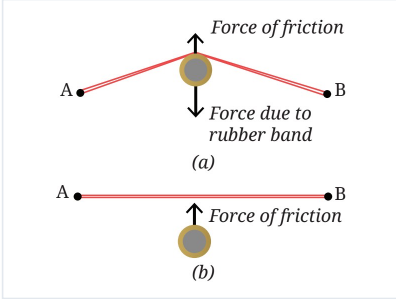

Fig. 6.13: Forces on the stack (a) on release, (b) only friction

c Conclusion

Although the rubber band is stretched by the same amount each time, the distance changes with the surface. So the force of friction is different on different surfaces: the smaller the friction, the more slowly the velocity decreases and the larger the distance travelled.

Therefore, the smoother the surface (the smaller the friction), the larger the distance travelled by the stack before it comes to rest.

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QUESTION 9 *Activity 6.2 · p. 99*

Pull the spring balance with gradually increasing force and note down the reading on it when the block just starts moving. What does this reading indicate? … If the velocity of the block is neither increasing nor decreasing, what can you say about the net force acting on the block? Does the reading of the spring balance indicate the magnitude of the force of friction acting on the wooden block?
Compare the readings of the spring balance for all surfaces. Are the readings different? Is the reading smallest for the surface on which the stack of coins travelled the largest distance? Is the reading largest for which the distance travelled was the smallest?

ANSWER

In Activity 6.2 a wooden block attached to a spring balance is pulled on the four surfaces of Activity 6.1. The forces on the block are the pull of the spring and the force of friction.

a What the reading indicates

The reading when the block just starts moving shows the force the spring must apply to overcome the force of friction between the block and the surface.

b Net force and friction

- If the velocity is neither increasing nor decreasing, the acceleration is zero, so the net force on the block is zero.
- Then the pull of the spring is equal in magnitude and opposite in direction to friction. So the reading of the spring balance gives an approximate measure of the magnitude of the force of friction.

c Comparing the surfaces

- Yes, the readings are different for different surfaces.
- Yes, the reading is smallest for the surface on which the stack of coins travelled the largest distance (the smoothest surface).
- Yes, the reading is largest for the surface on which the distance travelled was the smallest (the roughest surface).

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Fig. 6.14: A block being pulled by a spring balance

Therefore, a smaller spring-balance reading means a smaller force of friction, and the velocity of the coins then decreases more slowly and they travel farther.

QUESTION 10 *Think as a Scientist · p. 100*

Suppose, you find an object and a horizontal floor having such smooth surfaces that the force of friction between them is zero. Imagine, what will happen if you repeat steps 3 and 4 of Activity 6.1 with such an object and a horizontal floor? Will the velocity of the object decrease? Will the object ever come to rest or continue moving forever?

ANSWER

This is a thought experiment, used when the conditions needed are difficult to recreate in the real world.

a Reasoning

- After release, the force of the rubber band acts only until the object loses contact with it.
- With zero friction there is no force opposing the motion, so the net force on the object is zero.
- By Newton's first law, an object in motion with zero net force continues with constant velocity.

b Answer

The velocity of the object will not decrease. The object will never come to rest; it will continue moving forever in a straight line with the constant velocity it gained. Galileo reached the same conclusion through his thought experiments.

Therefore, with zero friction the object keeps moving forever with constant velocity.

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QUESTION 11 *Pause and Ponder 3 · p. 101*

An object is moving with a constant velocity. Is there a net force acting upon it?

ANSWER

Constant velocity means that neither the magnitude nor the direction of the velocity changes.

a **Reasoning**

Constant velocity ⇒ acceleration a = 0

Net force F = ma = m × 0 = 0

This agrees with Newton's first law: an object moves with constant velocity only when no net force acts on it.

Therefore, no net force acts on an object moving with a constant velocity (the net force is zero).

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QUESTION 12 *Pause and Ponder 4 · p. 101*

Suppose, no net force is acting on an object. Which of the following situations are possible?

(i) Object remains at rest if at rest.
(ii) Object keeps moving with a constant velocity if already moving.
(iii) Object is moving with a constant acceleration.

ANSWER

Use Newton's first law: if the net force is zero, the object cannot begin to move or change its velocity, and its acceleration is zero.

a Checking each situation

Situation	Possible?	Reason
(i) Remains at rest if at rest	Possible	Zero net force cannot start the motion
(ii) Keeps moving with constant velocity	Possible	Zero net force cannot change the velocity
(iii) Moves with constant acceleration	Not possible	Acceleration is zero when the net force is zero

Therefore, situations (i) and (ii) are possible; situation (iii) is not possible.

QUESTION 13 *Pause and Ponder 5 · p. 101*

In the real world, it is difficult to find a situation where no forces are acting on an object. But by applying additional forces, a condition can be achieved where the net force on the object is zero. Explain with the help of an example.

ANSWER

Real objects usually have several forces acting on them. If these forces balance one another, the net force is zero.

a Example: a box pushed on the floor (Example 6.2)

- The force of friction acts on a moving box in the backward direction.

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- A person applies an additional forward force equal to the force of friction.
- The two forces are equal and opposite, so the net force is zero and the box moves with constant velocity.

b Another example: a ball floating on water (Fig. 6.3b)

The gravitational force acts downwards and the buoyant force acts upwards. They are equal and opposite, so the net force is zero and the ball stays at rest.

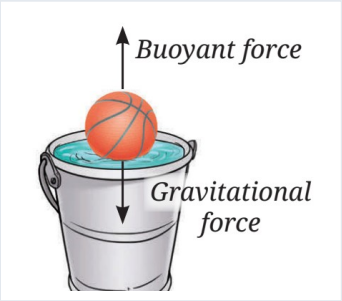

Fig. 6.3: (b) A ball floating on water

Therefore, adding a suitable force (or a balancing force from the surroundings) can make the net force on an object zero.

QUESTION 14 *Activity 6.3 · pp. 102–103*

Now, how can you test your hypothesis? … How can you apply forces of different magnitudes?

(Hypothesis: for the same object, a larger force results in larger acceleration.)

ANSWER

To test the hypothesis, forces of different magnitudes must be applied on the same object on the same surface, and the accelerations compared. Weights of different magnitudes give forces of different magnitudes.

a Method (Activity 6.3)

- A cart is pulled by a thread passing over a pulley. A paper cup at the free end of the thread is pulled down by the gravitational force.
- The cart starts from rest and travels the same distance s each time. The time is read from a slow-motion video: T_1 for the cup with some mass and T_2 after doubling the mass in the cup.

