

Module 13: Pressure and Gas Laws (SCI 2500)

Introduction

Gases behave differently from solids and liquids. Gas particles move freely and occupy the entire volume of their container.

Because gases are constantly moving, they exert forces on the surfaces they contact. These forces create pressure.

Understanding pressure and gas behavior is important in many scientific and practical applications, including:

- respiration in the human body
- weather systems
- medical equipment
- industrial processes

In this module we will examine how pressure is defined and how the behavior of gases can be described mathematically.

Pressure

Pressure describes the amount of force applied over a certain area.

The equation for pressure is:

$$P = F / A$$

where:

P = pressure

F = force

A = area

Pressure increases when force increases, and pressure decreases when the same force is spread over a larger area.

Example of Pressure

Imagine standing on snow while wearing regular shoes. Your feet sink into the snow because your weight is concentrated on a relatively small area.

Now imagine wearing snowshoes. The same weight is distributed over a larger area, so the pressure on the snow decreases and you sink less.

This example illustrates how increasing area reduces pressure.

Units of Pressure

Pressure can be measured in several different units.

Common units include:

Unit	Description
Pascal (Pa)	SI unit of pressure
Atmosphere (atm)	average atmospheric pressure
millimeters of mercury (mmHg)	used in medicine
kilopascal (kPa)	common in science

Standard atmospheric pressure at sea level is approximately:

$$1 \text{ atm} = 101,325 \text{ Pa}$$

Pressure in Fluids

Gases and liquids are classified as fluids because they can flow.

Fluids exert pressure in all directions.

In the atmosphere, air pressure results from the weight of the air above us.

As altitude increases, atmospheric pressure decreases because there is less air above.

This is why breathing becomes more difficult at very high elevations.

Gas Behavior

The behavior of gases depends on several variables:

- pressure (P)
- volume (V)
- temperature (T)
- amount of gas (n)

Scientists have discovered mathematical relationships that describe how these variables interact.

These relationships are known as gas laws.

Boyle's Law

Boyle's Law describes the relationship between pressure and volume when temperature is constant.

Boyle's Law states:

Pressure and volume are inversely related.

Mathematically:

$$P_1V_1 = P_2V_2$$

This means that when volume decreases, pressure increases.

Example

A gas has a volume of 4 liters at a pressure of 2 atm.

If the pressure increases to 4 atm, what is the new volume?

Use Boyle's Law:

$$P_1V_1 = P_2V_2$$

Substitute values:

$$(2)(4) = (4)(V_2)$$

$$8 = 4V_2$$

$$V_2 = 2 \text{ liters}$$

The new volume is 2 liters.

Charles's Law

Charles's Law describes how volume changes with temperature when pressure remains constant.

Charles's Law states:

Volume is directly proportional to temperature.

Mathematically:

$$V_1 / T_1 = V_2 / T_2$$

Temperature must be measured in Kelvin.

Example

A gas has a volume of 2 liters at 300 K.

If the temperature increases to 450 K, what is the new volume?

Use Charles's Law:

$$V_1 / T_1 = V_2 / T_2$$

$$2 / 300 = V_2 / 450$$

Solve for V_2 :

$$V_2 = 3 \text{ liters}$$

The gas expands as temperature increases.

The Ideal Gas Law

The most comprehensive equation describing gas behavior is the Ideal Gas Law.

$$PV = nRT$$

where:

P = pressure

V = volume

n = number of moles of gas

R = gas constant

T = temperature (Kelvin)

This equation combines several gas relationships into one formula.

Example Using the Ideal Gas Law

Suppose we have:

n = 1 mole of gas

T = 300 K

R = 0.0821 L·atm/mol·K

V = 10 L

Find the pressure.

Use:

$$PV = nRT$$

Solve for P:

$$P = nRT / V$$

Substitute values:

$$P = (1)(0.0821)(300) / 10$$

$$P \approx 2.46 \text{ atm}$$

Applications of Gas Laws

Gas laws help explain many natural and technological systems.

Examples include:

- breathing in the lungs
- scuba diving pressure changes
- weather balloon expansion
- internal combustion engines

Understanding gas behavior allows scientists and engineers to predict how gases will respond to changing conditions.

Practice Questions

1. What is the equation for pressure?
2. What happens to pressure when the same force is applied over a larger area?
3. State Boyle's Law.
4. State Charles's Law.
5. What variables appear in the Ideal Gas Law?

Calculation Practice

1. A gas has pressure 3 atm and volume 6 L.
If the pressure increases to 6 atm, find the new volume.
2. A gas has volume 4 L at 300 K.
Find the new volume at 450 K.
3. Using the Ideal Gas Law, calculate the pressure of 1 mole of gas at 273 K in a volume of 22.4 L.

Challenge Problems

1. Why must temperature be measured in Kelvin when using gas laws?
2. Explain why a balloon expands as it rises in the atmosphere.
3. Describe how pressure changes affect scuba divers underwater.