

Graphic Novel on Physics, Class - IX

Chapter 9 : Force and Laws of Motion

(Art Integrated Learning)



Force and Laws of Motion



0964CH08



Delhi Public School, Sec-45, Gurgaon

Message from Director Principal



The creation of this graphic novel has been a unique experience for all of us. It has, in a sense, involved the 4 Cs, the 21st Century skills : Creativity - since all of us have created these graphic novels, Collaboration- all departments came together to work as a team, Critical thinking- putting our heads together to think of the best ways to engage our learners and of course, Communication - among ourselves and more importantly, communicating learning outcomes to our audience.

I think the Graphic novel is a great way to break up complex modules and explain them through a story.

My heartfelt gratitude to Ms. Anita Karwal and Mr. Manoj Ahuja, for encouraging the teams to create this content. A debt of gratitude to Mr. Sandeep Sethi, without whose training and patient hand holding, this novel would not have seen the light of day!

Kudos to the teachers for venturing into uncharted waters and reaching their goal!

Aditi Misra
Director Principal
Delhi Public School
Sector 45 Gurgaon

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Disclaimer

This is a work of fiction by Delhi Public School, Sector 45, Gurgaon. The novel is designed to motivate young learners, ignite interest and provide a better understanding of text. It means to supplement, not replace the information in the textbook. The characters in this graphic novel are fictitious and any resemblance to names, characters or incidents is coincidental.

Preface

“Truth is ever to be found in the simplicity, and not in the multiplicity and confusion of things.”

- Isaac Newton

Science with all its theories, experiments and numericals has been an intriguing subject for many a student. Reading about the topics in black and white, over a number of pages becomes tedious and it's challenging to maintain students' interest. However, when some topic is retold in the form of a story with everyday examples, it becomes interesting as it is more comprehensible and stays in the mind forever.

Physics as a branch of Science, is quite logical and rationalizes with the human mind, when explained with the aid of some activities that we do or come across daily and observe minutely.

In this Graphic Novel, the three laws of motion given by Newton have been demystified through an interesting story of a family that is out on a short vacation to witness a cricket match. Not only their journey, but also the cricket match gives them an insight into the laws as explained by the famous scientist, Isaac Newton.

The entire team of DPS, Sector 45, Gurgaon, has worked together to bring to you this Graphic Novel. The motive behind this effort is to generate students' interest in Physics by simplifying certain topics with the aid of a novel, which is well illustrated and makes an informative as well as an easy read.

We hope the readers enjoy this novel and feel motivated and encouraged to explore Newton's laws in many more ways, as Science is omnipresent!

Class – IX

Subject : Physics

Chapter : Force and Laws of Motion

Balanced and unbalanced forces, Newton's First law of motion, Inertia, Second law of motion, Third law of motion, Momentum

Learning Outcomes

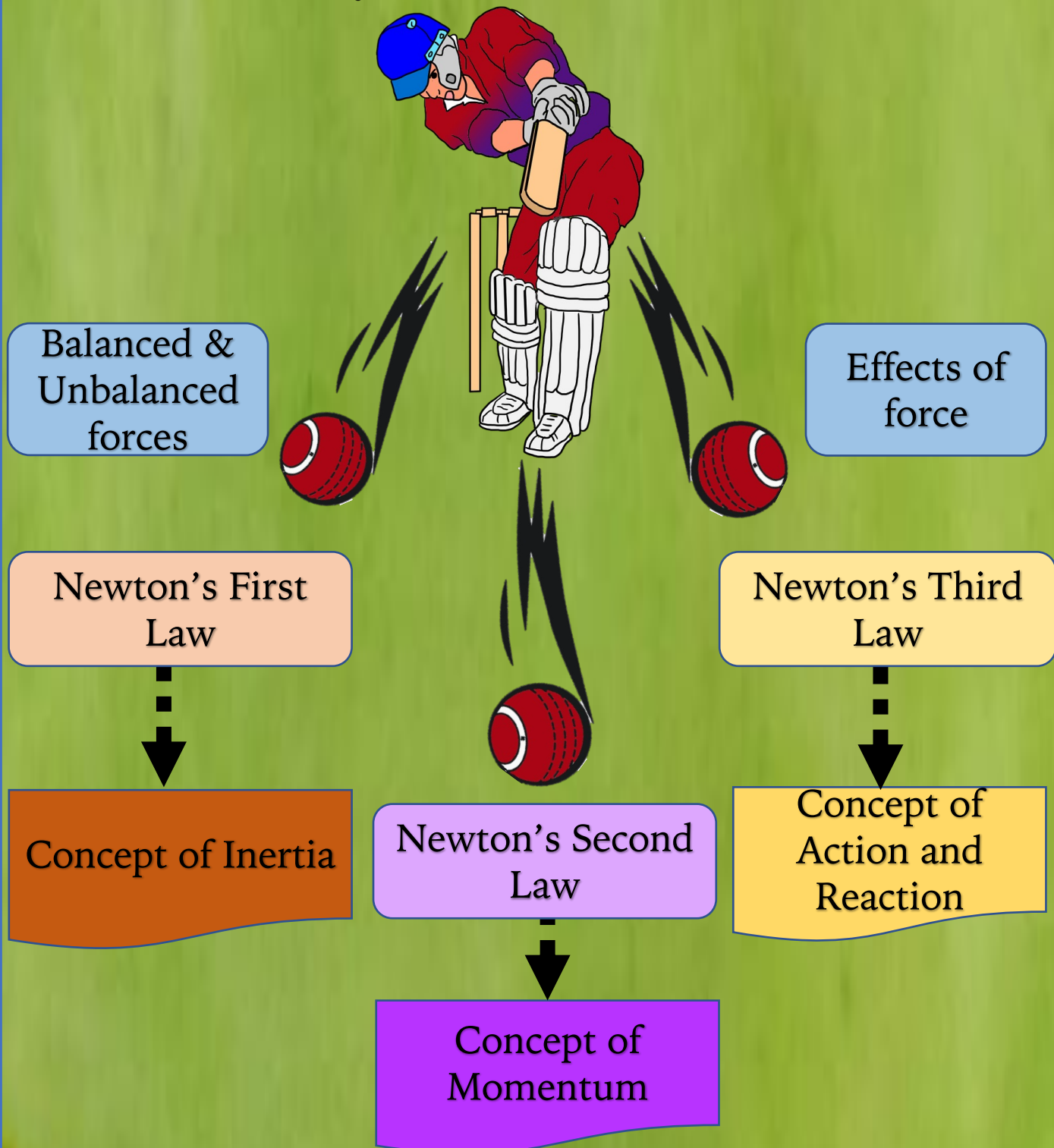
Students will be able to

- define force
- understand the effects of force on the state of motion of objects.
- relate the concept of law of inertia to daily life.
- understand the concept and significance of friction.
- state the importance of Newton's second law of motion.
- analyze acceleration of objects in motion.
- comprehend momentum of objects.
- explain Newton's third law of motion.
- apply scientific concepts of Newton's laws in daily life.

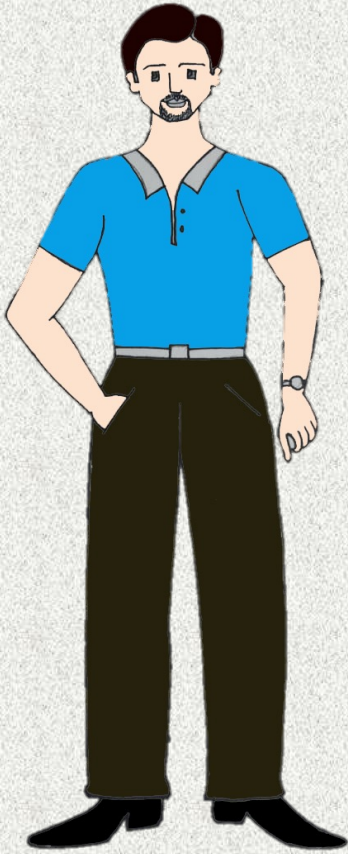
Storyboard

(Newton's Laws of Motion)

Applications of Physics in sports



Characters



ROHIT



NISHA
ROHIT'S WIFE



KARAN
ROHIT'S SON



AAROHI
ROHIT'S DAUGHTER

Characters



ARJUN
TEAM COACH
ROYAL STRIKERS



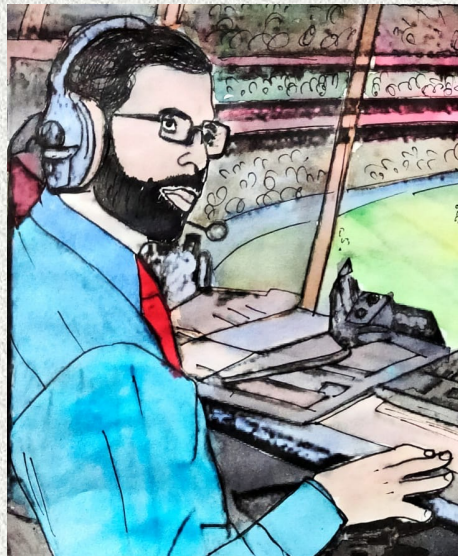
RAHUL
TEAM CAPTAIN
ROYAL STRIKERS



PRITHVI
TEAM CAPTAIN
SUPER CHALLENGERS



MANAV
TEAM PLAYER
ROYAL STRIKERS



COMMENTATOR



UMPIRE

It's a pleasant Friday morning. Rohit is having breakfast with wife Nisha and his children, Aarohi and Karan.

Nisha, I got an invitation for the final match of Indian Cricket League from my friend Arjun, who is the coach of Royal Strikers' team.

I will be going to Chandigarh day after tomorrow.

Daddy, I also want to see the match. Can we come along, please?

Don't you have to go to school?

No daddy! Our summer vacation is starting from tomorrow.



That's great!
Nisha, what do you think?



Sure, let's go!