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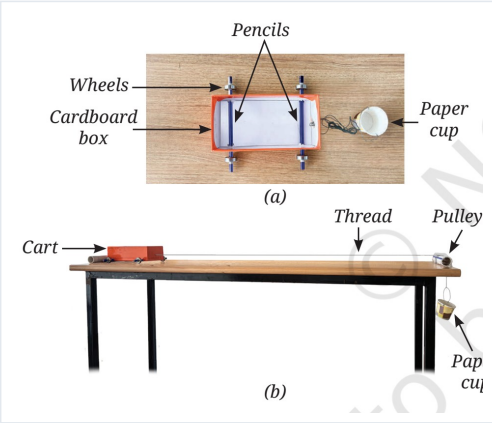

Fig. 6.17: (a) A cart, (b) a cart and pulley system

b **Analysis**

u = 0, so $s = \frac{1}{2} a_1 T_1^2$ and $s = \frac{1}{2} a_2 T_2^2$

Equating: $a_1 T_1^2 = a_2 T_2^2$

$a_1 / a_2 = T_2^2 / T_1^2$

With the larger force the cart takes less time ($T_2 < T_1$), so $a_2 > a_1$. The acceleration increased when the force on the same cart was increased. The increase may be a little less than a factor of two because of friction in the wheels.

Therefore, the acceleration of an object of fixed mass increases as the net force applied on it increases.

QUESTION 15 *Activity 6.4 · p. 103*

Now how can you test your second hypothesis?

(Hypothesis: for the same force, a smaller mass has a larger acceleration.)

Do you find that for the same force, when you increased the mass of the cart, the acceleration decreased?

ANSWER

The second hypothesis is tested by keeping the force constant and changing only the mass of the object.

a **Method (Activity 6.4)**

- Repeat Activity 6.3 but keep the mass of the cup and its objects constant.
- Double the mass of the cart by adding objects in it and measure its mass.
- Release the cart, record the time T for the same distance s, and find the ratio of accelerations.

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b **Analysis**

$a_1 / a_2 = T_2^2 / T_1^2$ (same s, u = 0)

With the heavier cart the time is longer ($T_2 > T_1$), so $a_2 < a_1$. Yes, the acceleration decreased when the mass of the cart was increased for the same force.

c **Newton's second law of motion**

The acceleration produced by a given force is inversely related to the mass, a = F/m, or F = ma. The object accelerates in the direction of the net force.

Therefore, for a given force, the acceleration of an object is inversely proportional to its mass.

QUESTION 16 *Pause and Ponder 6 · p. 106*

A toy car of mass 100 g is moving with a constant velocity of 0.5 m s^{-1}. What is the net force acting on the toy car?

ANSWER

Use Newton's second law, F = ma. The net force depends on the acceleration, not on the velocity.

a **Solution**

Mass m = 100 g = 0.1 kg

Velocity is constant, so acceleration a = 0

F = ma = 0.1 kg × 0 m s^{-2} = 0 N

Therefore, the net force acting on the toy car is 0 N.

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QUESTION 17 *Pause and Ponder 7 · p. 106*

Two children of different masses are sitting on identical swings. To impart identical initial acceleration, for which child would you require to apply a larger force? Explain why.

ANSWER

Newton's second law gives F = ma. For the same acceleration, the force is proportional to the mass.

a **Reasoning**

$F_1 = m_1 a$ and $F_2 = m_2 a$ (same a)

$F_2 / F_1 = m_2 / m_1$

The child with the larger mass needs the larger force.

Therefore, a larger force is required for the child of larger mass (heavier child), because F = ma.

QUESTION 18 *Pause and Ponder 8 · p. 106*

How are glass items packed for transportation using a bubble wrap or hay protected from damage?

ANSWER

The idea is the same as in catching a cricket ball with hands drawn back, or an airbag in a vehicle.

a **Explanation**

- If a glass item gets a jerk or hits something, its velocity changes to zero quickly, giving a large acceleration and so a large force (F = ma).
- Bubble wrap or hay is soft and compressible. It increases the time over which the velocity of the glass item changes.
- A longer time means a smaller acceleration, so a smaller force acts on the glass.

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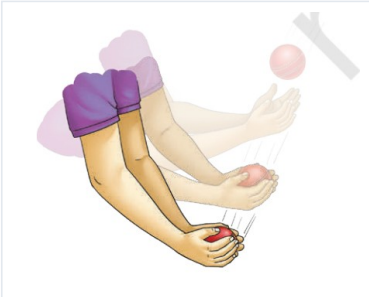

Fig. 6.18: Catching a cricket ball



Fig. 6.19: Inflated airbag in a vehicle

Therefore, bubble wrap or hay increases the stopping time, which reduces the force on the glass and protects it from breaking.

QUESTION 19 *Activity 6.5 · p. 107*

Sit on the chair with your legs raised above the floor. Now, using both your hands, push the table away from you … What happens to you? Does the chair you are sitting upon move in the opposite direction? Now, try to pull the table towards you … In which direction does your chair move now?
What conclusion can you draw from this activity?

ANSWER

A person sitting on a wheeled chair applies a force on a large heavy table (Fig. 6.23).

a Observations

Action on the table	Movement of the chair
Push the table away (forward force on the table)	Chair moves backwards, opposite to the push
Pull the table towards you (backward force on the table)	Chair moves forward, towards the table

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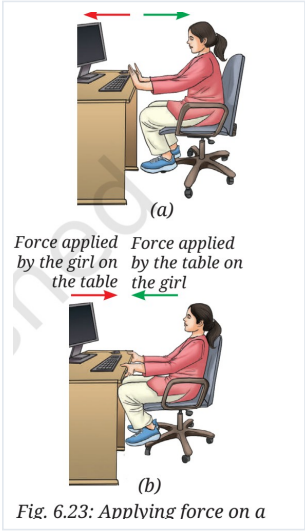

Fig. 6.23: Applying force on a

Fig. 6.23: Applying force on a table in the (a) forward direction, (b) reverse direction

b Conclusion

Each time the girl applied a force on the table, the table applied a force upon her in the opposite direction. The heavy table does not move but the chair (with the person) does.

Therefore, when one object applies a force on a second object, the second object applies a force on the first in the opposite direction.

QUESTION 20 *Activity 6.6 · p. 108*

Imagine that you are pulling the free end of the other spring balance with your other hand. Predict what will be the readings of their scales if the spring balances are stationary.
Now, carry out step 3. Repeat it multiple times by varying the magnitude of the force applied by you. Is your observation same as your prediction?

