## THE NEED TO MEASURE TIME

The need to measure time was felt by human beings a long time ago. In every civilization, however ancient, there has been evidence of people keeping track of time. In ancient times, people closely followed the movement of the sun, moon, and the stars. They notic... that once the sun rose in the morning, it would set after a considerable period. They coul... do many things from sunrise to sunset. This gave them a concept of 'time'. People kept track of the passage of time by keeping track of events that were repeated, such as sunris... the number of sunrises (days) between two full moons, the number of full moons betwe... two seasons, etc.

> **Fact File** C-8.1
>
> *The world's largest sundial is located in Jantar Mantar, Jaipur. It is called Virhat Samrat Yantra. This sundial is very accurate and we can read time to an accuracy of a few seconds.*

As the complexity of their lives increased, people felt the need to split the day into smaller periods. As civilizations grew, more ways of measuring time were devised. Today, we measure time for a variety of applications: we need to meet our clear-cut schedules, the doctor checks how many times our heart beats in one minute, we need to know when a train or plane will arrive, the amount of time a computer will take to perform an operation, and so on. The list is endless.

But how do we define time? The dictionary defines time as the period between two events. For example, sunrise and sunset can be taken as two events. Then the period between sunrise and sunset on a particular day would be the 'time' between the sunrise and sunset.

## MEASUREMENT OF TIME

In the beginning, people used calendars to keep a track of years, which were divided into months and days (not exactly what we use today, but something similar). Later, people started keeping track of the time of the day. They started building various instruments to divide the day into smaller parts. An instrument used to measure time is called a *clock*.

People used instruments such as *sundials* [Fig. 12.1(a)] and *hourglass* [Fig. 12.1(b)] to keep track of time. The movement of the shadow of a rod stuck upright in the ground, whose shadow changed direction with the movement of the sun across the sky, was used to make crude sundials. An hourglass consisted of two rounded glass bulbs connected by a narrow neck of glass. The top bulb was filled with sand and a measured amount of sand particles streamed down from the top bulb into the bottom bulb. The duration taken by sand to stream down from the top bulb into the bottom bulb gave the measure of time. An instrument known as *water clock* was also used in different parts of the world. It worked on the principle of regulated flow of water.

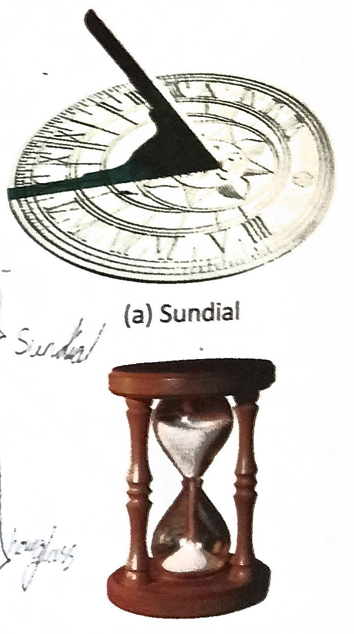



**Fig. 12.1** *Instruments used to measure time*

These devices were not very accurate and there was a need to improve accuracy and devise instruments that gave a better measurement of time. A major breakthrough came in 1656, when Christiaan Huygens made the first *pendulum clock*. It consisted of weights and a swinging pendulum. These clocks were much more reliable than the earlier ones.

**Tech Specs** C-5.1,6.1

A timer is a special type of clock. It is used to control the sequences of an event. It is used in traffic signals, appliances such as washing machines, and the highly explosive time bombs.

Another major advancement in timekeeping was the invention of the *atomic clock*, which is very accurate. Today, clocks do not just tell us the time of the day; they are also used as timers in ovens, in stopwatches, in various athletic events, etc. The SI unit of time is the *second*. Some other units of time are given in Table 12.1.

**Table 12.1** *Units of time*

| | |
|---|---|
| 60 seconds | 1 minute |
| 60 minutes | 1 hour |
| 24 hours | 1 day |
| 365¼ days | 1 year |
| 10 years | 1 decade |
| 10 decades | 1 century |
| 10 centuries | 1 millennium |

**Fact File** C-8.1 INDIA CONNECT

The National Physical Laboratory, an institute in New Delhi, maintains standard measurements (such as metre, kilogram, second, etc.) for our country. The national standard of time, the second, is maintained with the help of Caesium atomic clocks. These clocks are linked to clocks in other such institutes all over the world through satellites.

### Very Large and Very Small Time Scales

For various applications and research purposes, we need to measure time periods that are very large and also time periods that are very small.

We deal with very large time scales when we study the age of the Earth, Solar system, life cycles of stars and the age of the universe. These large time scales are measured in units such as petaseconds ($10^{15}$ s, i.e., 1000000000000000 s, which is 31.7 million years).

On the other hand, very small time scales are measured in units such as picoseconds ($10^{-12}$ s, i.e., 0.000000000001 s). This is one billionth of the time we take to blink!

**Know Your Scientist**

**Christiaan Huygens** was born in 1629 in Netherlands. He was from a wealthy and distinguished family and his father was a diplomat. He went on to become a very illustrious scientist. He made very important contributions in the fields of astronomy and light. His interest in astronomy led to his desire to constructing accurate clocks, and he invented the pendulum clock.

## Measurement of Time Using Periodic Motion

Any object that is moving is said to be in motion. In order to measure time, we need a motion that repeats itself in equal intervals. Such a motion is called *periodic motion*.

Some examples of periodic motion are the rotation of the Earth about its axis, the revolution of the Earth around the sun, the revolution of the moon around the Earth, the to-and-fro movement of a spring, and the oscillation of a pendulum. These types of periodic events are used to make clocks and calendars. Some of the first accurate clocks were based on the periodic movement of a pendulum.

### *Simple Pendulum*

*A setup that contains a small mass suspended from a fixed point and allowed to swing freely under the influence of gravity is called a* ***pendulum****.*

A ideal, simple pendulum consists of a small mass (like a stone or a metal ball) called a bob suspended by a string. See Figure 12.2.

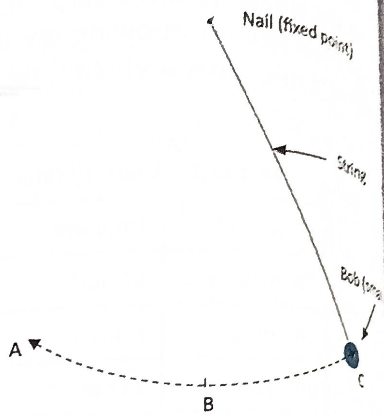



**Fig. 12.2** *A simple pendulum*

When the bob moves from one position and returns to the same position, it is said to complete one *oscillation*. *The time taken to complete one oscillation is called the* ***time period*** *of the pendulum*. It is measured in seconds. For example, if the bob starts from point A (Fig. 12.2), goes to points B and C, and returns to point A, it completes one oscillation.

**Fact File** C-6.1

Scientists have found that atoms and molecules of substances vibrate about a mean position. Some clocks (quartz clock) are also based on the oscillation of certain crystals such as quartz.

By studying the oscillations of a simple pendulum, the observations can be summarized as follows:

- The time taken by a pendulum to complete one oscillation (i.e., its time period) does not depend on the extent to which the bob of the pendulum is displaced.
- The time period does not depend on the mass of the bob used (within reasonable limits).
- The time period depends on the length of the string or wire used; greater the length of the string, greater is the time period (assuming that the string itself has negligible mass).

This means that if the length of the pendulum is fixed, its time period is constant. This was a wonderful discovery. Scientists began to build new clocks based on this property of the pendulum.

## Activity

C-6.2 SCIENTIFIC SKILLS EXPERIENTIAL LEARNING

**Aim:** To show the constancy of the time period of a pendulum

**Materials needed:** A string, a small stone, a doorknob/handle, and a stopwatch

## Let's Remember

**A. Write T for the True and F for the False statements. Correct the false statements.**

1. A sundial is used to measure sunrise and sunset. F
2. A ~~sand clock~~ atomic clock is the most accurate of all clocks. F
3. One century is equal to ~~ten years.~~ 100 decades F
4. The time period of a pendulum is dependent on the length of the string.

**B. Answer the following questions orally.**

1. Why do we need clocks? To measure time.
2. What is periodic motion? A motion that repeats itself
3. Name three units of time. Second, minute & hour
4. How many seconds are there in an hour? 3600 sec
5. What is the bob of a pendulum? Small ball

How fast or slow an object travels depend on the time it takes to travel a certain distance. It is closely related to the measurement of time. We will now discuss slow and fast motion and how we can measure it.

## SLOW AND FAST MOTION

C-2.1

Objects may travel fast or slow. For example, we may observe that an aeroplane travels very fast while a bicycle is slow. What, precisely, do we mean when we use the terms 'fast' and 'slow'?

When we say a body moves fast (or slow) we refer to its speed.

The ***speed** of an object is defined as the distance travelled by it in unit time.* The SI unit of speed is *metre per second* (m/s). Therefore, an object that moves faster covers more distance in a second (unit time) as compared to an object that moves slower.

We can calculate the speed of an object if we know the distance it travels in a given amount of time. Let us see how this is done.

In the above example, let us say it was a 100 m race. Shreya ran the race in 20 s. What is Shreya's speed? As speed is the distance travelled in unit time, Shreya's speed can be calculated by dividing the distance she ran by the time she took to cover that distance.

$$\text{Therefore, Shreya's speed is } = \frac{\text{Distance travelled}}{\text{Time taken to travel the distance}}$$

$$= \frac{100 \text{ m}}{20 \text{ s}} = 5 \text{ m/s}$$

Similarly, calculate the speed of Ronald, Sabina, and Kirit.

You will notice that, if the distance travelled is the same, the person who takes the shortest time to cover the distance runs the fastest.

Let us consider one more example.

**Example 1**

A school bus covers a distance of 7200 m in 1800 s. Calculate its speed.

*Solution*

We know that speed is given by the distance travelled divided by the time taken.

Given: Distance travelled by the bus = 7200 m

Time taken = 1800 s

$$\text{Speed} = \frac{\text{Distance travelled}}{\text{Time taken}}$$

$$= \frac{7200}{1800} = 4 \text{ m/s}$$

In practice, very few objects travel at a constant speed for long. Your school bus may speed up and slow down many times on the way to school. To estimate the speed in such cases, we use the concept of average speed. ***Average speed*** *is defined as the total distance travelled divided by the total time taken to travel that distance.*

INDIA CONNECT

**Case Study: Speed Detection Cameras**

You must have seen sign boards about speed limits on the roads, and big prominent billboards highlighting the dangers of speeding on roads. Speeding vehicles can cause serious injuries and even death of the passengers in the vehicle and also the pedestrians and other vehicles on the road. In order to discourage speeding, and to penalise and punish drivers for speeding, traffic police all over India have installed 'Speed Detection Cameras' at major roads and junctions. This move is intended to ensure safe driving and reduce the number of accidents and deaths on the Indian roads.

## Activity

C-6.2

**Aim:** To calculate the speed of a vehicle

**Materials needed:** A stopwatch or a wristwatch with a second hand, a notebook

**Note:** This activity requires a vehicle to be driven by an adult driver.

**Method:**

1. Make a table like the one below in your notebook.

| Starting km ($D_1$) | Finishing km ($D_2$) | Starting time ($t_1$) | Finishing time ($t_2$) | Distance km ($D_2$–$D_1$) | Time $t_2$–$t_1$ | Speed = [$D_2$–$D_1$/($t_2$–$t_1$)] |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |

2. Select a straight road that is not too crowded to go on a drive.
3. Note the starting kilometre reading from the odometer. Also note the starting time.
4. Let the vehicle move for some time, at a steady speed, as long as straight road and traffic permits. Note the finishing time and finishing distance.
5. At the end of the road, note the finishing time and the finishing distance.
6. Repeat steps 3, 4, and 5 for five or six runs.
7. At the end of the five or six runs, fill in the columns for ($D_2$–$D_1$) and ($t_2$–$t_1$). Calculate the speed for each run and fill in the last column.

### Different Units of Speed

Depending on the need and context, speed is measured in different units. As you already know, the SI unit of speed is metre per second (m/s). Other commonly used units are kilometre per hour (km/h) and miles per hour. When we talk about the speed of aeroplanes and cars, it would be more appropriate to use km/h than m/s.

Look at the typical speeds of some moving things given in Table 12.2 below. Find the speeds of the rest of them and fill in the vacant boxes.

**Table 12.2** *Typical speeds of common moving things*

| Moving thing | Speed | Moving thing | Speed |
|---|---|---|---|
| Elephant (Asian) | 40km/h | The Earth around the sun | 107,000 km/h |
| Shark (in the ocean) | 50 km/h | Rockets (to escape the Earth's gravity) | Over 40,000 km/h |
| Tortoise | 0.3 km/h | The moon around the Earth | 3683 km/h |
| Horse | 70 km/h | Speed of sound | 330 m/s |
| Snail | 0.05 km/h | Speed of light | $3 \times 10^8$ m/s |
| Leopard | 58 km/h | Car (average speed in the city) | 60 km/h |
| Reindeer | 80 km/h | Commercial airplane | 900 km/h |
| Migratory birds | 90 km/h | Supersonic fighter jets | 2500 km/h |
| World record for 100 m dash | 37.6 km/h | | |

necessary, ... the help of your teacher/PT teacher.

When a vehicle is moving, it is interesting to find out how fast it is moving. Have you seen a meter fitted inside a vehicle? In a car, the meter is fitted on the dashboard, and in scooters or motorcycles on the top. This is used to display the speed and distance travelled by the vehicle. *The instrument measuring the speed of the vehicle is called a* **speedometer** (Fig. 12.3). *The distance travelled by the vehicle is given by an instrument called* ***odometer*** (Fig. 12.3). Both of them are usually fitted together. These instruments will give the reading of speed and the distance travelled at the same time.

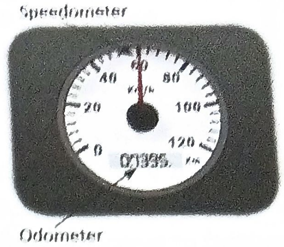



**Fig. 12.3** *Speed and distance travelled by the vehicle*

Speeding on the road is not something to feel proud of. It can lead to accidents. Please make sure that the person driving the vehicle does it within the safe speed limits appropriate for the road. This is essential for the safety of all the people travelling in the vehicle as well as for those using the road. Particular care must be taken to drive slowly close to schools, on winding roads and when visibility is poor. Standing still or going slowly in a speed lane can also be dangerous.

### *Speed in km/h*

Let us see how the speed of the school bus (given in Example 1) can be expressed in km/h.

Distance travelled by the bus = 7200 m

Distance travelled (in kilometres) = 7200 ÷ 1000

= 7.2 km

Time taken = 1800 s

Time (in hours) = 1800 ÷ 3600

= 0.5 h

Therefore, speed of the bus = $\frac{7.2}{0.5}$

= 14.4 km/h

**Fact File**

**Quick conversions**

*m/s to km/h*

If speed in m/s = M

speed in km/h = M x 18/5

*km/h to m/s*

If speed in km/h = K

Speed in m/s = K x 5/18

Now, express the speeds of all the moving things in Table 12.2 in the same unit and arrange them in ascending order of their speeds, in your notebook.

REMEMBERING UNDERSTANDING 21ST CENTURY SKILLS

## Let's Remember

**A. Fill in the blanks with the correct words.**

1. ________________ (Time/Speed) is the distance travelled by an object in unit time.
2. The SI unit of speed is ________________ (km/h, m/s).
3. ________________ (Hours per mile/Miles per hour) is a unit for speed.
4. An odometer is used to measure ________________ (speed/distance).

distance. Who runs faster?
2. After travelling in a car for an hour, Arun finds that he has travelled 65 km, while Varun has travelled 60km in the same time. Whose car was slower?
3. Which is faster—1km/s or 1m/s?

## DISTANCE AND TIME GRAPHS

Generally, a vehicle travelling on a road does not travel at a constant speed throughout its journey. If we note the distance travelled by the object at equal intervals of time (e.g., every second or every minute), we will get a clearer picture of its speed at different points of time. The data of the distance travelled and the time taken can be presented in many ways. One method would be to make a table. See Table 12.3. The information given in Table 12.3 can also be represented in a graph as shown in Figure 12.4.

**Table 12.3** *Tabular representation of distance travelled and time taken*

| Time (in min) | Distance (in km) |
|---|---|
| 2 | 2 |
| 4 | 4 |
| 6 | 6 |
| 8 | 7 |
| 10 | 8 |
| 12 | 9 |
| 14 | 9 |
| 16 | 9 |
| 18 | 9 |

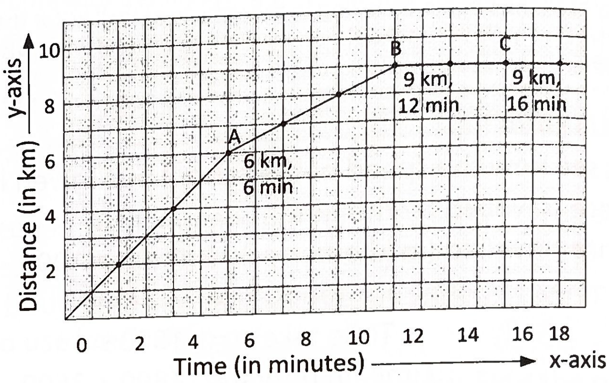



**Fig. 12.4** *Distance vs time graph*

This is called a *distance-time graph*. It is created by plotting a series of data points and connecting them to form a line. In Figure 12.4, we have taken time on the x-axis and the distance on the y-axis.

C-7.1

**Let's Discuss**

Why is it necessary to find the distance travelled every few seconds while making the distance-time graph?

We can get the following points by examining the distance–time graph:

1. The steepness of the slope of the graph gives the speed. If the slope is greater (i.e., if the slope is steeper as in line OA of Fig. 12.4), the speed is greater than the speed shown by line AB because its slope is flatter.
2. The speed is zero if the graph is flat (i.e., parallel to the 'time' axis) as in BC.

If we assume that the vehicle moves at constant speed, i.e., it covers the same distance in equal intervals of time, the data would be as shown in Table 12.4.

Now, if we plot a graph for this data, it will be as shown in Figure 12.5. The graph would be a steadily rising straight line. A motion that can be represented by a straight line as shown in Figure 12.5 is called 'uniform motion'. In other words, *a body is said to be in* ***uniform motion*** *if it covers equal distances in equal intervals of time.* The motion of a body as shown in Figure 12.4 is non-uniform as it does not cover equal distances in equal intervals of time.

**Table 12.4** *Tabular representation of distance travelled and time taken*

| Time (in min) | Distance (in km) |
|---|---|
| 2 | 2 |
| 4 | 4 |
| 6 | 6 |
| 8 | 8 |
| 10 | 10 |
| 12 | 12 |
| 14 | 14 |
| 16 | 16 |
| 18 | 18 |

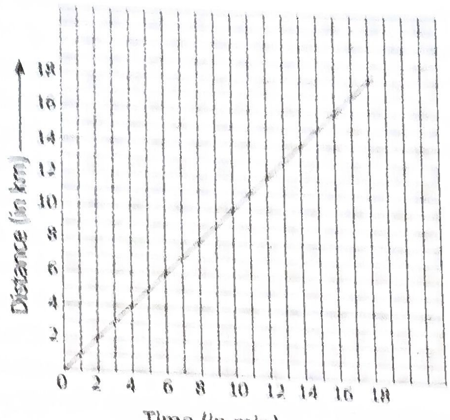
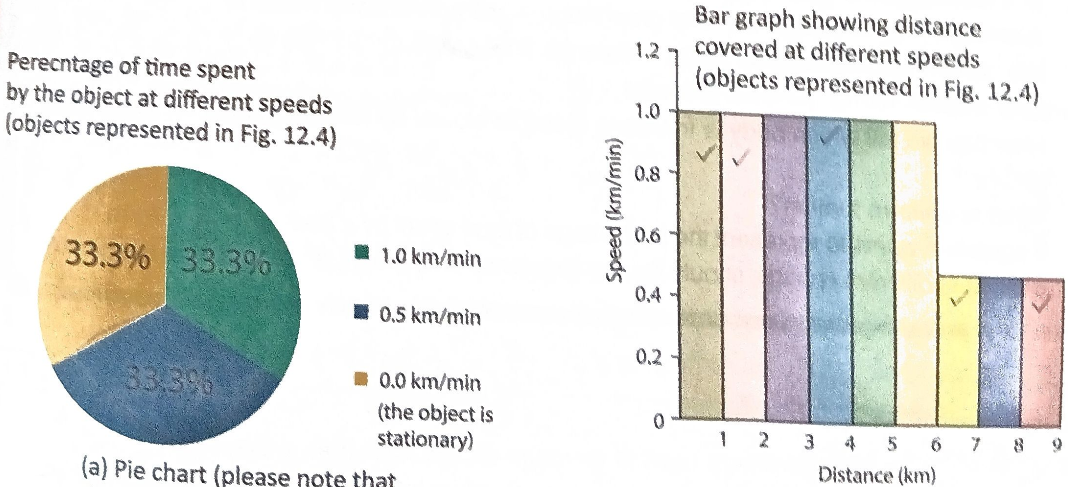



**Fig. 12.5** *Distance vs time graph*

The motion of an object can be analyzed in many different ways. Let us consider the motion of the object represented in Fig. 12.4 again. The graph shows that the object travels at different speeds over time. Now, if we want to find out the fraction (or percentage) of the time for which it travelled at these speeds, we could use a pie chart [Fig. 12.6 (a)]. Another point of view of the motion of the object represented in Figure 12.4 is to study the distance travelled by the object at different speeds. This can be represented in a bar graph [Fig. 12.6 (b)].




(a) Pie chart (please note that these are approximate values)

(b) Bar graph (please note that these are approximate values)

**Fig. 12.6** *Commonly used charts*

**Note:** When we try to locate an object, we usually relate it to some sort of reference point. This point is usually the origin, the zero point of an axis ($x$ or $y$). We provide a numeric value for an object's location by placing it either in the positive direction (+) or the negative direction (–) in relation to that reference point. We usually take the starting point as the origin ($x = 0$).

## Activity

C-6.2

**Aim:** To plot the distance vs time graphs for uniform motion

**Materials needed:** Graph paper and pencil

**Method:**

1. Take the speed at which the body moves as 10 m/s.
2. Calculate the distance travelled by the body at the end of 1, 2, 3, etc. (i.e., every second).
3. Take time on the x-axis and distance travelled on the y-axis.
4. Plot the distance vs time graph on a centimetre graph sheet taking 1 cm = 1 s.
5. Repeat steps 2–4 for a speed of 50 m/s and 5 m/s on the same graph sheet.
6. Observe the graphs obtained for different speeds.

**Observation:** A straight line graph is obtained.

**Conclusion:** The body is in uniform motion.

## Key Words

| | |
|---|---|
| **Clock** | An instrument used to measure time is known as a clock. |
| **Periodic motion** | The motion that repeats itself in equal intervals of time is called periodic motion. |

| | |
|---|---|
| **Pendulum** | A small mass that is suspended from a fixed point and allowed to swing freely under the influence of gravity is called a pendulum. |
| **Time period** | The time taken by an oscillating body to complete one oscillation is called its time period. |
| **Speed** | The distance travelled by an object in unit time is called speed. |
| **Speedometer** | The instrument used to measure speed of the vehicle is called speedometer. |
| **Odometer** | The distance travelled by a vehicle is given by an instrument called odometer. |
| **Distance–time graph** | A graph representing the distance travelled and the time taken is known as distance–time graph. |
| **Uniform motion** | A motion by which a body covers equal distances in equal intervals of time is called uniform motion. |

## Summary

- Time is defined as the period between two events. It is measured for a variety of applications.
- People have been using clocks for thousands of years, but the earlier clocks were neither as convenient nor as precise in their timekeeping as the ones used today.
- Some instruments used in ancient times for timekeeping were sundials, water clocks, and hourglasses.
- A pendulum consists of a small mass suspended from a fixed point and allowed to move freely.
- When the bob of a pendulum moves from one position and returns to the same position, it is said to have completed one oscillation.
- The time taken to complete one oscillation is called the time period of the pendulum.
- The time period of a pendulum depends only on the length of the pendulum used (within limits).
- The data of the distance travelled can be presented in many ways, e.g., in a tabular form or by plotting distance vs time graphs.