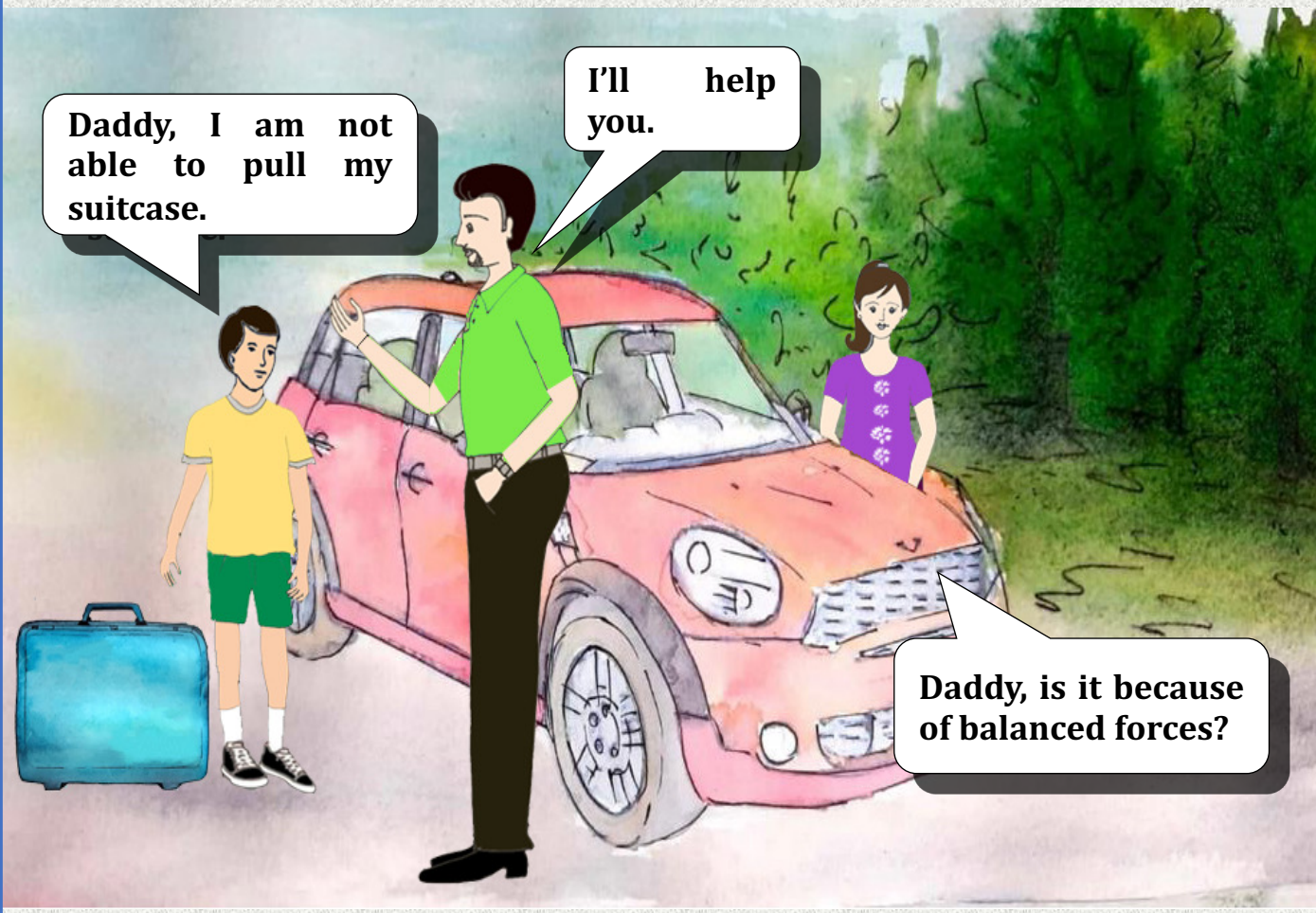


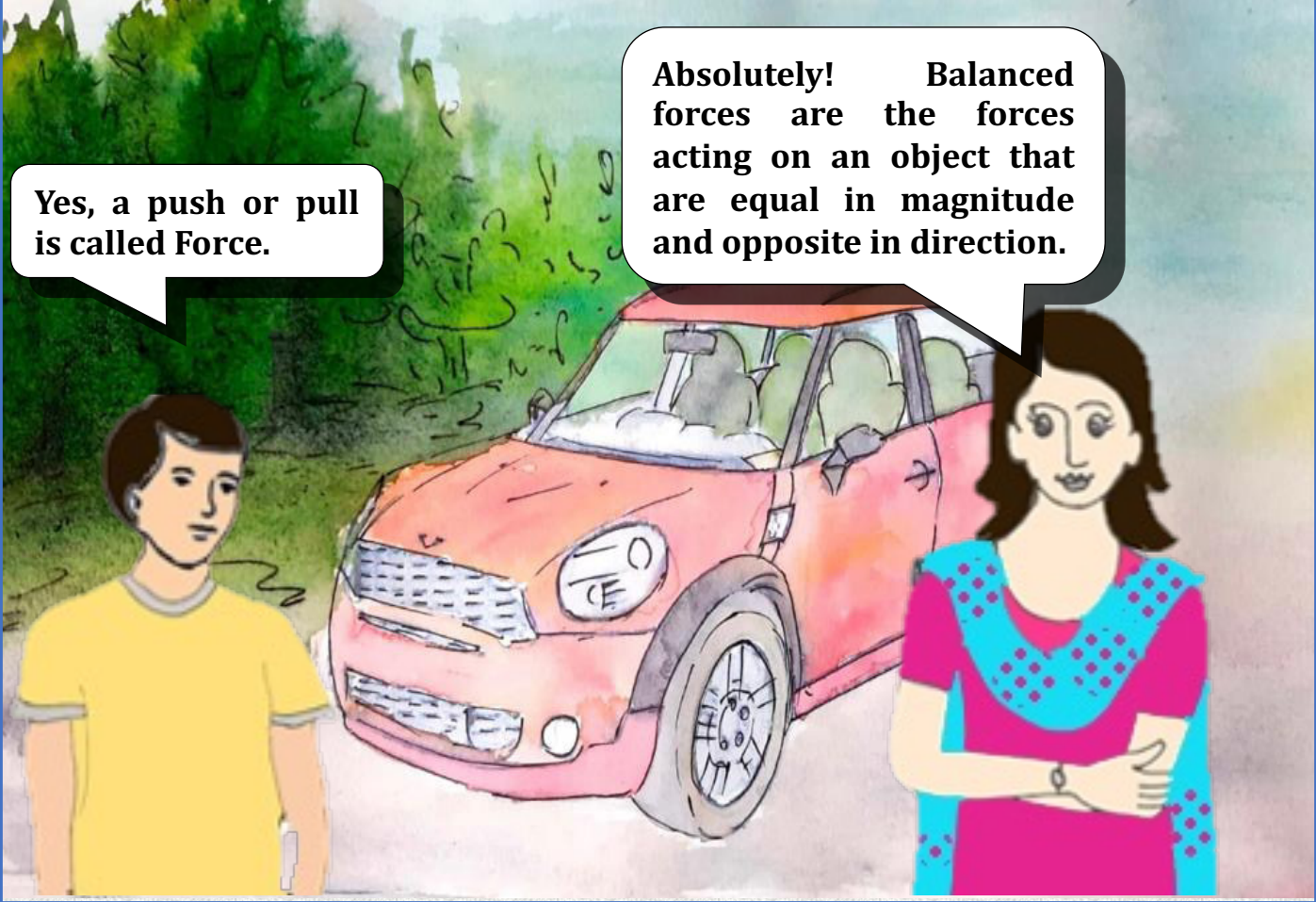
Okay! Then let's
pack our bags and
drive down to
Chandigarh.



Yayy !!!

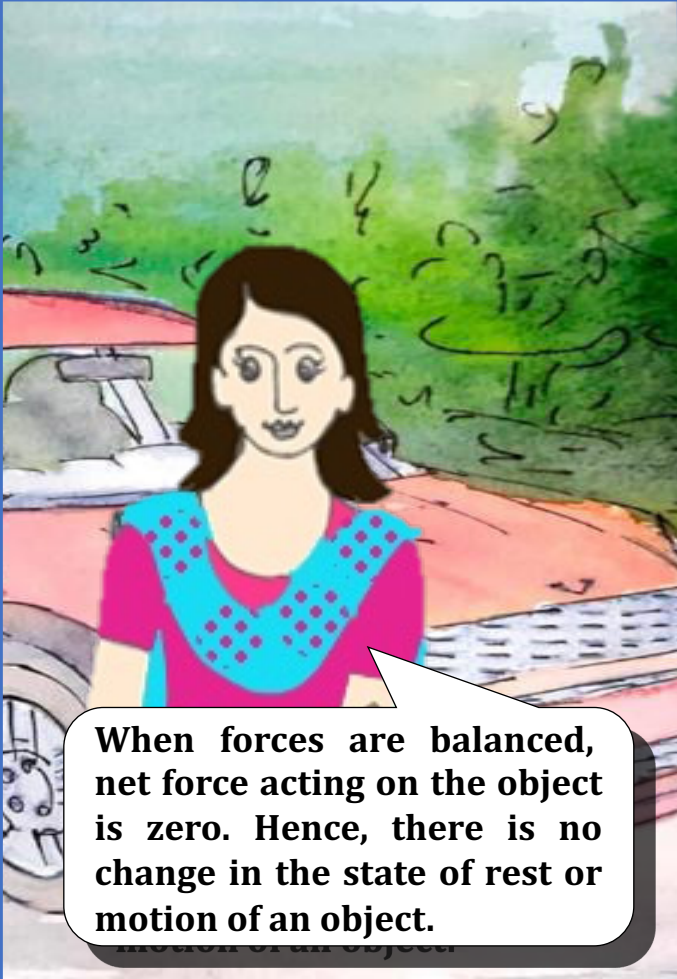
Early Sunday morning...Rohit and his family load the luggage in their car.



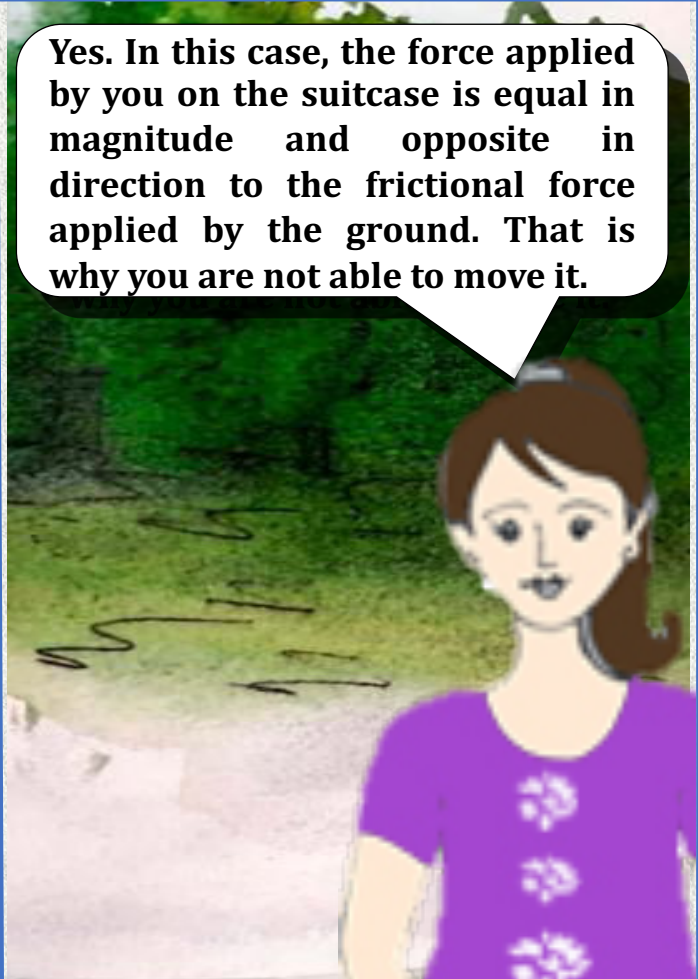


Yes, a push or pull is called Force.

Absolutely! Balanced forces are the forces acting on an object that are equal in magnitude and opposite in direction.



When forces are balanced, net force acting on the object is zero. Hence, there is no change in the state of rest or motion of an object.

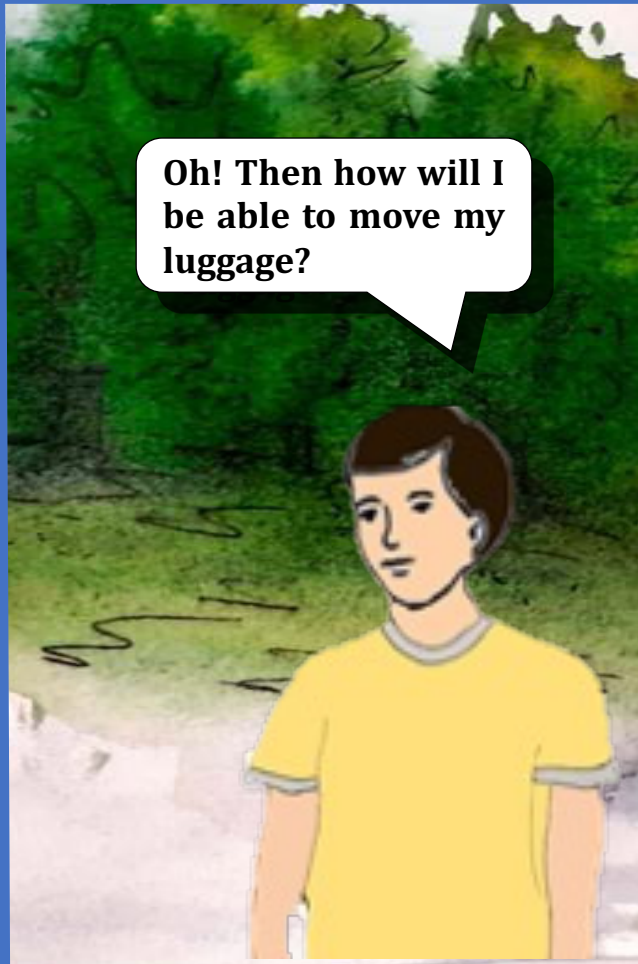


Yes. In this case, the force applied by you on the suitcase is equal in magnitude and opposite in direction to the frictional force applied by the ground. That is why you are not able to move it.