ANSWER

Two identical spring balances are hooked together on a table; one end is fixed and the free end of the other is pulled (Fig. 6.26).

a Prediction

Each balance pulls the other. The balances are stationary, so I predict that both scales show the same reading.

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b Observation

Yes, the observation matches the prediction. The readings of the two scales are the same every time, however much the pull is varied.



Fig. 6.26: Two spring balances connected together are pulled in opposite directions

c What it shows

The forces applied by the two balances on each other are equal in magnitude and opposite in direction. This is Newton's third law.

Therefore, whenever one object exerts a force on a second object, the second object simultaneously exerts an equal and opposite force on the first.

QUESTION 21 *Activity 6.7 · p. 109*

Remove the thread tied to the neck of the balloon and observe in which direction the straw and the balloon move.

ANSWER

An inflated balloon with a straw is hung on a taut thread; the thread at its neck is then removed (Fig. 6.29).

a Observation

The air rushes out of the neck in one direction, and the balloon with the straw moves along the thread in the opposite direction.

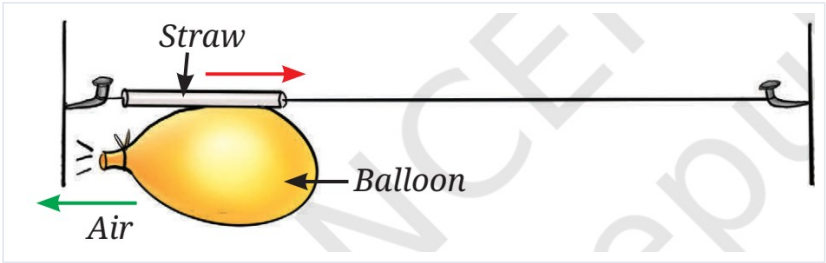

Fig. 6.29: Air rushing out of the balloon

b Explanation

- The stretched balloon material pushes the air molecules out as it shrinks.

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- The air rushing out exerts an equal force on the balloon material in the opposite direction, so the balloon moves opposite to the air.

Therefore, the balloon moves in the direction opposite to that of the rushing air (third law of motion).

QUESTION 22 *Section 6.6 · p. 109*

What will happen if the engine of a rocket moving in the space, fires in the direction of its motion?

ANSWER

The rocket moves by expelling gas, and the gas pushes the rocket in the opposite direction (Fig. 6.30).

a **Answer**

- If the engine fires in the direction of its motion, the exhaust gases are expelled forward.
- The gases exert an equal force on the rocket in the direction opposite to its motion.
- This force slows the rocket down.

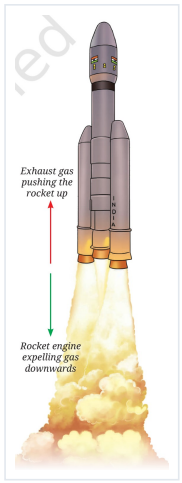

Fig. 6.30: Rocket launching

The Vikram lander of Chandrayaan-3 used this process to slow down and attain the necessary velocity for a soft landing near the south pole of the Moon.

Therefore, the rocket will slow down when its engine fires in the direction of its motion.

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QUESTION 23 *Pause and Ponder 9 · p. 110*

Why does a fireperson sometimes struggle when holding the pipe issuing water?

ANSWER

This is an application of Newton’s third law.

a **Explanation**

- The pipe pushes the water forward with a large force so that it comes out at high speed.
- By Newton’s third law the water pushes the pipe backwards with an equal and opposite force.
- This backward force acts on the pipe held by the fireperson, who has to apply a strong force to hold the pipe steady.

Therefore, the fireperson struggles because the water issuing forward pushes the pipe backward with an equal force.

QUESTION 24 *Pause and Ponder 10 · p. 110*

Suppose a spacecraft is moving in a region of space where the gravitational force acting upon it is negligible. Suggest how can it change its velocity.

ANSWER

A velocity can change only by a net force. In that region there is no gravitational force, so the spacecraft has to create a force itself.

a **Method**

- It fires its engine and expels exhaust gas in a direction opposite to the change in velocity it wants.
- The expelled gas exerts an equal and opposite force on the spacecraft (third law), which changes its velocity.
- To speed up it expels gas backwards; to slow down it expels gas forward; to change direction it expels gas to the side.

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Therefore, the spacecraft can change its velocity by firing its engine and expelling gas in the suitable direction.

QUESTION 25 *Section 6.6 · p. 110*

Is Newton’s third law applicable only for contact forces?

ANSWER

Contact forces act when objects touch each other; non-contact forces act at a distance.

a Answer

No. Newton’s third law applies to all types of forces, contact or non-contact, in everyday mechanical situations.

b Examples of non-contact forces

- Magnetic force: two bar magnets apply equal and opposite forces on each other (Fig. 6.31).
- Electrostatic force: two similarly charged balloons apply equal and opposite forces on each other (Fig. 6.32).
- Gravitational force: the Earth and the fruit apply equal and opposite forces on each other (Fig. 6.33).

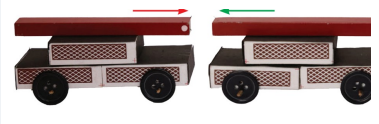

Fig. 6.31: Two bar magnets

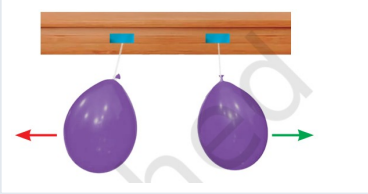

Fig. 6.32: Two similarly charged balloons

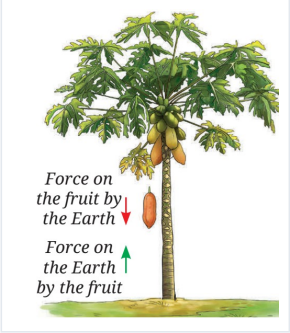

Fig. 6.33: The Earth and the fruit

Therefore, Newton’s third law holds for contact as well as non-contact forces.

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QUESTION 26 *Section 6.7 · p. 111*

But can we apply these laws to two or more objects connected together?

ANSWER

Yes. Two boxes of masses m_1 and m_2 joined by a string on a frictionless surface are treated as a single system (Fig. 6.34).

a Forces on the system

- Internal force: the tension T in the string acts on both the boxes (equal and opposite by the third law) and need not be considered.
- External force: only the force F that pulls the system from outside matters.

