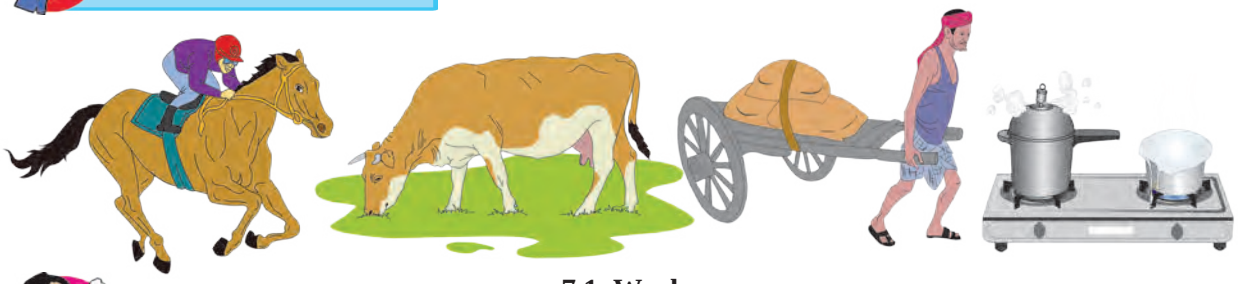
# 7. Motion, Force and Work

**Observe and discuss.**



7.1 Work

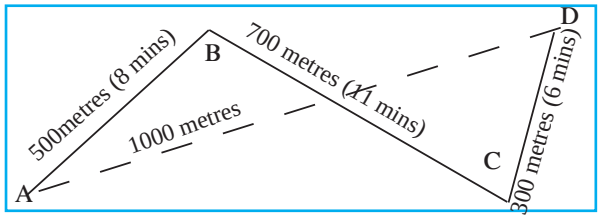
**Let's recall.**

What is meant by motion?
What causes a change in motion?

We have seen that a change occurs in the motion or the shape of a body when a force acts on it. Now let us see how work is done when a force acts.

## Distance and displacement

Ranjit's house is at place A. The figure alongside shows the distance traversed by Ranjit to reach his school at D. If we do not take direction into account, we find that Ranjit traversed a distance equal to AB+BC+CD. However, on doing this, his displacement was equal to AD. Ranjit's displacement from his house to the school is shown in the picture with the broken line AD. AD is the minimum distance along a straight line from Ranjit's house to the school.




7.2 Distance and displacement

The minimum distance traversed in a particular direction along a straight line is called displacement.

## Speed and velocity

1. What is meant by speed?
2. What is the formula for calculating speed?

When we say that the speed of a car is 40 km per hour, there is no need to specify the direction, but, to predict whether a storm will reach a particular place or not, a mention of its direction is essential.

**Distance :** The length of the route actually traversed by a moving body, irrespective of the direction, is called distance. Distance is a scalar quantity.

**Displacement :** The minimum distance traversed by a moving body in one direction from the original point to reach the final point, is called displacement.

In displacement, both distance and direction are taken into account. Therefore, displacement is a vector quantity.

The unit of measurement of distance and displacement is the metre, in the SI as well as in the MKS system of measurement.

**Velocity :** Velocity is the distance traversed by a body in a specific direction in unit time. The velocity of a body can be calculated by the following formula:

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Period of time required for the displacement}}$$

**Let's find the unit.**

| Task | Speed | Velocity |
|---|---|---|
| Write the formula | Speed = | Velocity = |
| Write the units of the quantities | Distance :<br>Time period : | Displacement :<br>Time period: |
| Insert the units instead of quantities in the formulae. You will get the unit of speed and velocity. | | |

The unit of speed or velocity is written as metres/second (m/s)

Let us now use the above formulae to find out Ranjit's velocity and speed when he goes to school as shown in the figure 7.2.

The actual distance traversed by Ranjit from home to school

= AB + BC + CD

= 500 m + 700 m + 300 m = 1500 m.