If $F = f$, then forces are balanced

Oh! Then how will I be able to move my luggage?



When there will be an unbalanced force.

Unbalanced force?

Yes, an unbalanced force. When two forces acting in opposite directions on an object, are not equal in magnitude, then such forces are known as unbalanced forces.

An unbalanced force acting on an object can bring it in motion or accelerate it.

That means, in this case, net force acting on the object is not zero.

Correct !

Tell me Karan, in order to win the game of tug-of-war, force applied by both teams should be equal or unequal?



It should be unequal.

Yes. The players on one side of the rope have to apply more force on it than the other side to win the game.



Absolutely! Now let's go, else we will get late.



After loading the luggage, everyone sits in the car.

Karan, wear your seat belt now.



But I am sitting at the back. Why do I need a seat belt?

So that you are not hurt, in case...

Suddenly, Rohit applies brakes as the car in front stops abruptly.
Karan falls off between the seats, due to the impact.

Aarohi: (picking up Karan and smiling) That's why!

(Karan makes a face and wears his seat belt)



Mom, you know we read about this in our class as well, when we were studying Newton's Laws of Motion.

Yes, you must have. Do you remember, which law explains it?

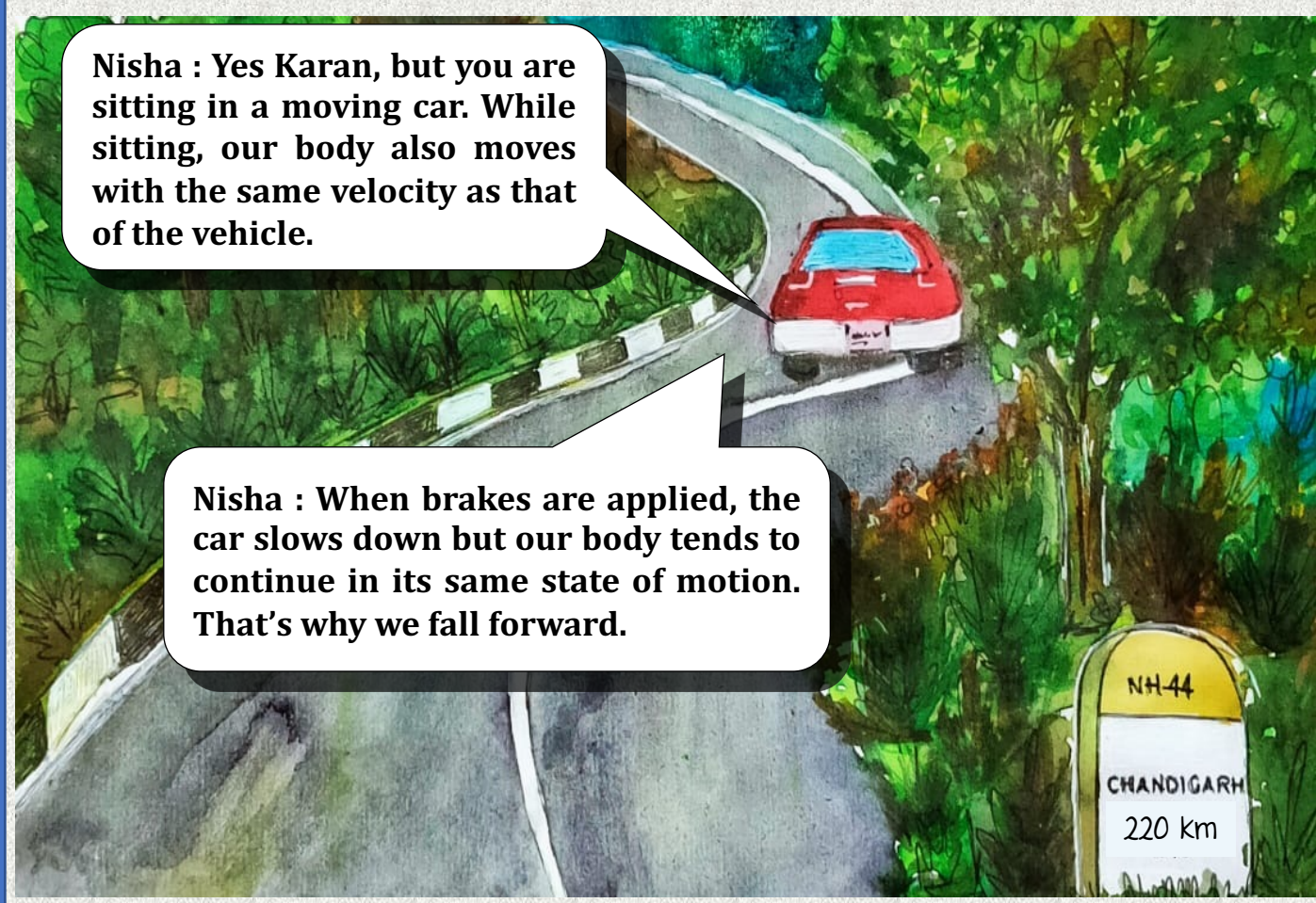
It's Newton's first law which says that, "An object remains in a state of rest or of uniform motion in a straight line, unless compelled to change that state by an applied force".

How is my falling down explained by this law? Which force is being applied!?



It was due to the sudden braking force applied by daddy, to stop the car.

If the force was applied on the car to bring it to rest, why did I fall? I was not moving.



Nisha : Yes Karan, but you are sitting in a moving car. While sitting, our body also moves with the same velocity as that of the vehicle.

Nisha : When brakes are applied, the car slows down but our body tends to continue in its same state of motion. That's why we fall forward.

NH44

CHANDIGARH
220 km



This is called the inertia of motion.

What is inertia?



Inertia is the natural tendency of an object to resist a change in its state of motion or of rest.



So we must always wear our seat belt as they exert a force on our body which makes the forward motion slower.

Absolutely correct !



Mom, sometimes we fall backwards also, when daddy starts the car suddenly. Why is that?



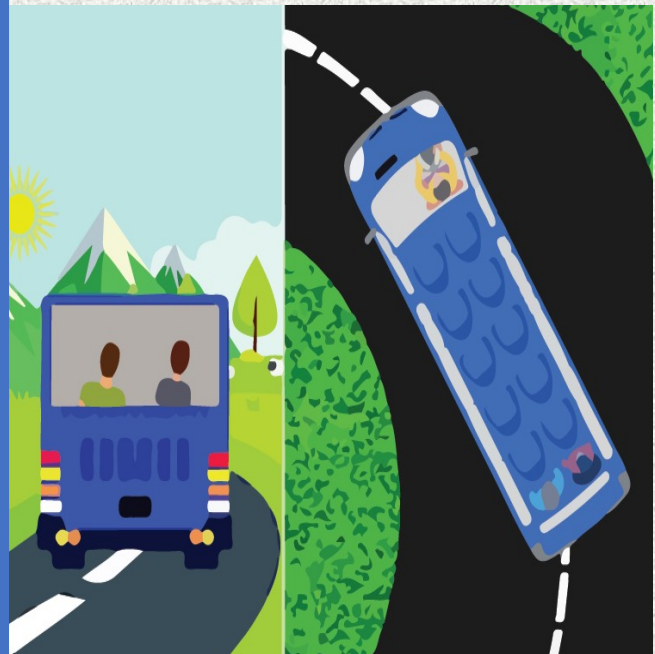
That is also due to inertia. The sudden start of the car, brings our feet (which are in contact with the floor of the car) in motion, but the rest of our body opposes this motion due to its inertia of rest. Thus, we tend to fall backward.

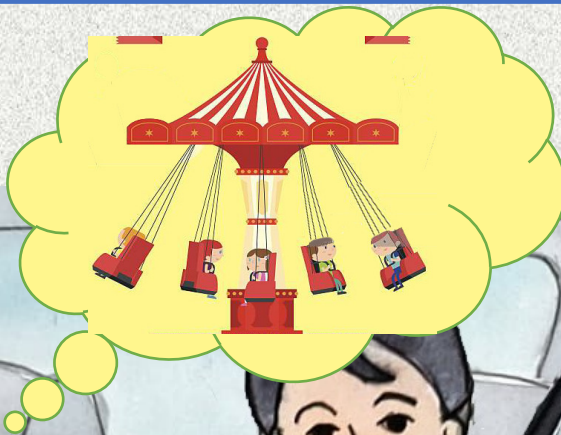


Karan, there is a third kind of inertia also, 'Inertia of direction'. When our car makes a sharp turn around a bend, we tend to get thrown to one side. This is due to inertia of direction.



When a force is applied by the engine to change the direction of motion of the car, we slip to one side of the seat.