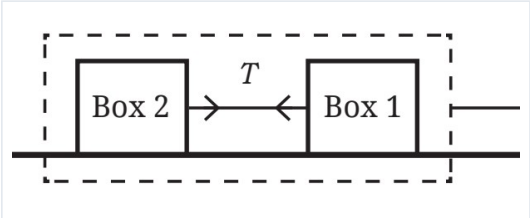

Fig. 6.34: A system of two boxes attached together by a string

b Acceleration of the system

$a = F / (\text{mass of the system}) = F / (m_1 + m_2)$ (Eq. 6.4)

The system accelerates just like a single object of mass $m_1 + m_2$. Analysing the boxes individually gives the same result.

Therefore, Newton's laws can be applied to connected objects by treating them as one system, which often simplifies the analysis.

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6.2

CLASS 9 SCIENCE · CHAPTER 6

Examples

Solutions · 8 examples

Directions (Examples 6.1–6.8): These are the worked examples of the chapter, in the order in which they appear. Each one is solved step by step, showing the data, the formula used and the final answer.

EXAMPLE 6.1 *p. 96*

Two forces of 10 N and 6 N are acting on a block lying on the table as shown in Fig. 6.6. What is the magnitude and the direction of the net force acting on the block in each case?

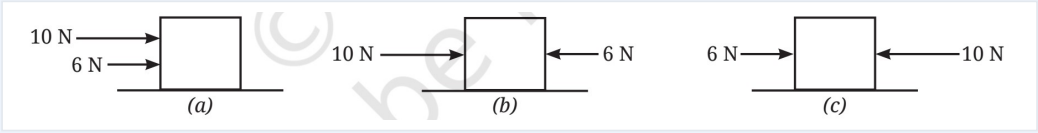

Fig. 6.6: Two forces acting on a block in three different manner

ANSWER

Forces along the same line are added if they point the same way and subtracted if they point opposite ways; the net force is along the larger one.

a Solution

Case	Working	Net force
(a) 10 N and 6 N, both to the right	10 N + 6 N	16 N towards the right
(b) 10 N to the right, 6 N to the left	10 N − 6 N	4 N towards the right
(c) 6 N to the right, 10 N to the left	10 N − 6 N	4 N towards the left

Therefore, the net force is (a) 16 N to the right, (b) 4 N to the right and (c) 4 N to the left.

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EXAMPLE 6.2 *p. 101*

A person is exerting a force on a moving box in the forward direction which is equal to the force of friction acting between the bottom surface of the box and the floor. Will the box continue moving or will it come to rest after some time?

ANSWER

Find the net force on the box and apply Newton's first law.

a **Solution**

Forward force by the person = force of friction (backward)

The two forces are equal and opposite, so they balance each other

Net force = 0

As per Newton's first law, an object in motion with zero net force continues to move with constant velocity.

Therefore, the box will continue moving with constant velocity and will not come to rest.

EXAMPLE 6.3 *p. 101*

Draw (i) position-time, and (ii) velocity-time graphs for an object on which no net force is acting.

ANSWER

With no net force there are two possibilities: the object is at rest, or it is moving with a constant velocity.

a **Object at rest (Fig. 6.15)**

- Position does not change with time: the position-time graph is a horizontal straight line (Fig. 6.15a).
- Velocity stays zero: the velocity-time graph lies along the time axis (Fig. 6.15b).

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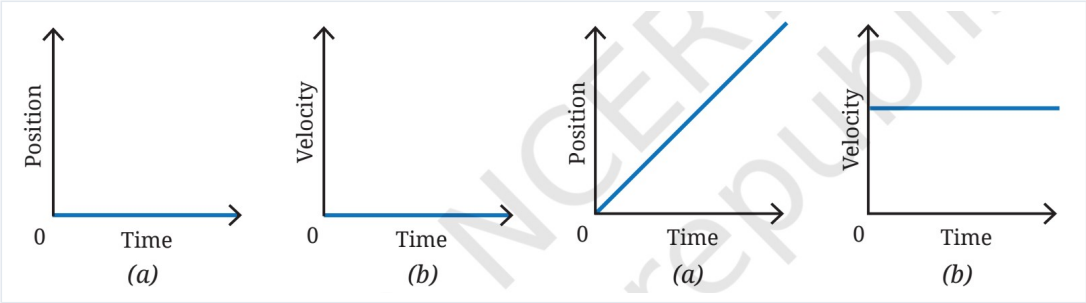
b Object moving with constant velocity (Fig. 6.16)

- The velocity-time graph is a horizontal straight line at the constant value of velocity (Fig. 6.16b).
- The position-time graph is an inclined straight line (Fig. 6.16a).



Figs. 6.15 (first two) and 6.16 (last two): (a) position-time graph, (b) velocity-time graph

Therefore, for zero net force the graphs are those of Figs. 6.15 and 6.16.

EXAMPLE 6.4 *p. 105*

A weight lifter is holding a barbell with mass of 10 kg fixed on each side of the bar (Fig. 6.8). The mass of the bar itself is 10 kg. How much force is she applying to keep the barbell steady?

ANSWER

For the barbell to stay steady the force of the lifter must balance the weight of the barbell.

a Solution

Total mass of the barbell = 10 kg + 10 kg + 10 kg = 30 kg

Weight = F = mg = 30 kg × 9.8 m s^{-2} = 294 N (downwards) [Eq. 6.3]

Net force must be zero, so she applies 294 N upwards.

Therefore, the weightlifter applies a force of 294 N in the upward direction.

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EXAMPLE 6.5 *p. 105*

A student is trying to push a stationary block of 25 kg on a horizontal floor. The maximum force of friction opposing this motion is 50 N. Determine the displacement of the block in 2 seconds if Rahul pushes it with a constant force of (i) 50 N and (ii) 55 N in the forward direction.

ANSWER

Compare the applied force with the maximum force of friction. If there is a net force, use F = ma and then s = ut + ½at².

a **(i) Applied force 50 N**

Applied force = maximum friction = 50 N, so the forces are balanced

Net force = 0, so the block stays stationary

Displacement = 0 m

b **(ii) Applied force 55 N**

Net force = 55 N − 50 N = 5 N

$a = F/m = 5\ N / 25\ kg = 5\ kg\ m\ s^{-2} / 25\ kg = 0.2\ m\ s^{-2}$

$s = ut + \frac{1}{2}at^2 = (0\ m\ s^{-1} \times 2\ s) + \frac{1}{2} \times 0.2\ m\ s^{-2} \times (2\ s)^2$

$s = 0 + \frac{1}{2} \times 0.2 \times 4 = 0.4\ m$

Therefore, the displacement is 0 m for 50 N, and 0.4 m in the forward direction for 55 N.