Total time from home to school = 8 minutes + 11 minutes + 6 minutes = 25 minutes

Ranjit's displacement from home to school, AD = 1000 metres

Thus, Ranjit's velocity when going from home to school

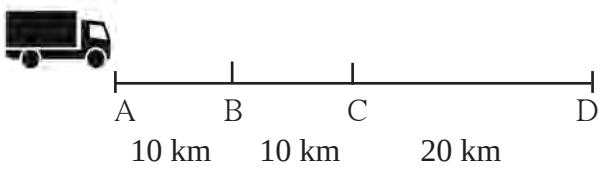
$$\text{Velocity} = \frac{\text{Displacement}}{\text{Total time}} = \frac{1000 \text{ metres}}{25 \text{ minutes}} = \frac{40 \text{ metres}}{60 \text{ seconds}} = 0.66 \text{ metres/second}$$

Ranjit's speed while going to school

$$\text{Speed} = \frac{\text{Distance traversed}}{\text{Total time}} = \frac{1500 \text{ metres}}{25 \text{ minute}} = \frac{60 \text{ metres}}{60 \text{ seconds}} = 1 \text{ metre/second}$$

Ranjit did not take the straight route of minimum distance while going to the school. Therefore, the magnitudes of his velocity and speed came out to be different. Had Ranjit actually gone by the straight route AD, then the magnitude of his velocity and speed would have been the same.

**Average velocity and instantaneous velocity :** The velocity of an object can change even while it is moving along a straight line. Suppose that a truck is covering a distance of 40 km from A to D in a straight line. That is, its displacement will be 40 km.




**7.3 Displacement**

If it requires altogether 1 hour for this, its average velocity is 40 km/hour. However, if the truck traverses the 10 km distance AB in 10 minutes, BC in 20 minutes and CD in 30 minutes, then

$$\text{Velocity for the distance AB in km/hr} = \frac{10 \text{ km}}{10 \text{ minutes}} = \frac{60 \text{ km}}{60 \text{ minutes}} = 60 \text{ km /hr}$$

Now deduce the velocities for the distances BC and CD. We see that the velocity of the truck is different in the different segments of the road AB, BC and CD. However, the average velocity for the entire route AD is 40 km/hour. The velocity at a particular moment of time is called instantaneous velocity. The instantaneous velocity can be different at different times.

## Acceleration

In the previous example, the truck covered the distance AB at the velocity of 60 km/hour, BC at 30 km/hour and CD at 40 km/hour. It means that the velocity for the distance CD is greater than the velocity for the distance BC. From the number of seconds required for this change in velocity to take place, the change in velocity per second can be deduced. This is called acceleration. What is the cause of acceleration?

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time taken for change}}$$

You know that the truck driver increases or decreases the velocity of the truck by means of the accelerator. You might have seen a toy car that runs on a clockwork spring. When it is released on a flat floor, after winding up the spring, it goes in a straight line. However, when it is hit on one side, it changes direction and keeps going. If it collides into a wall, it stops. It means that its velocity changes. How did this change take place? It happens because the car comes into contact with something external to it. On a football ground, how does the direction of the ball moving in a straight line, change? We see some player changing its direction by kicking it. When its direction changes, the velocity of the ball changes, that is to say, an acceleration takes place. The interaction that brings about the acceleration is called force. Force acts on a body.

**Use your brain power!**

The unit of acceleration is $m/s^2$. Verify this.

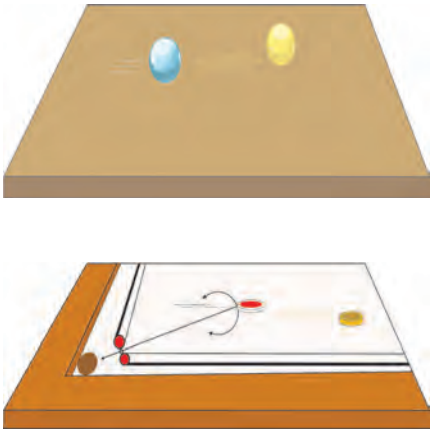
## Force and accleration

**Try this.**

Take a glass marble and let it roll on a big smooth tabletop. After some time its velocity will decrease and it will stop. On a carrom board, too, the carrom coin, pushed by a striker will move forward some distance, and then come to a stop. If the coin is pushed after applying talcum powder to the carrom board, it will keep moving for a longer time and then come to a stop.

What can we infer from this?

The velocity of the coin decreases due to the force of friction, and the coin stops. If the friction between the carrom board and the coin is reduced, the coin keeps moving for a longer time. It would mean that, if no force of friction is acting on a moving body, it will keep on moving with a constant velocity.



**7.3 Force and acceleration**

The scientist Sir Isaac Newton was the first to study force and the resulting acceleration.

**Newton's First Law of Motion :** If no force is acting on a body, its velocity does not change, i.e. the body does not accelerate. In other words, if a body is stationary, it will remain stationary. If it is in motion, it

will continue moving with the same velocity and in the same direction.

You have learnt what is meant by force. You have seen that a body is accelerated due to force. Suppose, you place the 1 kilogram standard weight (See the chapter on 'Measurement'.) on a surface with no friction and pull it with an acceleration of 1m/s$^2$, the force applied is called 1N (1 Newton).