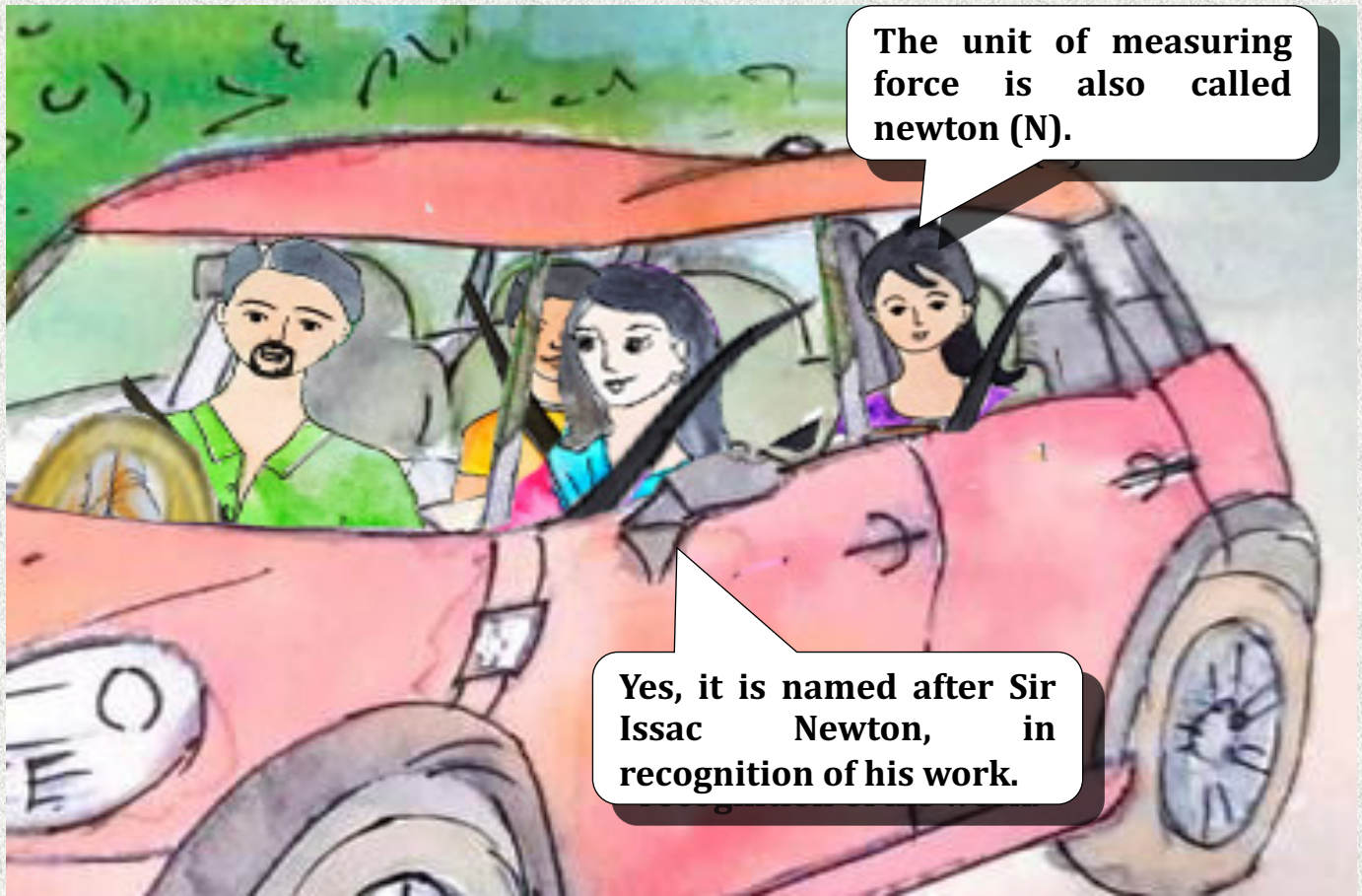


Remember, we sat in a merry-go-round last month, when we had gone to the amusement park! While sitting, we were pushed towards the outer edge of the seat. That is also an example of inertia of direction.

So we have inertia of rest, inertia of motion and also inertia of direction. In fact, Newton's first law is also known as "law of inertia".

Mom, why are they called Newton's laws?

The three fundamental laws that govern the motion of all objects, were presented by Sir Issac Newton.



The unit of measuring force is also called newton (N).

Yes, it is named after Sir Issac Newton, in recognition of his work.

Daddy, is there any science in cricket also?

Yes, Karan! Everything is governed and explained by laws of Physics.

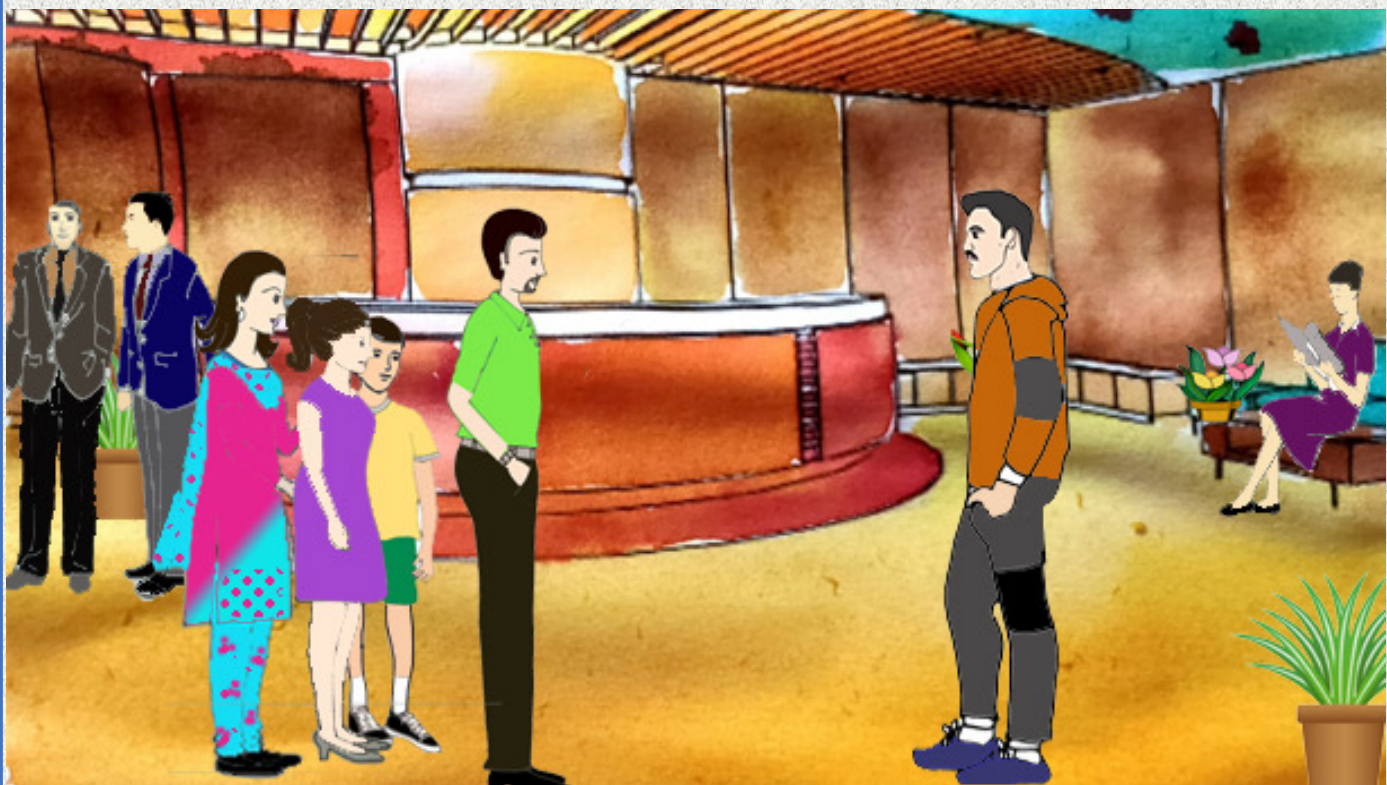
Oh! I thought we study laws of science only at school.

Yes, you study them at school and apply them in daily life. Science is everywhere.



(Karan looks out of the window, trying to explore science around him)

Rohit and his family arrive at the guest house in Chandigarh. Arjun invites Rohit and his family to watch their practice session and promises Karan that he would let him meet his favourite players during the break.



Arjun, who is engaged in the catching drill, looks at them and nods. Arjun is standing in the middle and the players are at the boundary. He is batting in all directions.

Look Karan, the ball is changing its direction or its speed on being hit with the bat.

Yes, because a force can change the speed and direction of an object.

Hmm.... But, why is uncle throwing the ball in random directions?

So that the players may have enough practice to run and catch the ball.

Wow! See, how high the ball has gone.

Oh look! That player is going to catch it!

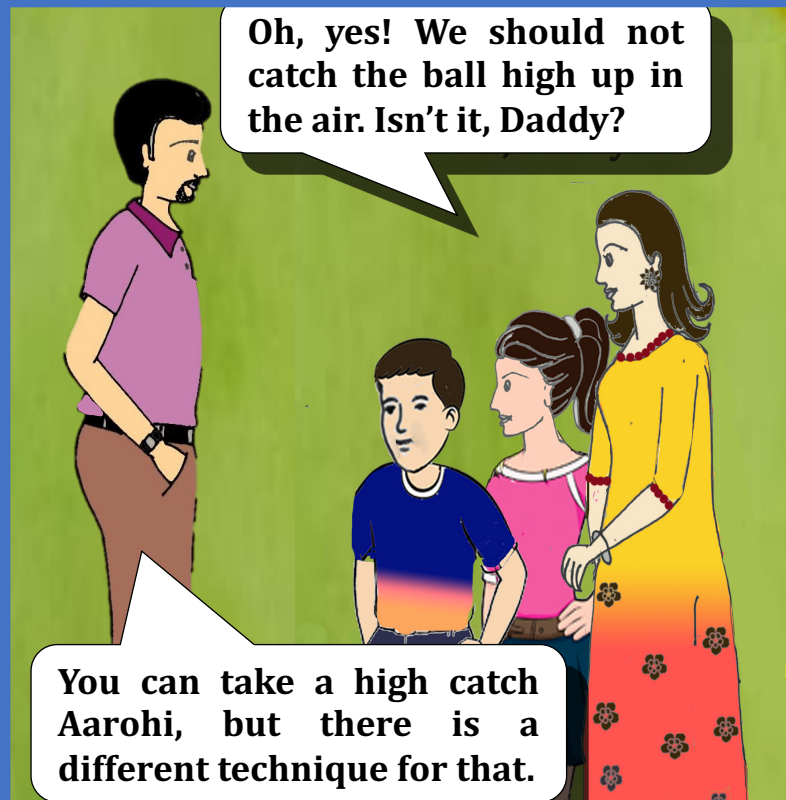
Let's Try To Answer

1. The first law of motion states
 - a. that an object at rest will remain at rest.
 - b. that an object in motion will remain in motion.
 - c. that an unbalanced force can change the state of an object.
 - d. all of the above.
2. Due to inertia, an object tends to move
 - a. towards a larger object.
 - b. in a curved path.
 - c. away from a larger object.
 - d. in a straight path.
3. Newton's first law is also known as the law of inertia because
 - a. inertia is the tendency of objects to resist changes to their motion.
 - b. inertia describes the application of force to an object at rest.
 - c. inertia describes the applications of force to an object in motion.
 - d. inertia is the same thing as friction.
4. A magician suddenly gives a jerk to a tablecloth and is able to take it out from under the dishes on a table. This demonstrates
 - a. an action-reaction pair of forces.
 - b. that the dishes have inertia.
 - c. that gravity tends to hold the dishes securely.
 - d. that the dishes have no acceleration.
5. Heavy objects have more inertia than light objects.
 - a. True
 - b. False
6. Earth rotates from west to east. If you jumped straight up, then according to Newton's first law of motion,
 - a. you will land east of the place, from where you jumped
 - b. you will land west of the place, from where you jumped
 - c. you will land in the same place from where you jumped
 - d. you may land anywhere on earth

Unfortunately, the catch is dropped, as Manav(Player 1) gets hurt. Arjun puts his arm around Manav and takes him out of the field. He asks Rahul to continue with the practice.



After leaving Manav with the physician, Arjun comes towards Rohit's family.



A boy in a purple shirt is pointing towards a fielder in the distance who is crouching to catch a red ball. Another boy in a blue and orange shirt stands to the left, watching. The background is a green field with a yellow line.

See... that fielder is gradually pulling his hands backwards with the moving ball, in order to catch it.

Yes, but why is he lowering his hands?

In doing so, the fielder increases the time to catch the ball and the force exerted on his hand decreases.

$$\{F = m(v-u)/t\}$$

A man in a purple shirt and brown trousers is standing and talking to a girl in a pink shirt and dark skirt. The background is a green field.

Yes Aarohi, absolutely correct!

But why will the player get hurt?

A woman in a yellow and orange sari is standing and talking to a boy in a blue and orange shirt. The background is a green field.

Karan, when you catch a ball, its speed is reduced to zero, in a very short interval of time.

So, when the ball stops, does the force become zero?



No, its momentum becomes zero, due to which the rate of change of momentum of the ball becomes large. Therefore, a larger force would have to be applied for holding the catch, which may hurt the palm of the fielder.