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EXAMPLE 6.6 *p. 106*

A sports car of mass 1500 kg is moving towards the east and its velocity-time graph is shown in Fig. 6.21. Calculate the force acting on the car during

(i) 0 s to 5 s
(ii) 5 s to 10 s
(iii) 10 s to 15 s

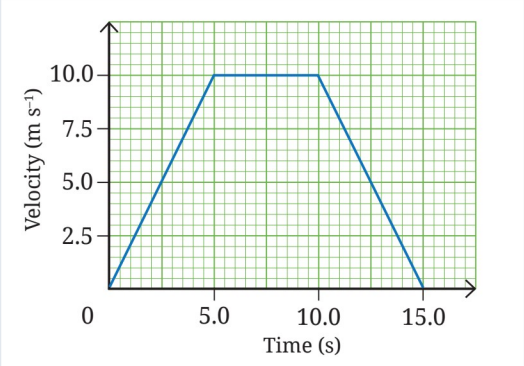

Fig. 6.21: Velocity-time graph for a sports car

ANSWER

Read the velocity from the graph, find the acceleration from v = u + at, and then use F = ma.

a (i) 0 s to 5 s

Straight inclined line: constant acceleration, u = 0 m s^{-1}, v = 10 m s^{-1}, t = 5 s

$10 = 0 + (a \times 5) \Rightarrow a = 2$ m s^{-2}

F = ma = 1500 kg × 2 m s^{-2} = 3000 N towards the east

b (ii) 5 s to 10 s

The graph is a straight line parallel to the time axis, so the velocity is constant (10 m s^{-1}) and the acceleration is zero. Hence F = 1500 × 0 = 0 N: no net force acts on the car.

c (iii) 10 s to 15 s

u = 10 m s^{-1}, v = 0 m s^{-1}, t = 5 s

$0 = 10 + (a \times 5) \Rightarrow a = -2$ m s^{-2}

F = ma = 1500 kg × (−2 m s^{-2}) = −3000 N

The negative sign shows that the force acts opposite to the direction of motion, i.e. towards the west.

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Therefore, the force is 3000 N towards the east (0–5 s), 0 N (5–10 s) and 3000 N towards the west (10–15 s).

EXAMPLE 6.7 *p. 110*

As shown in Fig. 6.33, the Earth and the fruit apply equal and opposite gravitational forces on each other. Then why does the fruit move towards the Earth while the Earth doesn't seem to move towards the fruit?

ANSWER

By Newton's third law the forces are equal, but the accelerations are decided by Newton's second law, a = F/m.

a Solution

- The forces on the Earth and on the fruit are equal in magnitude.
- The mass of the Earth is so large compared to the fruit that the acceleration of the Earth, a = F/m, is extremely small.
- The mass of the fruit is small, so its acceleration is large and it falls towards the Earth.

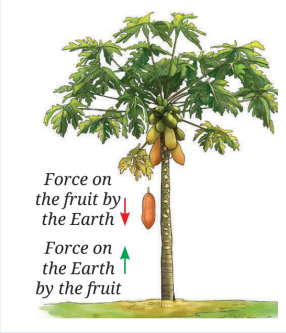

Fig. 6.33: The Earth and the fruit applying equal and opposite gravitational forces on each other

Therefore, the Earth's acceleration is too small to be noticed, while the fruit's acceleration is large, so the fruit moves towards the Earth.

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EXAMPLE 6.8 *p. 110*

When a 0.1 kg bullet is fired from a 5 kg gun with a force of 2 N, the gun recoils. What are the magnitudes of initial accelerations of the bullet and the gun?

ANSWER

By Newton's third law the recoil force on the gun equals the force on the bullet. Then use a = F/m for each.

a Solution

Force on the bullet = 2 N, so the recoil force on the gun = 2 N

Acceleration of the gun = force / mass of gun = 2 N / 5 kg = 0.4 m s^{-2}

Acceleration of the bullet = force / mass of bullet = 2 N / 0.1 kg = 20 m s^{-2}

The forces are equal in magnitude, but the accelerations are not equal because the masses are different.

Therefore, the initial acceleration of the gun is 0.4 m s^{-2} and of the bullet is 20 m s^{-2}.

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CLASS 9 SCIENCE · CHAPTER 6

6.3 Revise, Reflect, Refine

Solutions · 16 questions

Directions (Questions 1–16): These are the Revise, Reflect, Refine questions at the end of the chapter (pages 112–114). Every calculation is shown step by step, and multiple-choice questions are answered with reasons.

QUESTION 1

Using a horizontal force F, a table is moved across the floor at a constant velocity. How much is the frictional force exerted by the floor on the table?

ANSWER

Constant velocity means zero acceleration, so by Newton’s first law the net force on the table is zero.

a **Solution**

Net force = applied force F − force of friction = 0

Force of friction = F

The friction is equal in magnitude to the applied force and acts in the direction opposite to it.

Therefore, the frictional force exerted by the floor on the table is F (opposite to the direction of F).

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QUESTION 2

For a ball moving on a smooth frictionless surface, choose the appropriate option that will make the following statements physically correct.

(i) If no net force is applied on the ball, the velocity of the ball will remain the same/increase/decrease.
(ii) If a net force is applied on the ball in the direction of its motion, the magnitude of the velocity of the ball will remain the same/increase/decrease.
(iii) If a net force is applied on the ball in a direction opposite to the direction of its motion, the magnitude of the velocity of the ball will remain the same/increase/decrease.

ANSWER

On a frictionless surface only the applied net force changes the velocity (first and second laws).

a **Answers**

Statement	Choice	Reason
(i) No net force	remain the same	Zero net force gives zero acceleration (first law)
(ii) Net force along the motion	increase	Acceleration is in the direction of motion, so the speed increases
(iii) Net force opposite to the motion	decrease	Acceleration is opposite to the motion, so the speed decreases

Therefore, the velocity (i) remains the same, (ii) increases and (iii) decreases.

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QUESTION 3

Two blocks P and Q on a smooth horizontal surface are shown in Fig. 6.36a and Fig. 6.36b. Two forces of magnitudes 4 N and 5 N are acting in opposite directions on block P, while block Q is moving with a constant velocity.

Which of the following statement is correct?

(i) P experiences a net force and Q does not experience a net force.
(ii) P does not experience a net force and Q experiences a net force.
(iii) Both P and Q experience a net force.
(iv) Neither P nor Q experiences a net force.

