

# Laws of Motion

## What is force?

What happens when you push or pull objects?

Some examples of pushing and pulling –



Kicking



Pushing



Lifting

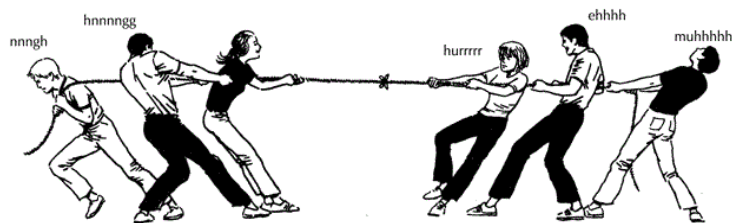


Squeezing

## Definition

Force:

## Activity: Tug of war



In a tug of war, both the teams are pulling at the rope. However, if both the teams are evenly matched then there is hardly any movement of the rope. Why?

Balanced Force:



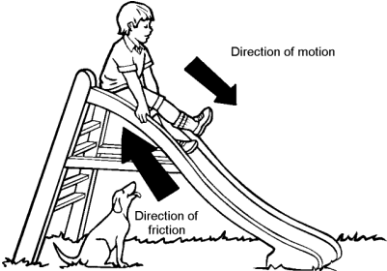
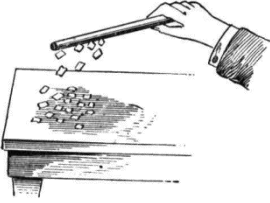

## Checkpoint

Can a balanced force is acting on a body; can it change the velocity of an object?

Can a balanced force change the shape of an object?

## Types of Forces

Identify the forces shown in the picture below. Also tell whether if the force can act at a distance or requires contact with the object.

Example	Force Involved	Contact / Non-contact Force
		
		
		
		
		


## Inertia and Newton's first law of motion – "Objects are Lazy"

### Activity: Kicking a football

Take a football and place it on the ground. If no one were to come and kick the football, will it change its position?

Now kick the football. Measure the distance travelled by the football. Repeat the exercise on a smooth tiled floor.

Nature of surface	Distance travelled by the football (m)
Rough ground	
Smooth tiled floor	



Why do you think the football stops moving after sometime?

What would happen if kicked the football on a surface where the friction between the football and that surface is 0?

### Activity: Accident!!!

In the adjoining figure what will happen to the boy when the bus hits the barrier? Why?



### Definition

Newton's first law of motion:

## Checkpoint

Explain why a fan continues to rotate for some time after you switch it off.

Why should one put on the seat belt while driving?



## Galileo Galilei

Collect information about Galileo Galilei.

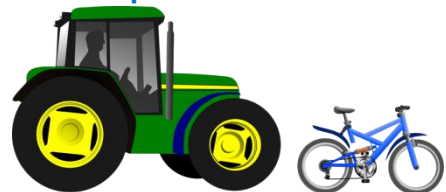


## Momentum and Newton's second law of motion – “Calculating force”

### Activity: Relation between mass of an object and the force required

What can you push more easily – a tractor or a bicycle?

Why?



**Activity: Relation between change in velocity and the force required**

Ask your friend to stand at a distance of about 10 m from you. Kick the football gently towards your friend and measure the time taken by the football to reach him. Calculate the velocity of the football.



Now kick the football with all the energy that you've got and again calculate the velocity of the football. Is there a correlation between the force you exert and the change in velocity of the football?

**Activity: Relation between the time taken to change the velocity and the force required**

Suppose you were to start cycling from your house towards the school. Your initial speed is 0 km/h. As you pedal you slowly accelerate to attain a speed of say 20 km/h in 2 minutes.

If you want to attain the same speed in 1 minute what would you have to do?



Can you identify the 3 factors that determine the amount of force required from the activities above?

- 1.
- 2.
- 3.

**Definition**

Momentum:

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

**Mathematical representation of the second law of motion:**

### Checkpoint

Why is long jump athlete made to fall on a sand bed?

