Chapter 1: Scientific learning

Introduction

In this chapter, we explore how scientists study nature using experiments, logic, and measurements. We'll also learn about variables, their types, and how we measure physical quantities using units. Let's get started,

Scientific study

Science is the logical and systematic study of the natural world. It includes facts, theories, models, and experiments. Scientists investigate the causes and effects of natural events using scientific methods and measurable evidence.

When we see something happening in nature, like a plant wilting, we get curious. Why did it wilt? Was it due to lack of water, too much sunlight? That curiosity is the starting point of scientific investigation.

By testing different conditions like watering the plant or moving it to the shade, we find out what caused the change. This helps us predict what might happen in the future under similar circumstances.

What are variables in science?

A variable is any factor, trait, or condition that can change or be changed.
For example, in the catapult experiment, using a rubber band:

- You chain how much the rubber band is stretched.
- You observe how far the paper bullet travels.

Both of these, the stretch and the distance, are variables.

A variable is any physical quantity whose value can vary. These are essential to understanding cause and effect in science.

Types of variables

Variables in experiments are classified into three main types.

1. Independent variable:

This is the variable that you change deliberately in an experiment. It is the cause. In our rubber band catapult experiment, the amount of stretch is the independent variable. You decide how far to stretch the band. 4 cm, 6 cm, 8 cm, or 10 cm.

More examples:

- Amount of sunlight in a plant growth experiment.
- Time of exercise in a heartbeat experiment.

2. Dependent variable

This is the variable you measure or observe. It is the effect and it depends on the independent variable. In the catapult example, the distance travelled by the paper bullet is the dependent variable. It changes depending on how far the band was stretched.

More examples:
- Growth of the plant depending on sunlight
- Heartbeat after exercise depending on duration

Controlled Variables

These are all the other variables that must be kept constant throughout the experiment to keep the test fair and results valid. In the catapult experiment, you must keep the thickness of the rubber band and the size of the paper bullet the same in every trial. If you change too many things at once, it becomes impossible to know what caused the change in the result. That's why we control everything else except the independent and dependent variables.

Examples of controlled variables in other experiments:
- Water, air, and fertilizer in a plant experiment
- Type of exercise in a heartbeat experiment

Important rules:

1. Use only one independent variable.
2. Have one dependent variable.
3. Control all other variables for accuracy.

Representing Variables Mathematically

Each variable is usually given a symbol to make writing easier. For example:
- Stretch of the rubber band = **e**
- Distance travelled by the paper bullet = **x**

If there's a direct relation, we may write it as:

$$\mathbf{x} \propto \mathbf{e}$$

This shows that x (distance) increases as e (stretch) increases.
In equations, we write:
- Dependent variable on the left
- Independent variable on the right

For example:

$$\mathbf{s} = \mathbf{v} \times \mathbf{t}$$

Here, **s** is distance (dependent), **t** is time (independent), and **v** is speed (controlled).

Also, when we draw graphs:
- Dependent variable → Y-axis (vertical)
- Independent variable → X-axis (horizontal)

1.2 Units in Scientific Measurement

To measure anything in science, we use units. A unit gives us a standard way to express physical quantities like mass, length, time, temperature, etc.

There are **two main types of units:**

1. Fundamental Units

These are the basic units that are not made by combining other units.
There are **7 SI (International System) fundamental units:**

Quantity	**Unit**	**Symbol**
Length	metre	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin	K
Electric current	ampere	A
Luminous intensity	candela	cd
Amount of substance	mole	mol

Derived Units

These are formed by combining fundamental units. They are used for more complex physical quantities.
Examples:

Quantity	**Formula**	**Unit**
Speed	distance/time	m/s
Force	mass × acceleration	$kg \cdot m/s^2 = N$
Pressure	force/area	N/m2 = Pa
Work	force × distance	$kg \cdot m^2/s^2 = J$
Power	work/time	$kg \cdot m^2/s^3 = W$
Frequency	1/time	1/s = Hz

To find out the composition of any derived unit, break down its formula.
Example:

- Force: F = m × a
  Units: kg × m/s2 = N (newton)
- Area: length × breadth = m × m = m^2

Unit Analysis: Validating Equations

Unit analysis is used to check if an equation is dimensionally correct.
Let's test this with an example:
Equation: **s = v × t**

- s (distance) → m
- v (speed) → m/s
- t (time) → s

Units: m = m/s × s = m → (VALID)

But what about: $s = v / t$
● Units: $m = m/s \div s = m/s2$ → (INVALID)

Only quantities with the same units can be added or subtracted.
Example:

- $u + v$ → valid (both in m/s)
- $s + at$ → invalid ($s = m$, $at = m/s$)