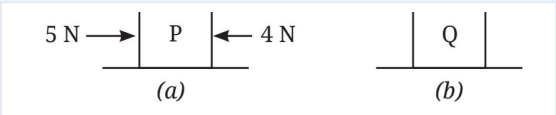

Fig. 6.36

ANSWER

Find the net force on each block.

a **Block P**

Forces in opposite directions: net force = 5 N − 4 N = 1 N (towards the 5 N force)

The net force on P is non-zero, so P experiences a net force.

b **Block Q**

Q moves with a constant velocity, so its acceleration is zero and the net force on it is zero.

Therefore, the correct statement is (i): P experiences a net force and Q does not experience a net force.

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QUESTION 4

While practising for the snake boat race (Vallum kalli in Kerala), 100 oarsmen are rowing a boat together. Out of these, 95 row backwards to propel the boat forward. But by mistake, 5 oarsmen row in the opposite direction. If each oarsman applies a horizontal force of 200 N, what is the net force on the snake boat? (Ignore drag forces, air friction, etc.)

ANSWER

Forces along the same line: add those in the same direction and subtract those in the opposite direction.

a **Solution**

Force from 95 oarsmen (forward) = 95 × 200 N = 19 000 N

Force from 5 oarsmen (backward) = 5 × 200 N = 1 000 N

Net force = 19 000 N − 1 000 N = 18 000 N

Check: 95 − 5 = 90 oarsmen effectively propel the boat, and 90 × 200 N = 18 000 N.

Therefore, the net force on the snake boat is 18 000 N in the forward direction.

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QUESTION 5

When a net force acts on an object, we observe that the object accelerates:

(i) opposite to the direction of force, with acceleration proportional to the force acting on the object.
(ii) opposite to the direction of force, with acceleration proportional to the mass of the object.
(iii) in the direction of force, with acceleration inversely proportional to the force acting on the object.
(iv) in the direction of force, with acceleration proportional to the force acting on the object.

ANSWER

Newton's second law: the object accelerates in the direction of the net force, and a = F/m.

a **Checking the options**

- The acceleration is in the direction of the force, so (i) and (ii) are wrong.
- a = F/m shows acceleration is proportional to F (not inversely proportional), so (iii) is wrong.

Therefore, the correct option is (iv).

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QUESTION 6

The position-time graph for four objects A, B, C and D moving along a straight line are given in Fig. 6.37. A net force acts on:

(i) Object A
(ii) Object B
(iii) Object C
(iv) Object D

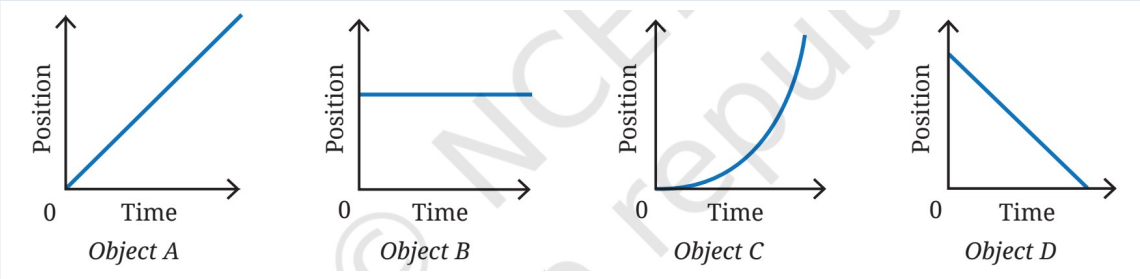

Fig. 6.37

ANSWER

A net force acts only if the velocity changes, i.e. if the position-time graph is not a straight line. The slope of the graph gives the velocity.

a Analysis of the graphs

Object	Position-time graph	Velocity	Net force
A	Inclined straight line	Constant	Zero
B	Horizontal straight line	Zero (at rest)	Zero
C	Curve with increasing slope	Increasing (accelerated)	Non-zero
D	Inclined straight line (falling)	Constant	Zero

Therefore, a net force acts on object C, option (iii).

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QUESTION 7

A sailor jumps out from a small boat to the shore (Fig. 6.38). As the sailor jumps forward, will the boat move? If yes, in which direction and why.



Fig. 6.38: A sailor jumping forward

ANSWER

Apply Newton's third law to the sailor and the boat.

a Explanation

- To jump forward, the sailor pushes the boat backwards with his feet.
- The boat pushes the sailor forward with an equal and opposite force. This force makes the sailor jump towards the shore.
- The force on the boat is directed backwards, so the boat accelerates backwards.

Therefore, yes, the boat moves backwards (away from the shore), because of the equal and opposite force exerted by the sailor on it.

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QUESTION 8

During a high jump event, a landing mat or sand bed is placed for the athlete to fall upon (Fig. 6.39). Explain the reason behind it.

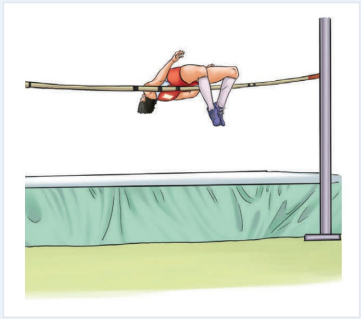

Fig. 6.39: A landing mat for a high jump event

ANSWER

The athlete lands with a large velocity, which must be reduced to zero. By F = ma, the force depends on how fast the velocity changes.

a Explanation

- On a hard floor the athlete would stop in a very short time, giving a very large acceleration and a very large force.
- A soft mat or sand bed compresses and increases the time over which the velocity becomes zero.
- A longer time gives a smaller acceleration and hence a smaller force on the athlete, which reduces the risk of injury.

Therefore, the landing mat or sand bed increases the stopping time and reduces the force exerted on the athlete.

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QUESTION 9

A hand cart loaded with vegetables collides with an identical but empty hand cart. During the collision:

(i) the loaded cart exerts a force of larger magnitude on the empty cart.
(ii) the empty cart exerts a force of larger magnitude on the loaded cart.
(iii) neither cart exerts a force on the other.
(iv) the loaded cart and the empty cart, both exert an equal magnitude of force on each other.

ANSWER

This is a case of Newton's third law.

a **Reasoning**

- When one cart exerts a force on the other, the other cart simultaneously exerts an equal and opposite force on the first, whatever their masses are.
- The two carts will have different accelerations because their masses are different, but the forces are equal in magnitude.

Therefore, the correct option is (iv).

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QUESTION 10

The acceleration-mass graph for the acceleration produced by a force on objects of different masses is plotted in Fig. 6.40. Plot the force-mass graph for this case.