### Sample Problem

Calculate the momentum of a field gun of mass 500 kg when it recoils with a velocity of 0.50 m/s after firing a shell from it.

**Given:**

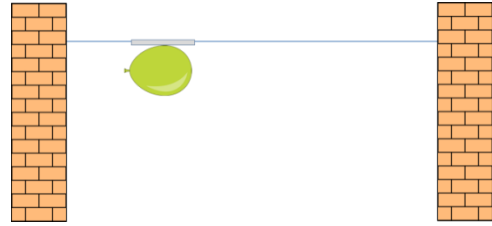
**Find:**

**Formula:**

## Newton's third law of motion and Law of conservation of momentum

### Activity: Balloon rocket

Blow a balloon and attach a straw to its side. Take a long string and pass it through the straw. Stretch and tie the string between two supports as shown in the figure above. Let the air escape out of the balloon. You will observe that the balloon will move along the string as the air escapes out.

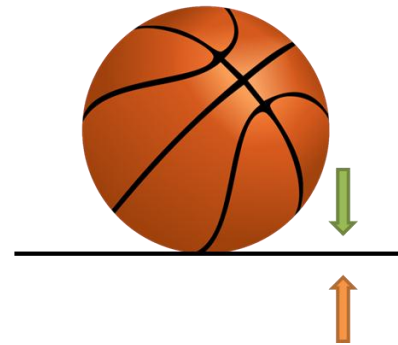


Which direction does the balloon move in? Why?

### Activity: Bouncing ball

Drop a rubber ball from a height of one meter. Catch it when it bounces back up to its maximum height. Name the force which caused the ball to start moving. What must have happened in order for the ball to bounce back to your hand?

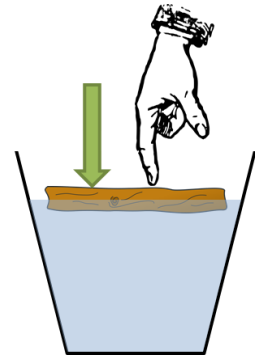
After the ball bounces and starts to move upward, what happens to its motion? Why?



### Activity: The force of water

Place a wooden block in a bucket of water so that it floats. Push the block down into the water and release it. What happens? Why?

What do you notice if you push the block down to greater and greater depths in the bucket? How can you explain this in terms of forces?



### Definition

Newton's third law of motion:

### Law of conservation of momentum

Calculating momentum before and after a collision:

Law of conservation of momentum:

Identify two scenarios where Newton's third law of motion helps us in everyday life.

- 1.
- 2.



Draw a diagram representing the action and reaction forces for the scenarios identified by you.

### Checkpoint

If action and reaction are equal and opposite why don't they cancel each other?

### Sample Problem

Two balls of masses 50 g and 100 g are moving along the same line with velocities 3 m/s and 1.5 m/s respectively. They collide and after collision the first ball moves with a velocity of 2.5 m/s. Calculate the velocity of the second ball.

Given:

Find:

Formula:

## Sir Isaac Newton

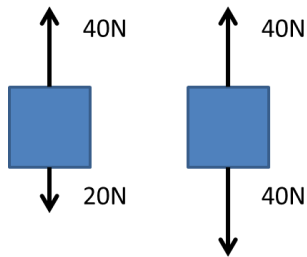
Collect information about Sir Isaac Newton



## Questions and Problems

### Balanced force

- If the net force acting upon an object is 0 N, then the object must \_\_\_\_\_.
  - be moving
  - be accelerating
  - be at rest
  - be moving with a constant velocity
  - both c and d
- Calculate the net force acting on the object in the cases below. Which of the two indicates a balanced force?