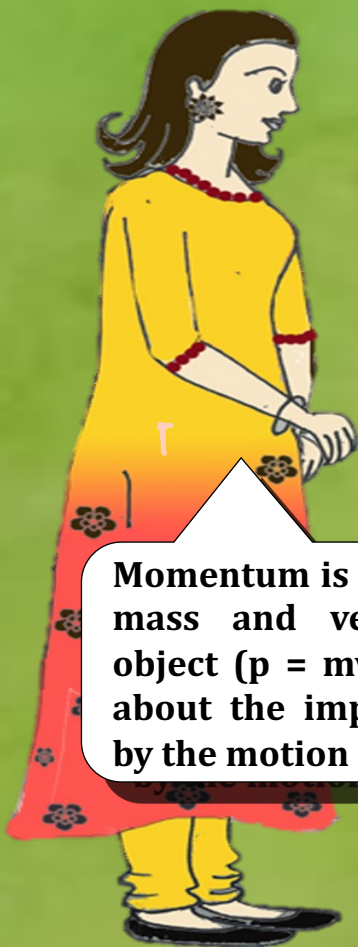


Ah yes! This is explained by Newton's second law of motion, which states that, "The rate of change of momentum of an object is proportional to the applied unbalanced force." ($F = \text{change in momentum/time taken}$). Also, $F = ma$.



What is momentum ?





Momentum is the product of mass and velocity of an object ($p = mv$). It tells you about the impact produced by the motion of an object.

What does that mean, mom ?



Suppose a table tennis ball and a cricket ball, moving with the same velocity, strike a window pane. Which one would cause a greater damage?

Cricket ball!

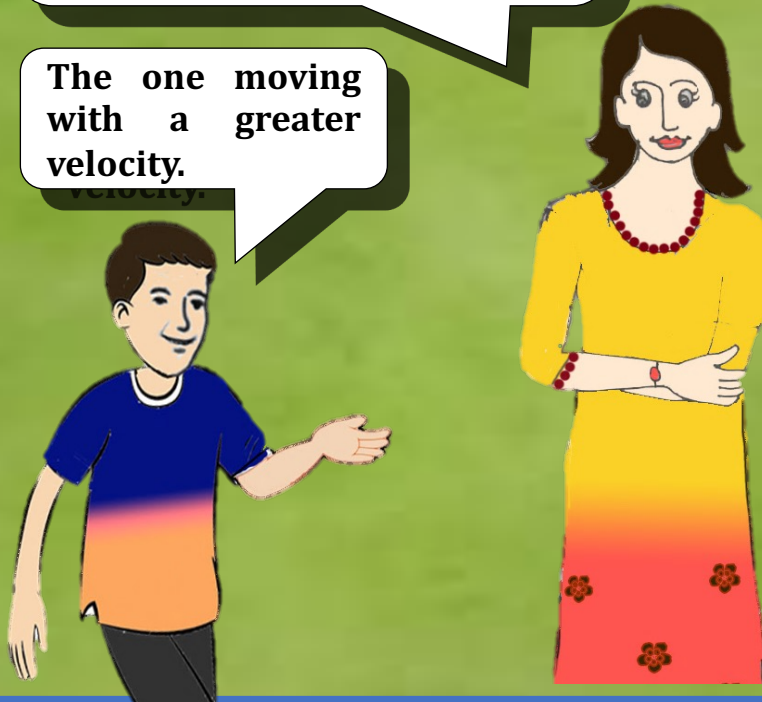


Exactly! Since the cricket ball has more mass, it will have a greater impact. That means it has more momentum.



And if two similar cricket balls strike the window pane with different velocities, then which one will cause more damage?

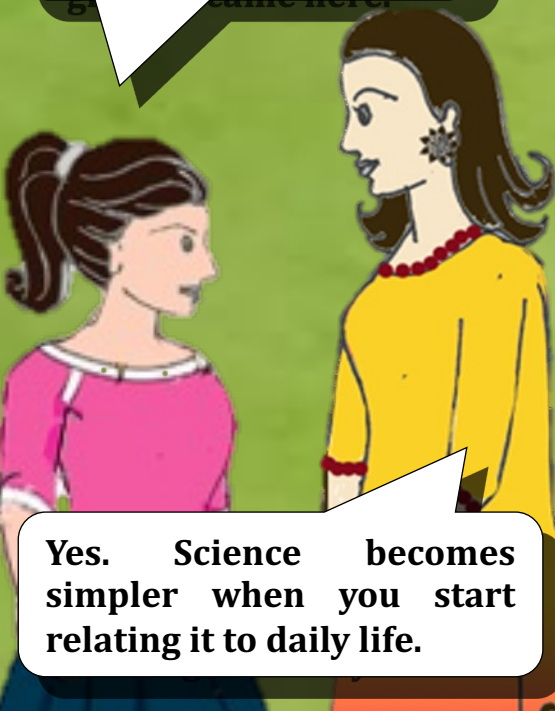
The one moving with a greater velocity.



Correct. Thus, the impact produced by the motion of objects depends on their mass and velocity or we can say, it depends on their momentum.



Mom, whatever we learnt in the class is making sense now. I'm glad we came here.



Yes. Science becomes simpler when you start relating it to daily life.

Wow!!! I am looking forward to tomorrow's match!



Rohit and his family return to their guest house after an eventful day.

Worksheet – 2

Newton's Logic Puzzle

Five students **A**, **B**, **C**, **D** and **E** forgot to label the mass and accelerations of their respective carts and are now trying to backtrack and identify all their data.

The carts may have

- one of the following values for mass
-4.5kg, 6kg, 9kg, 9kg, 12 kg
- one of the following values for acceleration
-5m/s², 4 m/s², 3 m/s², 2.5 m/s², 2 m/s².

Using the following clues (and your understanding of Newton's 2nd Law of Motion), help them to determine the mass of their cart, the acceleration of their cart, and the force they applied to their carts.

Clues:

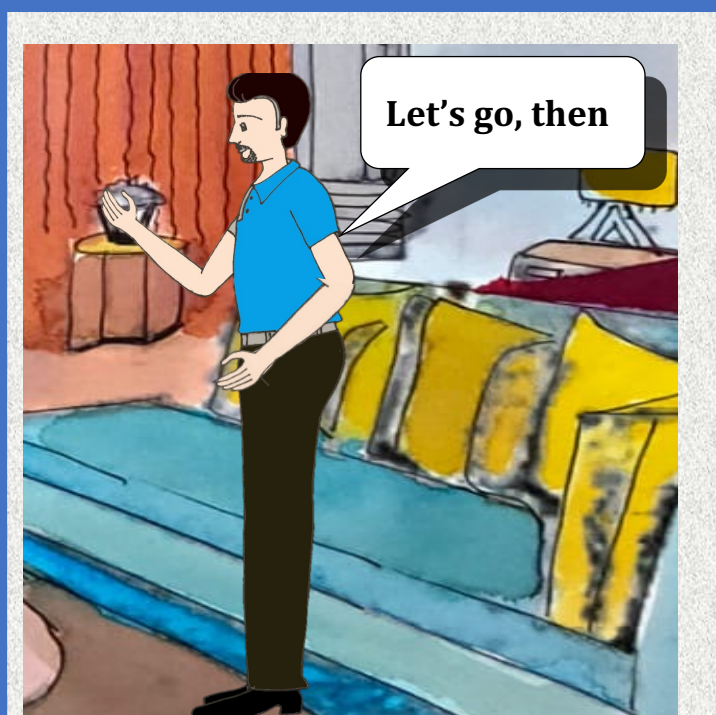
1. **A**'s cart has 50% more mass than **C**'s cart.
2. Mass of **D**'s cart is neither the smallest nor the largest.
3. The mass of **E**'s cart is greater than **D**'s cart.
4. **D**'s cart had twice the mass of **B**'s cart.
5. **C**'s acceleration was half of **E**'s acceleration.
6. **B**'s acceleration was greater than **D**'s.
7. **D**'s acceleration was greater than **C**'s.
8. **A** had less acceleration than **D**.
9. The force **D** applied to his cart was larger than **B**.
10. **A** applied a force of 18N.
11. **E** applied more than 40N of force.
12. **C** applied least amount of force.
13. **B**'s force was less than 20N.

Solution:

	Mass (Kg)	Acceleration (m/s ²)	Force (N)
A			
B			
C			
D			
E			

(Day of the match - Indian Super League finals between Royal Strikers and Super Challengers, at Mohali Cricket Stadium.)

Karan and Aaroahi wake up early and quickly get ready to go to the stadium.



All of them reach the dining hall. The players (dressed up in their team jerseys and tracks) are having breakfast.



After breakfast, everyone leaves for Mohali Cricket Stadium.

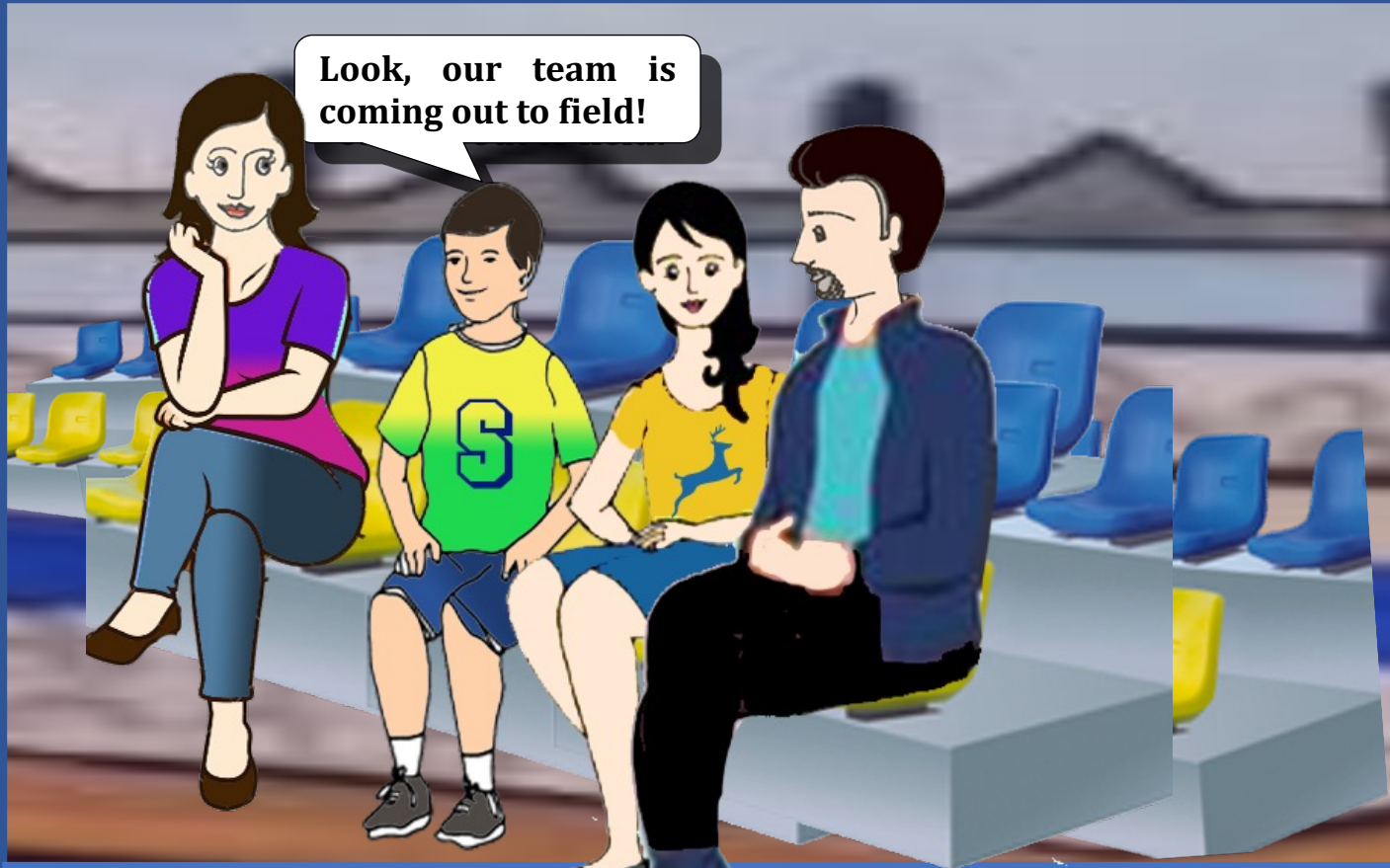


At the stadium, Rohit and his family occupy their seats in the pavilion.