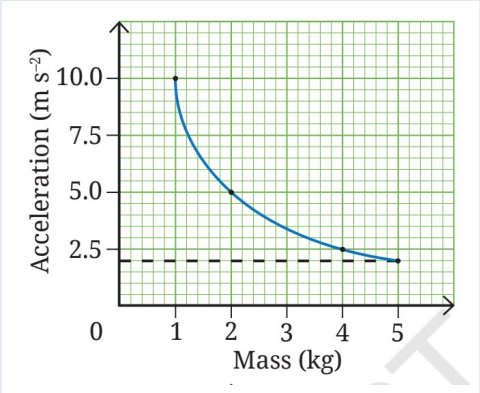

Fig. 6.40

ANSWER

From Newton's second law F = ma. Read a for each mass from Fig. 6.40 and find F.

a Reading the graph and calculating F

Mass m (kg)	Acceleration a (m s^{-2})	Force F = ma (N)
1	10.0	1 × 10.0 = 10
2	5.0	2 × 5.0 = 10
3	≈ 3.3	3 × 3.3 ≈ 10
4	2.5	4 × 2.5 = 10
5	2.0	5 × 2.0 = 10

The product ma is the same (10 N) for every mass, so the same force of 10 N acts on all the objects.

b Force-mass graph

Plotting force on the vertical axis and mass on the horizontal axis gives a straight line parallel to the mass axis at F = 10 N.

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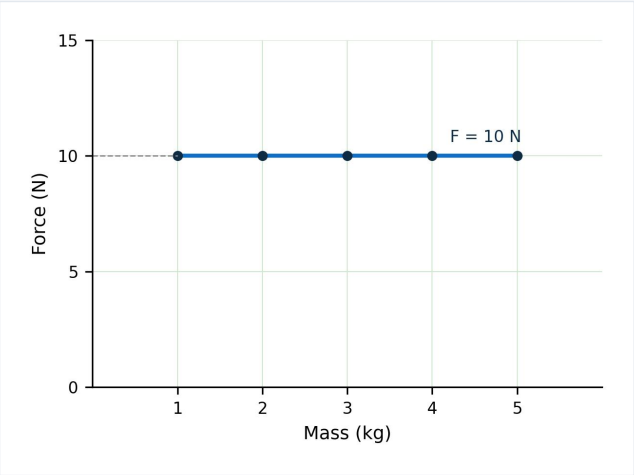

Force-mass graph for Fig. 6.40: a straight line parallel to the mass axis at F = 10 N

Therefore, the force-mass graph is a horizontal straight line at F = 10 N.

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QUESTION 11

The velocity-time graph of an object of mass 10 kg moving along a straight line is shown in Fig. 6.41. Calculate the force acting on the object by using the graph.

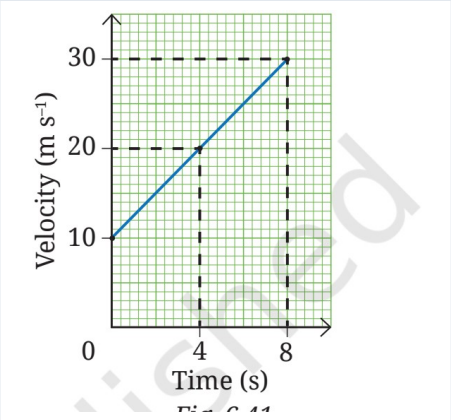

Fig. 6.41

ANSWER

The slope of a velocity-time graph is the acceleration. Find it from the graph and use F = ma.

a **Solution**

From the graph: at t = 0 s, v = 10 m s^{-1}; at t = 4 s, v = 20 m s^{-1}; at t = 8 s, v = 30 m s^{-1}

a = (30 − 10) / (8 − 0) = 20 / 8 = 2.5 m s^{-2} (check: (20 − 10)/4 = 2.5)

F = ma = 10 kg × 2.5 m s^{-2} = 25 N

Therefore, a constant force of 25 N acts on the object in the direction of its motion.

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QUESTION 12

A bullet of mass 50 g moving with a speed of 100 m s^{-1} enters a heavy stationary wooden block and stops after penetrating a distance of 50 cm. Estimate the stopping force acting on the bullet (assume that the bullet undergoes constant acceleration within the block).

ANSWER

First find the (negative) acceleration from the kinematic equation $v^2 = u^2 + 2as$, then use $F = ma$.

a **Given**

$m = 50\ g = 0.05\ kg$, $u = 100\ m\ s^{-1}$, $v = 0$, $s = 50\ cm = 0.5\ m$

b **Solution**

$v^2 = u^2 + 2as \Rightarrow 0 = (100)^2 + 2 \times a \times 0.5$

$a = -10\,000 / 1 = -10\,000\ m\ s^{-2}$

$F = ma = 0.05\ kg \times (-10\,000\ m\ s^{-2}) = -500\ N$

The negative sign shows that the force acts opposite to the direction of motion of the bullet.

Therefore, the stopping force on the bullet is 500 N, opposite to its motion.

QUESTION 13

An ace footballer converted a penalty shot by kicking the football with a speed of 108 km h^{-1}. The estimated force they imparted was 800 N. The mass of the football was 0.4 kg. Calculate the time of contact between their foot and the ball.

ANSWER

The ball is at rest before the kick. Convert the speed to m s^{-1}, find the acceleration with $F = ma$, then use $v = u + at$.

a **Given**

$u = 0$, $v = 108\ km\ h^{-1} = 108 \times 1000\ m / 3600\ s = 30\ m\ s^{-1}$

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F = 800 N, m = 0.4 kg

b **Solution**

a = F/m = 800 N / 0.4 kg = 2000 m s^{-2}

v = u + at ⇒ 30 = 0 + 2000 × t

t = 30 / 2000 = 0.015 s

Therefore, the time of contact between the foot and the ball is 0.015 s (15 milliseconds).

QUESTION 14

An object of mass 2 kg moving with a constant velocity of 10 m s^{-1} encounters a rough patch where the force of friction on the object is 7 N. At the same time, an additional constant force of 3 N opposing the motion is applied on the object. After entering the rough patch, how much distance does the object travel before coming to rest?

ANSWER

Both the friction and the additional force oppose the motion, so they add up. Find the deceleration and then use $v^2 = u^2 + 2as$.

a **Solution**

Total opposing force = 7 N + 3 N = 10 N

a = −F/m = −10 N / 2 kg = −5 m s^{-2}

$v^2 = u^2 + 2as \Rightarrow 0 = (10)^2 + 2 \times (-5) \times s$

10 s = 100 ⇒ s = 10 m

Check: time to stop t = (0 − 10)/(−5) = 2 s, and s = ut + ½at^2 = 20 − 10 = 10 m.

Therefore, the object travels 10 m before coming to rest.