**Use your brain power!**

Acceleration is a vector quantity. Is force a vector quantity, too?

**Try this.** Place a weight of 1 kilogram on a smooth wooden table. Spread some talcum powder evenly on the table. Now pull the 1 kg weight with an acceleration of 1 m/s$^2$. Again pull it with an acceleration of 2m/s$^2$. It means that, now, you have applied a force of 2N. You will have to take many trials for this experiment.

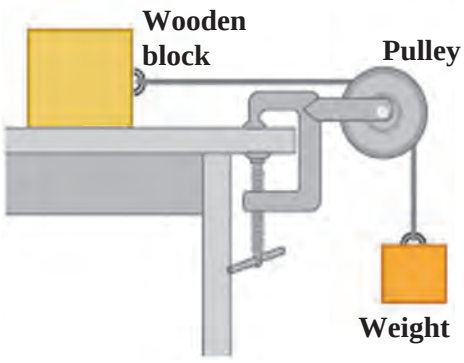
Force is measured by the acceleration that it produces.

We have learnt about the relationship between the displacement of a body resulting from the force applied to it and the work done. We have also learnt about the work-energy relationship and that the ability to do work is called energy.

## Force, displacement and work

In the figure alongside, a string, attached to a wooden block on a table, is passed over a pulley and tied to a weight. On applying a sufficient weight, the block will be seen to move.

Which force is being applied here? How can this force be increased? What will happen on applying more force? When can we say that work is done by the applied force?




**7.4 Work**

If the block moves forward, we can say that it has been displaced. Due to the displacement, we say that the force has done some work. Can we measure this work? We know that work done depends on the force and the displacement. The following formula expresses this relationship :

Work (W) done by the force = force (F) applied to the body × displacement (s) of the body that takes place in the direction of the force,

$W = F \times s$

In the SI system, the unit of work is Joule (J), while the unit of force is Newton (N) and the unit of displacement is metre (m). In the CGS system the unit of work is erg.

If a force of 1N parallel to the surface of the table is applied to a wooden block on the table, and the block is displaced by 1 metre, then it can be said that the force has done 1 Joule of work. In this example, the displacement is in the direction of the force.

## Exercise

**1. Fill in the blanks with the proper words from the brackets.**

(stationary, zero, changing, constant, displacement, velocity, speed, acceleration, stationary but not zero, increases)

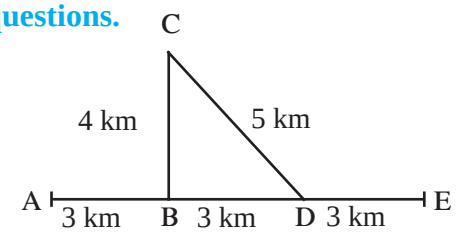
(a) If a body traverses a distance in direct proportion to the time, the speed of the body is ..... .

(b) If a body is moving with a constant velocity its acceleration is ..... .

(c) ..... is a scalar quantity.

(d) ..... is the distance traversed by a body in a particular direction in unit time.

**2. Observe the figure and answer the questions.**




Sachin and Sameer started on a motorbike from place A, took the turn at B, did a task at C, travelled by the route CD to D and then went on to E. Altogether, they took one hour for this journey. Find out the actual distance traversed by them and the displacement from A to E. From this, deduce their speed. What was their velocity from A to E in the direction AE? Can this velocity be called average velocity?

**3. From the groups B and C, choose the proper words, for each of the words in group A.**

| A | B | C |
|---|---|---|
| Work | Newton | erg |
| Force | Metre | cm |
| Displacement | Joule | dyne |

**4. A bird sitting on a wire, flies, circles around and comes back to its perch. Explain the total distance it traversed during its flight and its eventual displacement.**

**5. Explain the following concepts in your own words with everyday examples : force, work, displacement, velocity, acceleration, distance.**

**6. A ball is rolling from A to D on a flat and smooth surface. Its speed is 2 cm/s. On reaching B, it was pushed continuously up to C. On reaching D from C, its speed had become 4cm/s. It took 2 seconds for it to go from B to C. What is the acceleration of the ball as it goes from B to C?**


**7. Solve the following problems.**

(a) A force of 1000N was applied to stop a car that was moving with a constant velocity. The car stopped after moving through 10m. How much is the work done?

(b) A cart with mass 20 kg went 50m in a straight line on a plain and smooth road when a force of 2N was applied to it. How much work was done by the force?

**Project :**

Collect information about the study made by Sir Isaac Newton regarding force and acceleration and discuss it with your teacher.

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