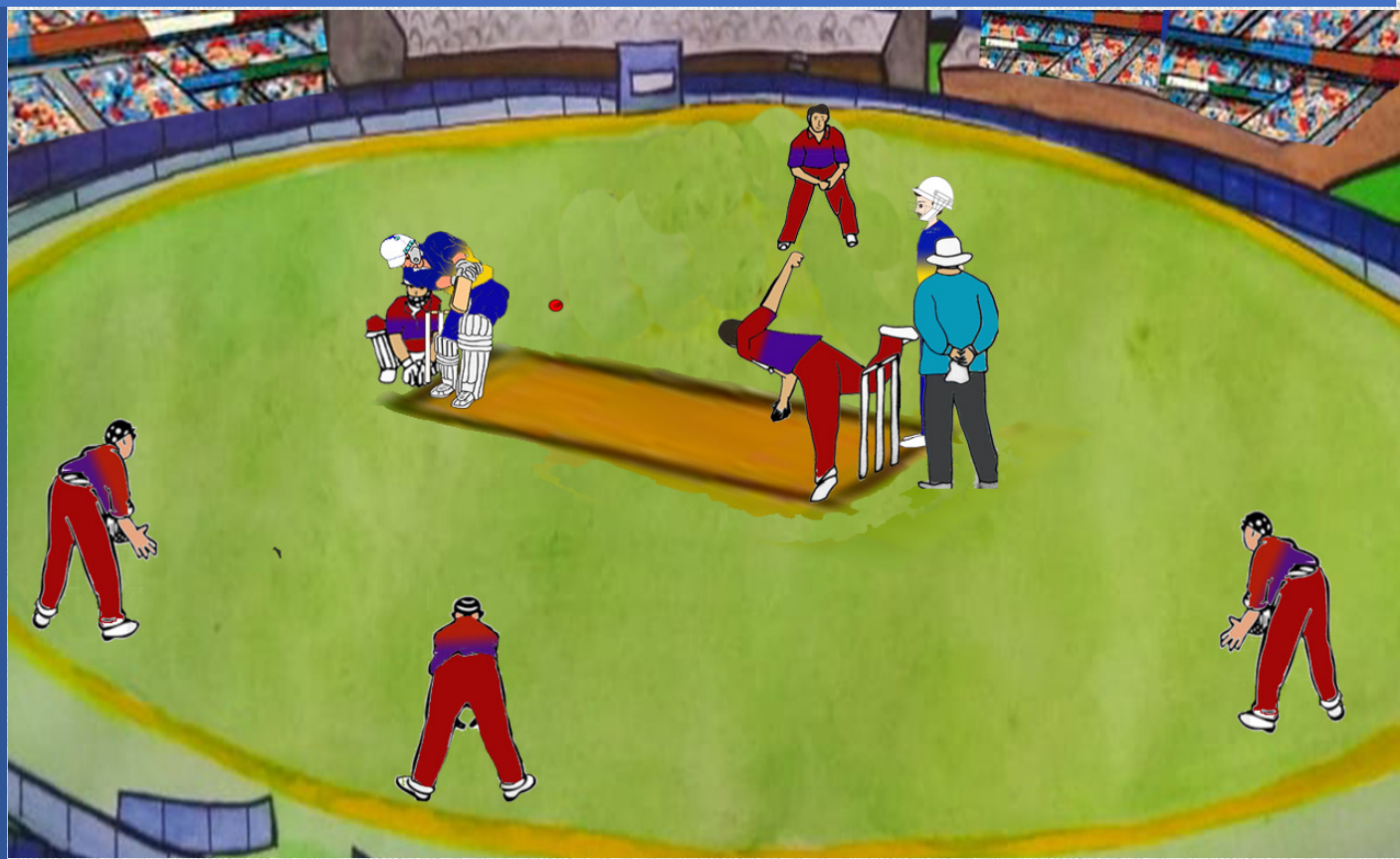


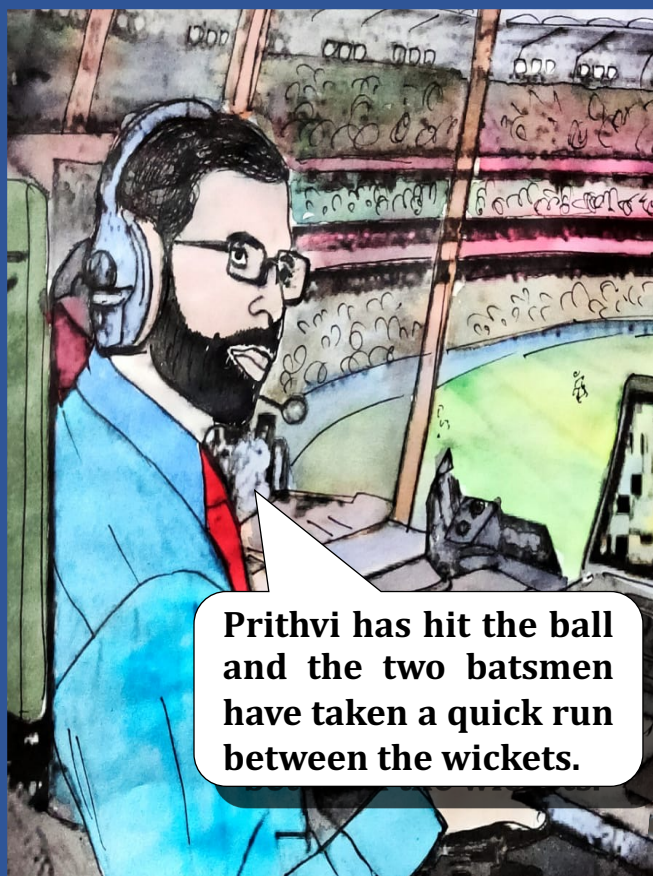
The team captains, Rahul (Royal Strikers) and Prithvi (Super Challengers) come out for the toss. Royal Strikers win the toss and choose to field first.





Royal Strikers take their positions in the field. Super Challengers' captain, Prithvi takes his position as the opening batsman, along with his teammate.



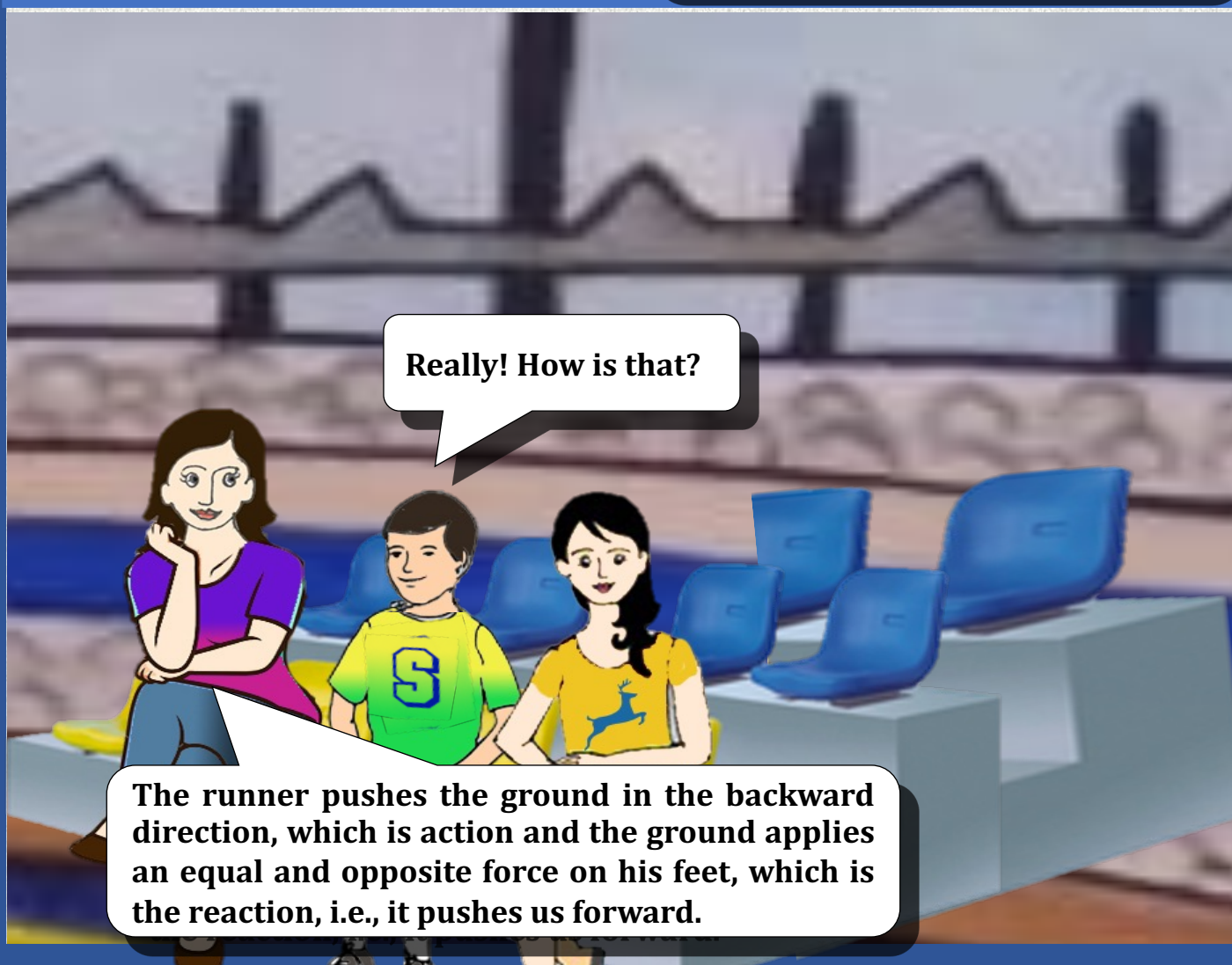


Prithvi has hit the ball and the two batsmen have taken a quick run between the wickets.

Wow! The batsmen are running so quickly.



Do you know running is based on Newton's third law of motion, which states that "for every action, there is an equal and opposite reaction"?



Really! How is that?

The runner pushes the ground in the backward direction, which is action and the ground applies an equal and opposite force on his feet, which is the reaction, i.e., it pushes us forward.

Newton's third law is also applicable to swimming. When we push the water back with our arms, it is action. And when the water pushes us forward, it is reaction.

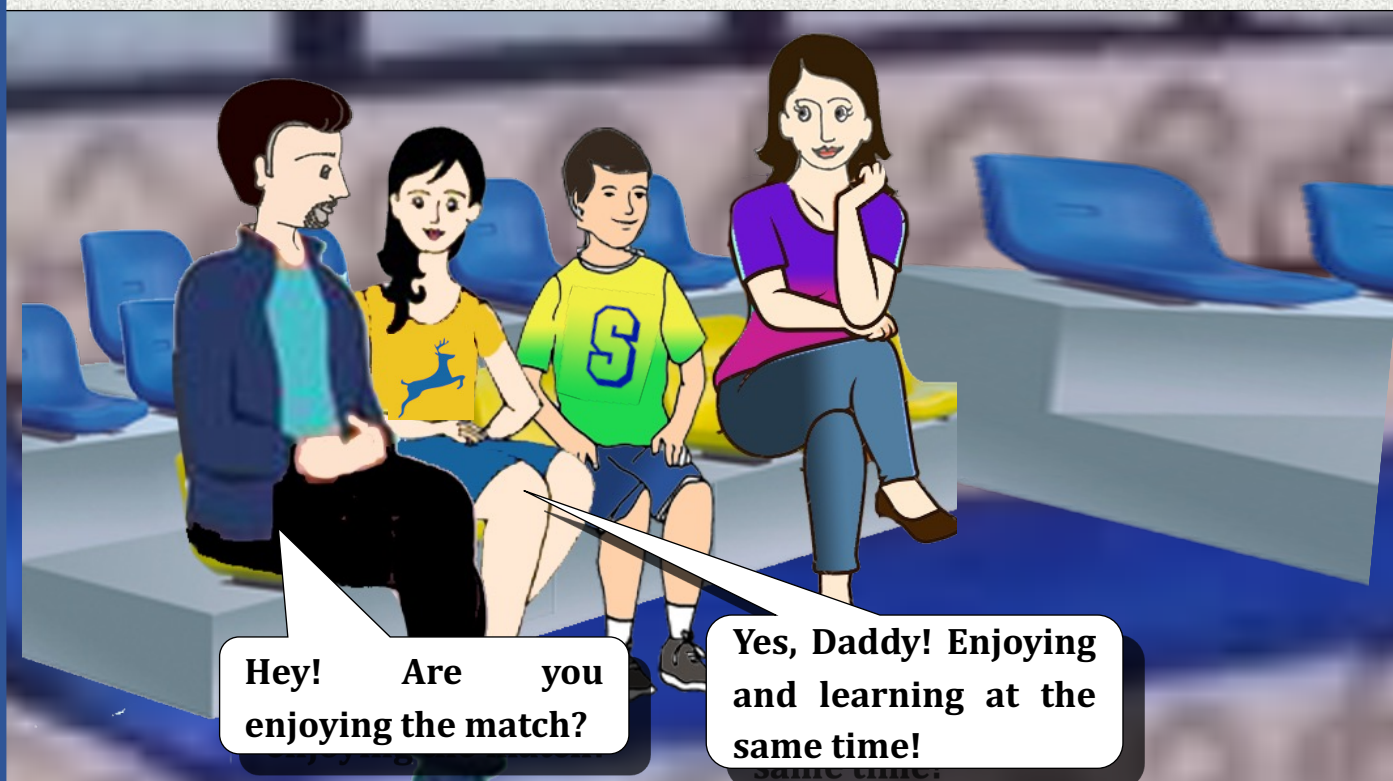


Yes. And, even jumping out of a boat onto the shore applies the same law. When we jump out of the boat and move forward, it's action, while the boat being pushed backwards at the same time, is reaction.



Wow!!! Physics is so cool. It is everywhere.

The match continues. There is a twenty-minute break between the innings.



Manav and another player come out to open the inning. Prithvi gives instructions to his fielders. 2nd innings starts at a slow pace.

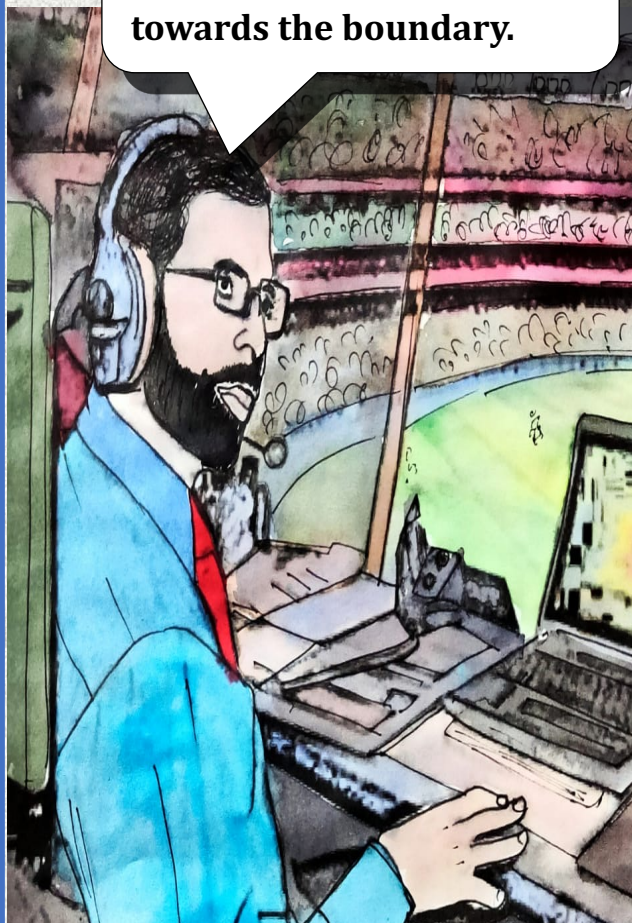


Why are they not making runs faster?



Have patience, little brother!

What a beautiful shot by Manav! The ball is moving towards the boundary.

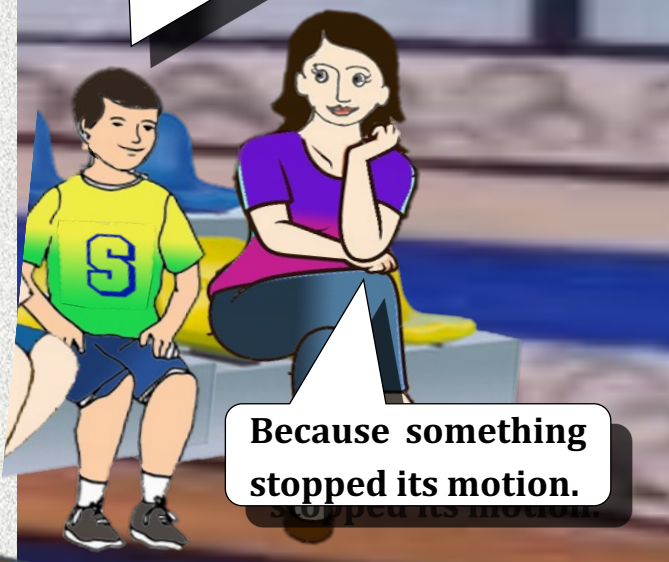


Now, that should be 4 runs!



The ball stops short of the boundary and only 2 runs are scored by Royal Strikers.

Oh, no! I thought the ball would touch the boundary. Why did it stop?



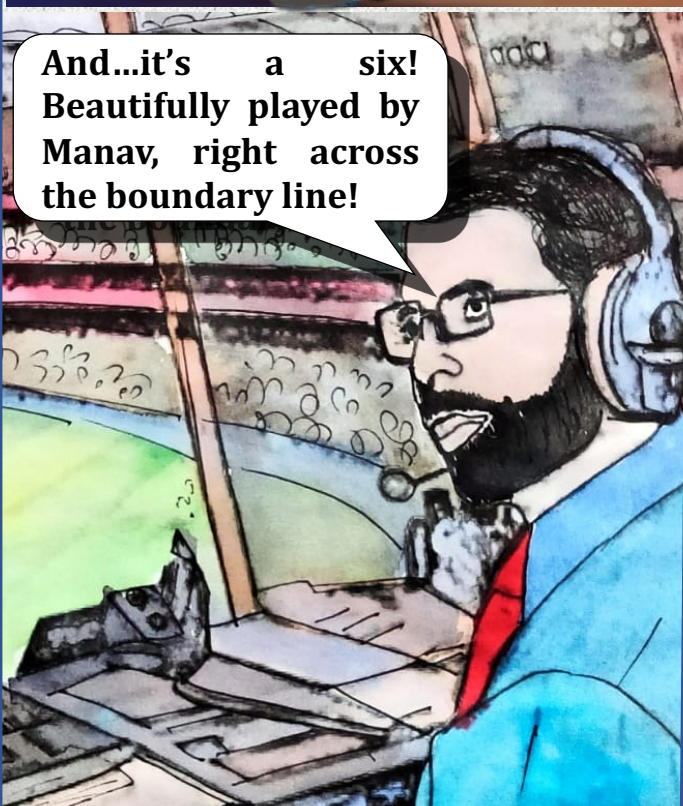
Because something stopped its motion.

Let me guess...
hmm... frictional
force?

Yes, correct. This force is
always acting and
opposing the motion of
the ball.



And...it's a six!
Beautifully played by
Manav, right across
the boundary line!

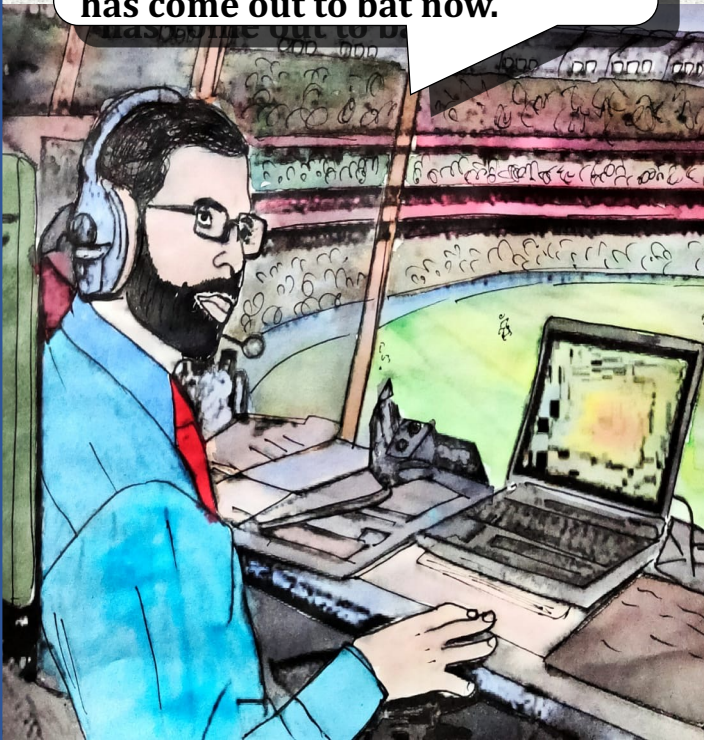


That's great!



The match continues. After a sluggish start, at the completion of 10 overs, the Royal Strikers' score is 80 for 3. Manav remains not out.

After the fall of the 3rd wicket,
Royal Strikers' Captain, Rahul
has come out to bat now.



Yayy!!



Rahul scores a century and that too in just 42 balls. There is a wave of excitement in the stadium. The target of 193 is achieved in 19 overs, at a loss of 3 wickets.

Royal Strikers win the Indian super League by beating Super Challengers.

**Congratulations
Royal Strikers
ISL Champions**



Well done, boys! You have made me very proud!

Thank you, Sir!



Congratulations, Uncle!



Thank you! You have been my lucky charms!



All of them return to their guesthouse.

I have been too busy.
I hope all of you
enjoyed the trip.

We did Uncle! And, we also
learnt a lot. Thanks to
you!

Great! So, what did you
learn? Is there more
Physics in cricket or, more
cricket in Physics?

Um...I think, more
Physics in cricket!



All of them have a hearty laugh.

Which Law?

Sir Isaac Newton formulated the three laws of motion. Fill in the missing words in each of these laws and identify which law explains each of the examples given below.

Newton's FIRST Law of Motion

An object at _____ stays at _____ & an object in _____ keeps moving with the same _____ unless an _____ force acts on it.

Newton's SECOND Law of Motion

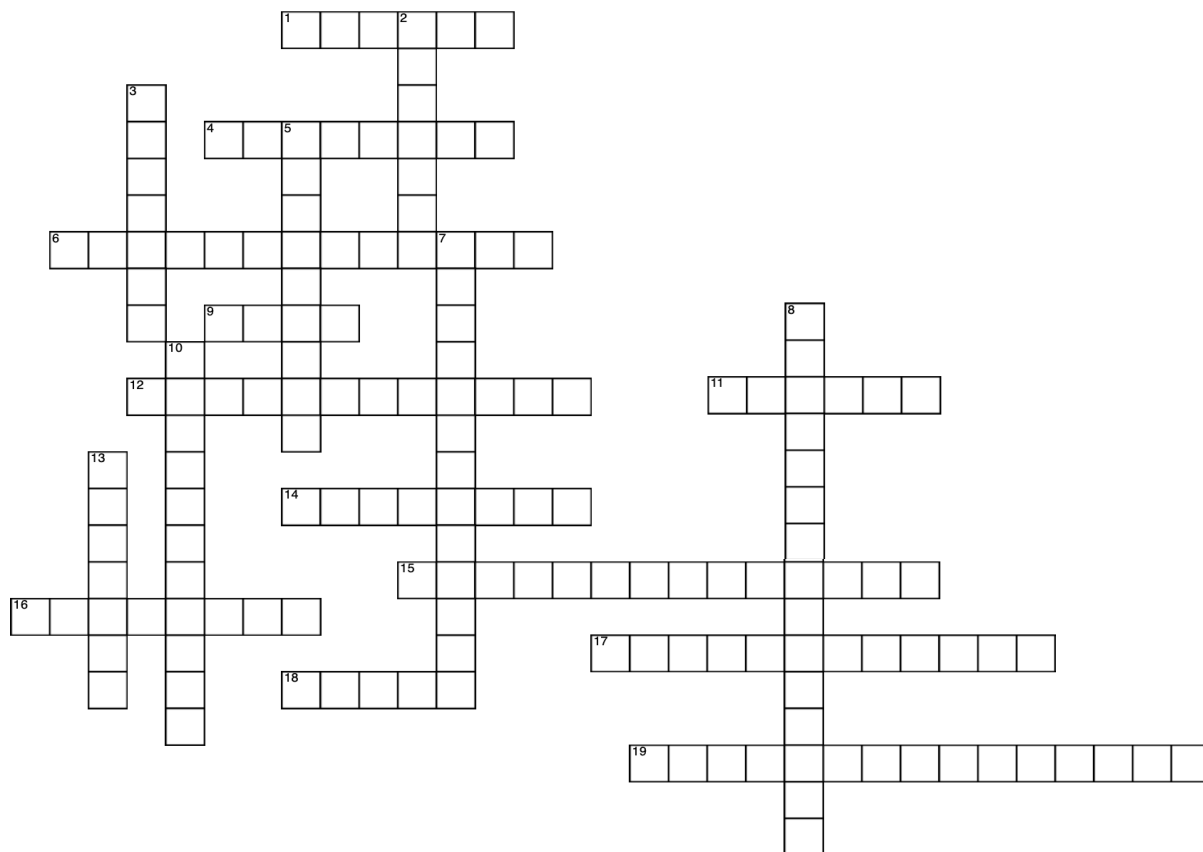
The amount of _____ needed to make an object change its _____ depends on the _____ of the object.

Newton's THIRD Law of Motion

When one object exerts a _____ on a second object, the second object exerts an _____ and _____ force on the first object.

- _____ 1. As the fuel in a rocket ignites, the gases are expelled from the back of the rocket, while pushing the rocket forward.
- _____ 2. When you are standing in a bus and it comes to a sudden stop, your _____ body continues to move forward.
- _____ 3. After you start cycling, the more force you apply, the faster it goes.
- _____ 4. A pitched baseball goes faster than one that is gently thrown.
- _____ 5. A swimmer pushes water back with her arms, but her body moves forward.
- _____ 6. As an ice skater pushes harder with his leg muscles, he begins to move faster.
- _____ 7. 5 year old Ravi and his father are skipping pebbles on the lake. The pebbles that Ravi's father throws, go farther and faster than his.
- _____ 8. When you paddle a boat, the boat moves forward.

Crossword Puzzle



Across

1. The measure of intensity of the force exerted on an object by gravitational field

4. The resistance that one surface encounters when moving over another

6. Floating on water is an example of _____ force

9. Amount of matter present in an object

11. SI units of force

12. Rate of change of velocity

14. The physical quantity which is the product of mass and velocity

15. The perpendicular force that a surface exerts on an object

16. Vector sum of all the forces acting on an object

17. Another name for Newton's first law

18. A push or a pull

19. The force that causes change in state of motion of the object

Down

2. The famous Italian scientist, who formulated the correct law for uniformly accelerated objects.

3. Force acting for a short duration

5. According to Newton's second law, acceleration is _____ proportional to the mass of the object

7. Force acting in opposite direction

8. For every action, there is an equal and opposite reaction

10. Force acting in one direction

13. State of rest or motion of an object

Answers - Let's Try To Answer

1. d. all of the above.
2. d. in a straight path
3. a. inertia is the tendency of objects to resist changes to their motion.
4. b. that the dishes have inertia
5. a. True
6. c. you will land in the same place from where you jumped

Answers - Newton's Logic Puzzle

	Mass (Kg)	Acceleration (m/s^2)	Force (N)
A	9	2	18
B	4.5	4	18
C	6	2.5	15
D	9	3	27
E	12	5	60

Answers - Which Law?

Sir Isaac Newton formulated the three laws of motion. Fill in the missing words in each of these laws and identify which law explains each of the examples given below.

Newton's FIRST Law of Motion
An object at rest stays at rest
& an object in motion keeps
moving with the same velocity
unless an unbalanced force
acts on it.

Newton's SECOND Law of Motion
The amount of force needed to
make an object change its velocity
depends on the mass of the object.

Newton's THIRD Law of Motion
When one object exerts a force on
a second object, the second object
exerts an equal and opposite
force on the first object.

Third law 1. As the fuel in a rocket ignites, the gases are expelled from the back of the rocket, while pushing the rocket forward.

First law 2. When you are standing in a bus and it comes to a sudden stop, your body continues to move forward.

Second law 3. After you start cycling, the more force you apply, the faster it goes.

Second law 4. A pitched baseball goes faster than one that is gently thrown.

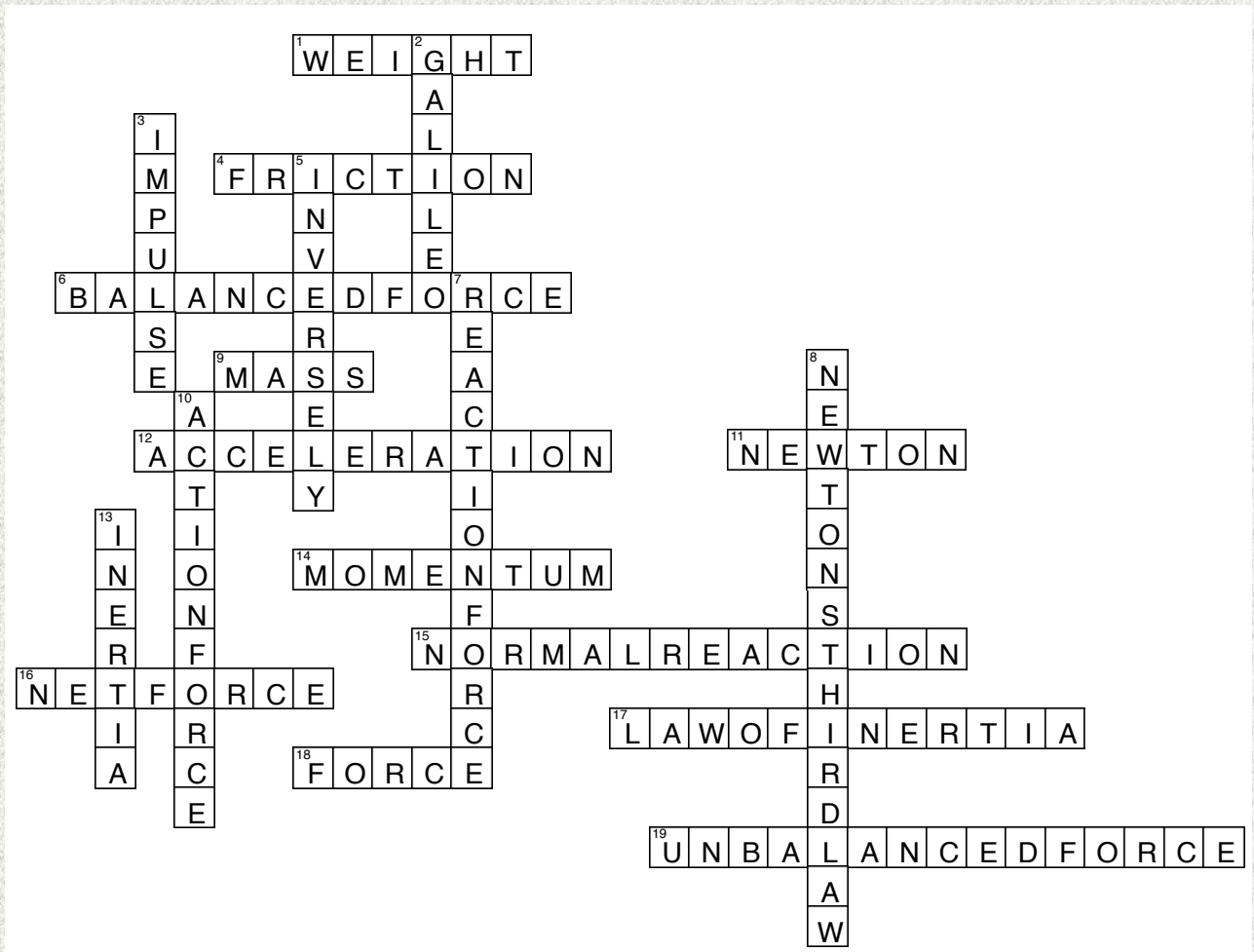
Third law 5. A swimmer pushes water back with her arms, but her body moves forward.

Second law 6. As an ice skater pushes harder with his leg muscles, he begins to move faster.

Second law 7. 5 years old Ravi and his father are skipping pebbles on the lake. The pebbles that Ravi's father throws, go farther and faster than his.

Third law 8. When you paddle a boat, the boat moves forward.

Answers - Crossword Puzzle



Glossary

- Mass –The amount of matter contained in an object.
- Force – A force is a push or pull upon an object, resulting from one object's interaction with another.
- Balanced Force - Force acting on an object which does not cause any change in the state of rest or of uniform motion of the object.
- Unbalanced Force - Force acting on an object which causes a change in the state of rest or of uniform motion of the object.
- Inertia – The natural tendency of objects to resist a change in their state of rest or of uniform motion is called inertia.
- Weight – The force acting on an object due to gravity.
- Velocity – The rate of change of displacement of an object.
- Acceleration - The rate of change of velocity of an object.
- Momentum – The product of mass and velocity of an object.
- Impulse – The force acting on an object, for a very short interval of time.
- Action and Reaction – A force acting in one direction is called action and the force acting in the opposite direction is called reaction.
- Friction - Friction is the resistance to the motion of an object, moving relative to another.

Bibliography

- ❖ Science Textbook for Class IX (NCERT)

IT tools used :

- ❖ MS PowerPoint
- ❖ Expression Editor - many-fe.noprod-b.kmt.orange.com
- ❖ Autodesk Sketchbook version 8.7.1
- ❖ Adobe Photoshop

Rohit is off to Chandigarh with his family – his wife and two children, to witness the finals of Indian Super League. Their journey to the destination by car is not just fun but a lot of learning for his young, school-going children as they get to understand some basic concepts of Physics with life-like examples. Even during the cricket match, quite interestingly, Newton's Laws unravel for the kids with some live examples from the match itself. This not only makes their short vacation entertaining and educating, but also a memorable one. The application of Newton's three laws of motion is bound to stay in the minds of the readers with this simple and entertaining read.



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