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QUESTION 15

A tractor pulls a harrow (a ploughing tool) of mass m_1 with a net force F resulting in an acceleration of a_1. The same tractor pulls a trolley of mass m_2 with a force F producing an acceleration of a_2. If the tractor now pulls the trolley with the harrow placed on it (with the same force F), then obtain an expression for the resulting acceleration in terms of a_1 and a_2. Ignore friction.

ANSWER

Express each mass through F and its acceleration using m = F/a, then apply a = F/(total mass) to the combined system.

a **Solution**

$a_1 = F/m_1 \Rightarrow m_1 = F/a_1$

$a_2 = F/m_2 \Rightarrow m_2 = F/a_2$

Total mass $= m_1 + m_2 = F/a_1 + F/a_2 = F\,(a_1 + a_2) / (a_1 a_2)$

$a = F / (m_1 + m_2) = a_1 a_2 / (a_1 + a_2)$

Therefore, the resulting acceleration is $a = a_1 a_2 / (a_1 + a_2)$.

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QUESTION 16

When the pole of a bar magnet is brought close to a magnetic compass, the bar magnet and the compass needle (which is also a magnet) exert a magnetic force on each other. As per Newton's third law of motion, both the forces are equal in magnitude and opposite in direction. However, the compass needle moves, whereas the bar magnet does not move (Fig. 6.42). Explain why.



Fig. 6.42: A bar magnet and a magnetic compass

ANSWER

The forces are equal, but the effect of a force depends on the mass of the object on which it acts (a = F/m).

a Explanation

- The compass needle has a very small mass and is free to turn about its pivot, so the force gives it a large acceleration and it moves.
- The bar magnet has a much larger mass, so the same force gives it a very small acceleration that is too small to notice.
- The force of friction between the bar magnet and the surface on which it rests can also balance this small magnetic force.

Therefore, the forces are equal, but the compass needle (small mass) accelerates noticeably while the heavier bar magnet does not move.

NCERT ARCHIVE

6.4

CLASS 9 SCIENCE · CHAPTER 6

The Journey Beyond

Solutions · 4 questions

Directions (Questions 1–4): These are the activity-based questions in The Journey Beyond section (page 115). Model answers and the expected observations are given; record your own readings wherever an experiment is involved.

QUESTION 1 *The Journey Beyond · p. 115*

You know that the force of friction depends on the nature of the surfaces in contact. Does it also depend on how hard the surfaces press each other? Is the friction acting on an object that is about to move larger than the friction after motion begins? Is the friction which acts on a rolling object less than that on a sliding object? Find answers to these questions and create an infographic. Such observations help explain why the invention of the wheel was a major milestone in human history.

ANSWER

These are activity-based questions; model answers and the points for the infographic are given below.

a **Answers**

Question	Answer
Does friction depend on how hard the surfaces press each other?	Yes. The harder the surfaces are pressed together (e.g. a heavier load), the larger the force of friction.
Is friction on an object about to move larger than after motion begins?	Yes. A larger force is needed to start an object moving than to keep it moving, so friction is larger just before the motion begins.
Is friction on a rolling object less than on a sliding object?	Yes. Rolling friction is much smaller than sliding friction.

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b Why the wheel was a milestone

Since friction on a rolling object is much less than on a sliding object, heavy loads can be moved with a much smaller force when wheels are used.

c Points to put in the infographic

- Friction depends on the nature of the surfaces and on how hard they press each other.
- It is larger before motion begins than after motion starts.
- Rolling friction is less than sliding friction, with a labelled picture of a wheel.

Therefore, friction depends on the surfaces and the pressing force, and rolling reduces it, which is why the wheel was so important.

QUESTION 2 *The Journey Beyond · p. 115*

Take two toy cars of equal mass and stick a bar magnet on top of each (Fig. 6.32). Fix a metre scale on a smooth surface. Place the cars near the midpoint of the metre scale with the like poles touching. Release the cars and record the time taken (using two stopwatches), and distance travelled by each before coming to a rest. Repeat the experiment after adding equal masses to both cars. Did the cars travel equal distances in opposite directions? Plot a graph of distance travelled versus mass. Analyse and discuss your findings.



Fig. 6.31: Two bar magnets applying equal and opposite magnetic forces on each other

ANSWER

Like poles repel, so each magnet exerts a force on the other. Record your own readings; the expected analysis is given below.

a Analysis

- The magnetic forces on the two cars are equal in magnitude and opposite in direction (Newton's third law).

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- The cars have equal masses, so by a = F/m they get equal accelerations in opposite directions.
- So the cars travel (nearly) equal distances in opposite directions and take (nearly) equal times. Small differences come from friction and measurement errors.

b Adding equal masses to both cars

The cars remain equal in mass, so they still move equal distances in opposite directions. With a larger mass the same force gives a smaller acceleration, so each car is expected to travel a shorter distance. The graph of distance versus mass therefore falls as the mass increases.

Therefore, the cars travel equal distances in opposite directions, and the distance is expected to decrease as the mass is increased.

QUESTION 3 *The Journey Beyond · p. 115*

Wrap a rope once around a rough tree branch or post. Attach a heavy bucket to one end and try to hold it by the other end (Fig. 6.43). Now, add one more turn of the rope and repeat.



Fig. 6.43

ANSWER

This activity shows how the friction between a rope and a branch depends on the contact between them.

a Observation and explanation

- Each extra turn increases the ‘grip’ between the rope and the branch, which increases the force of friction.
- The force required to hold the same load reduces, making it much easier to hold the bucket.
- The reduction in effort is much larger than expected from one extra turn, so friction does not increase in a simple linear way. Small changes in contact can lead to large changes in force.

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b Application

In the same way, friction between a rope and a post allows large ships to be held safely at a pier.

Therefore, each extra turn of rope greatly increases friction and greatly reduces the force needed to hold the load.

QUESTION 4 *The Journey Beyond · p. 115*

It is often instructive to examine how scientific ideas develop over time. If you are interested, explore how Newton formulated the laws of motion by reading excerpts from his original work, the Principia. Both the original text and commentaries are available online.

ANSWER

This is a reading activity. Use the points from the chapter as a guide while you read.

a Points to look for

- Newton presented his three laws of motion in 1687 in the Principia.
- Newton used the word ‘inertia’ for the tendency of objects to resist change in their state of rest or uniform motion, and used this idea in his first law.
- Before Galileo (17th century), people mistakenly believed that a force is needed to keep an object moving with constant velocity.
- Note down how each law is stated in the original text and compare it with the statements in this chapter.

Therefore, reading the Principia shows how the ideas of Galileo and Newton developed into the three laws of motion.

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