### Newton's first law and Inertia

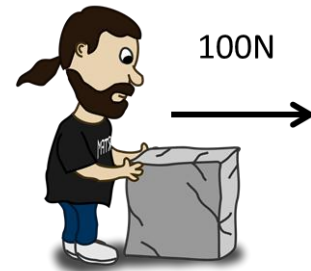
- The amount of inertia possessed by an object is dependent solely upon its \_\_\_\_\_.
- Two bricks are resting on edge of the lab table. Priya wants to know which of the two bricks are most massive. Since she is short, she is unable to reach high enough and lift the bricks; she can however reach high enough to give the bricks a push. Discuss how the process of pushing the bricks will allow Priya to determine which of the two bricks is most massive. What difference will she observe and how can this observation lead to the necessary conclusion?
- Would Priya be able to conduct this same study if she was on a spaceship in a location in space far from the influence of significant gravitational forces?
- State whether the following statements are true or false
  - A force is required to keep an object moving in a given direction. (Assume no friction and resistance from air).
  - If an object is at rest, then there are no forces acting upon the object.
  - An upward moving object must be experiencing an upward force.

7. Calculate the force required to keep a 10 kg object moving on a frictionless surface with a constant velocity of 2 m/s.

### Newton's second law and momentum

8. A man pushes a box whose mass is 10 kg with a force of 100 N. Calculate the acceleration of the box.

Given:

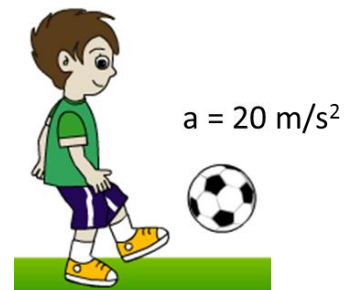


Find:

Formula:

9. Calculate the force with which a footballer has kicked the football if produces an acceleration of  $20 \text{ m/s}^2$ . Assume the mass of the football to be 300 g.

Given:



Find:

Formula:

10. A basketball star exerts a force of 3000 N (average value) upon the gym floor in order to accelerate his 75 kg body upward. (a) Determine the acceleration of the player. (b) Determine the final speed of the player if the force endures for a time of 0.150 seconds.

Given:

Find:

Formula:

11. A hockey player accelerates a hockey ball having a mass of 200 g from rest to a velocity of 50 m/s in 0.01 s. Determine the acceleration of the puck and the force applied by the hockey stick to the puck.

Given:

Find:

Formula:

12. Momentum is a \_\_\_\_\_ quantity.
- Scalar
  - Vector

13. Calculate the velocity of a bowling ball having a mass of 2.5 kg if its momentum is the same as that of a cricket ball having a mass of 0.5 kg and moving with a velocity of 30 m/s.

Given:

Find:

Formula:

14. A bus with a mass of 1000 kg is at rest at a stoplight. When the light turns green, it is pushed by a net force of 2000 N for 10 s.

- What is the value of the acceleration that the car experiences?
- What is the value of the change in momentum that the car experiences?
- What is the final velocity of the car at the end of 10 seconds?

Given:



Find:

Formula:

15. An 8000 kg engine pulls a train of 5 wagons, each having a mass of 2000 kg along a horizontal track. If the engine exerts a force of 40000 N and the track offers a resistance of 5000 N, then calculate –
- the net accelerating force
  - the acceleration of the train
  - the force of wagon 1 on wagon 2

Given:

Find:

Formula:

16. A hammer of mass 500 g moving at 50 m/s strikes a nail. The nail stops the hammer in a very short time of 0.01 s. What is the force of the nail on the hammer?

Given:

Find:

Formula:

17. A 0.1 kg hockey puck is at rest. It encounters a force of 20 N for 0.2 s which sets it into motion. Over the next 2.0 s, it encounters 0.4 N of resistance force. Finally, it encounters a final force of 24 N for 0.05 seconds in the direction of motion. What is the final velocity of the hockey puck?

Given:

Find:

Formula:



**Newton's third law and conservation of momentum**

18. Two objects each with a mass of 1.5 kg are moving in the same line but in opposite directions. The velocity of the first object is 5 m/s and that of the second object is -2 m/s. Calculate the velocity of the second object after the collision if the velocity of the first object is 1 m/s.  
Given:

Find:

Formula:

19. An object of mass 1 kg moving a straight line with a velocity of 10 m/s strikes a stationary wooden block of mass 5 kg. Then they both move together in the same straight line. Calculate their velocity.  
Given:

Find:

Formula: