

# Understanding Motion Through Experience

Reflect on the following:

- Why do we feel pushed backward when a bus suddenly starts moving?
- Can an object be at rest for one observer but moving for another?
- How do athletes decide the best angle to throw a ball so that it travels the maximum distance?
- Can we measure motion using simple tools available in the classroom?

Discuss your ideas with classmates before beginning the activities.

## 2.1 What is Motion?

An object is said to be in motion if its position changes with time with respect to a reference point. Motion can be slow or fast, straight or curved, uniform or non-uniform. Understanding motion becomes easier when we observe it directly and measure it ourselves.

### Activity 2.1: Let's observe

**Materials:** Notebook, stopwatch (mobile timer), measuring tape

#### Steps:

1. Mark two points 5 meters apart in the classroom corridor or playground.
2. Ask one student to walk normally from one point to another while another student measures the time taken using a stopwatch.
3. Repeat the experiment with the student running.
4. Record the distance and time in a table.

**Observation:** - Compare the time taken for walking and running. - Which motion is faster? How can you calculate speed?

Can motion be described using measurable quantities such as distance and time?

## 2.2 Frame of Reference

A frame of reference that is at rest or moving with constant velocity is called an inertial frame. Newton's laws hold without modification in such frames. A frame that is accelerating is called a non-inertial frame, and we will see in later sections that special corrections (pseudo forces) become necessary in such frames.

To describe the state of motion of an object, we must specify a reference point. Without it, we cannot say whether an object is moving or at rest.



### Activity 2.2: Motion is Relative

**Materials:** Two students as props

**Steps:**

1. Let one student stand still while another walks past him.
2. Ask each student to describe the motion of the other student.
3. Now let both students walk in the same direction with the same speed and describe the motion again.

**Discussion:** - When both students walk together at the same speed, they appear at rest relative to each other but moving relative to the classroom.

### 2.3. Scalars and Vectors

Physical quantities are of two types: -

**Scalars:** Quantities having magnitude only (distance, time, mass, speed and work)

**Vectors:** Quantities having both magnitude and direction (displacement, velocity, force).

### Activity 2.3: Direction Matters

**Materials:** Chalk, measuring tape

**Steps:**

1. Draw a straight 5-metre line on the ground and mark the starting point as A and the end as B.
2. Walk from A to B and note the distance covered.
3. Next walk from A to B and then back to A.
4. Compare the distance travelled and displacement.

**Observation:** - Distance changes but displacement becomes zero when returning to the starting point.

### 2.4 Vector Addition (Graphical Method)

**Vectors** are physical quantities that have both magnitude and direction, such as displacement, velocity, and force. When two or more vectors act together, we combine them to find a single vector called the **resultant**. This process is known as **vector addition**. Vectors can be added graphically using methods like the **triangle method** or the **parallelogram method**.



### Activity 2.4: Graphical Addition of Displacements

**Materials:** Graph paper, ruler, pencil

**Steps:**

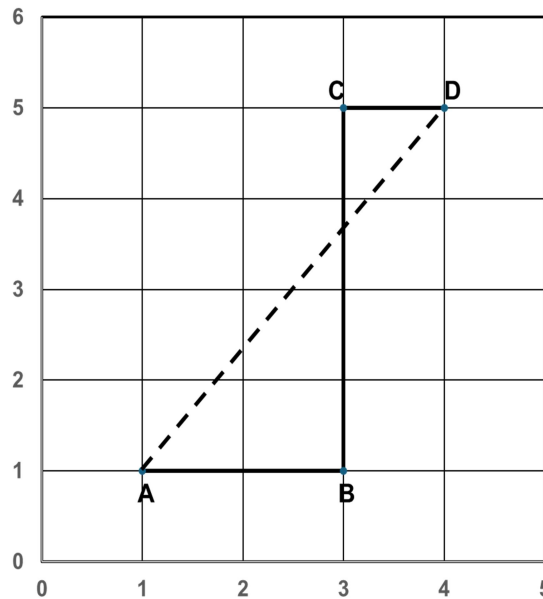
1. On graph paper, draw a vector representing 4 units towards the east.
2. From the head (end) of this vector, draw another vector representing 3 units towards the north.
3. Now join the tail (starting point) of the first vector to the head of the second vector.

**Observation:**

The line joining the starting point to the final point represents the **resultant displacement**.

This is how two vectors can be combined graphically to find a resultant vector, and how both magnitude and direction are important in describing motion.

**Practice Question:**



Points A at (1,1), B at (3,1), C at (3,5) and D at (4,5) (All the values mentioned in the graph are in km) represent Sita's House, bus stop, traffic signal and school respectively. In the morning Sita travels from A to B on foot, then B to D via C in the school bus. (All the values mentioned in graph are in km) Then calculate:

- (a) Distance traveled by Sita on foot,
- (b) Distance traveled by Sita by the school bus,
- (c) Total displacement of Sita from her house to the school.



## 2.5. Equations of Motion

When an object moves with constant acceleration, its motion can be described using equations which are given as:

$$V = u + at$$

$$S = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

where,  $u$  is initial velocity,  $v$  is final velocity,  $a$  is acceleration, and  $s$  is displacement.

### Activity 2.5: Observing Accelerated Motion Using a Toy Car

**Materials:** Toy car (or small wheeled object), smooth floor, measuring tape, stopwatch (mobile timer), chalk/tape

#### Steps:

1. Mark a straight line on the floor and label the starting point as O.
2. Place the toy car at point O and give it a gentle push so that it moves forward.
3. Use a stopwatch and note the position of the car at equal time intervals (every 1 second).
4. Mark these positions on the floor using chalk or tape.
5. Measure the distance from the starting point to each marked position and record it in a table.

**Observation:** The distance travelled in successive intervals increases, showing acceleration.

#### Conclusion:

The motion is **accelerated motion**, as the velocity increases with time.

#### 4<sup>th</sup> equation of motion distance travelled in the $n^{\text{th}}$ second

From the **second equation of motion**:

$$s = ut + \frac{1}{2}at^2$$

where,

$u$  = initial velocity

$a$  = acceleration

$t$  = time

$s$  = displacement in time  $t$



### Distance travelled in $n$ seconds

$$s_n = u(n) + \frac{1}{2}an^2$$

### Distance travelled in (1) second

$$s_{n-1} = u(n-1) + \frac{1}{2}a(n-1)^2$$

### Distance travelled in the $n^{\text{th}}$ second

$$\text{distance in } n^{\text{th}} \text{ second} = s_n - s_{n-1} = \left[ \frac{1}{2}an^2 \right] - \left[ u(n-1) + \frac{1}{2}a(n-1)^2 \right]$$

Solving:

$$= un + \frac{1}{2}an^2 - un + u - \frac{1}{2}a(n^2 - 2n + 1) = u + \frac{1}{2}a[2n - 1]$$

### Final Formula

$$s_n = u + \frac{a}{2}(2n - 1)$$

This is the distance travelled in the  $n^{\text{th}}$  second, often called the fourth equation of motion. Here  $n$  must be a positive integer representing the  $n^{\text{th}}$  second of motion. The formula gives the displacement specifically during that one-second interval, not a cumulative displacement.

## 2.6 Reflect and Discuss

- Why is specifying a reference frame necessary to describe motion?
- How do direction and magnitude together describe displacement?
- Which daily activities around you involve accelerated motion?

## 2.7 Project-Based Learning

Design a simple experiment using everyday materials to measure the speed of a moving object (using a bicycle, or a walking student). Present your method, observations, calculations, and conclusions to the class.

### Check Your Understanding

1. Define a frame of reference in your own words.
2. Give two real-life examples where motion depends on the observer.
3. Why does a person sitting in a moving train appear at rest to another passenger?
4. Classify the following as scalar or vector quantities: speed, velocity, displacement, distance, acceleration and mass.



5. Explain the difference between distance and displacement with an activity diagram.
6. Give two everyday examples of vector quantities.
7. Draw two vectors of 4 units east and 3 units north and find the resultant using the triangle method.
8. Explain how vector subtraction is performed graphically.
9. Draw two opposite vectors of equal magnitude. Calculate its resultant.
10. A body starts from rest and accelerates at  $4 \text{ m/s}^2$ . Find the distance travelled in the 6th second.
11. A car with initial velocity  $8 \text{ m/s}$  accelerates at  $2 \text{ m/s}^2$ . Find the distance covered in the 5th second.

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