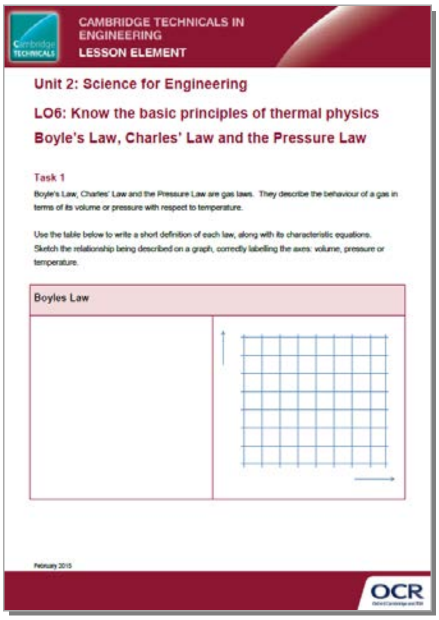
Unit 2: Science for Engineering

LO6: Know the basic principles of thermal physics

Boyle's Law, Charles' Law and the Pressure Law

Instructions and answers for teachers

These instructions should accompany the OCR resource '*Boyle's Law, Charles' Law and the Pressure Law*' activity *which supports OCR Level 3 Cambridge Technicals in Engineering Level 3.*


CAMBRIDGE TECHNICALS IN ENGINEERING
LESSON ELEMENT

Unit 2: Science for Engineering

LO6: Know the basic principles of thermal physics

Boyle's Law, Charles' Law and the Pressure Law

Task 1

Boyle's Law, Charles' Law and the Pressure Law are gas laws. They describe the behaviour of a gas in terms of its volume or pressure with respect to temperature.

Use the table below to write a short definition of each law, along with its characteristic equations. Sketch the relationship being described on a graph, correctly labelling the axes: volume, pressure or temperature.

Boyles Law	

The Activity:

In this activity the learners are tasked to investigate Boyle's Law, Charles' Law and the Pressure Law.

This activity offers an opportunity for English skills development.

This activity offers an opportunity for maths skills development.

Suggested timings:

2 hours

Activity 1

In Activity 1, learners are tasked to investigate Boyle's Law, Charles' Law and the Pressure Law. This activity might be undertaken as a research task or as part of a class lesson. Teachers might use worked problem examples to illustrate each of the gas laws.

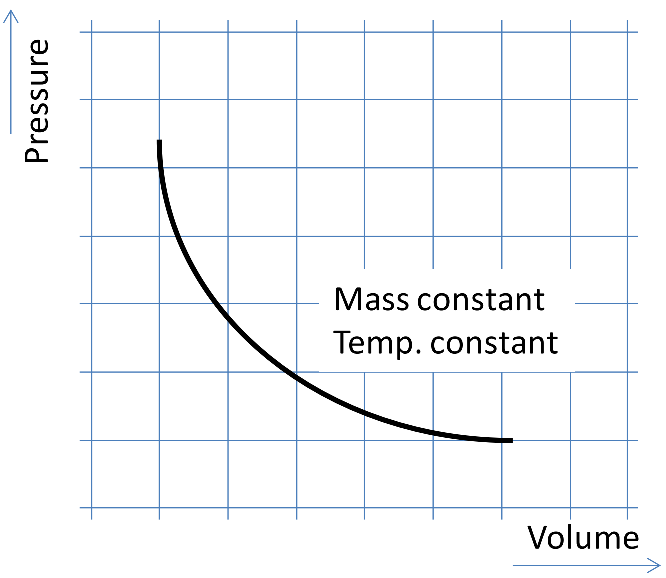
Boyle's Law

Boyle's Law states that for a fixed mass of gas at constant temperature the pressure is inversely proportional to the volume.

$$pV = C$$

where p is the pressure of the gas, V is the volume of the gas and C is a constant

$$p_1V_1 = p_2V_2$$



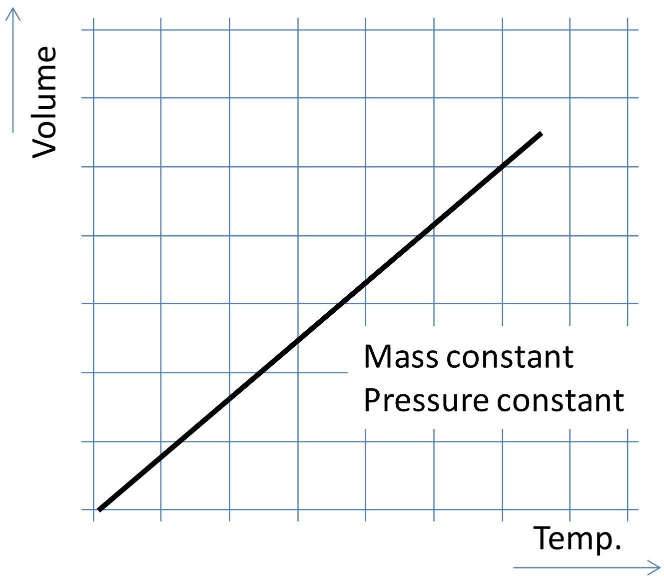
Charles' Law

Charles' Law states that for a fixed mass of gas at constant pressure, the volume is directly proportional to the temperature.

$V/T = C$

where V is the volume of the gas, T is temperature and C is a constant

$V_1/T_1 = V_2/T_2$



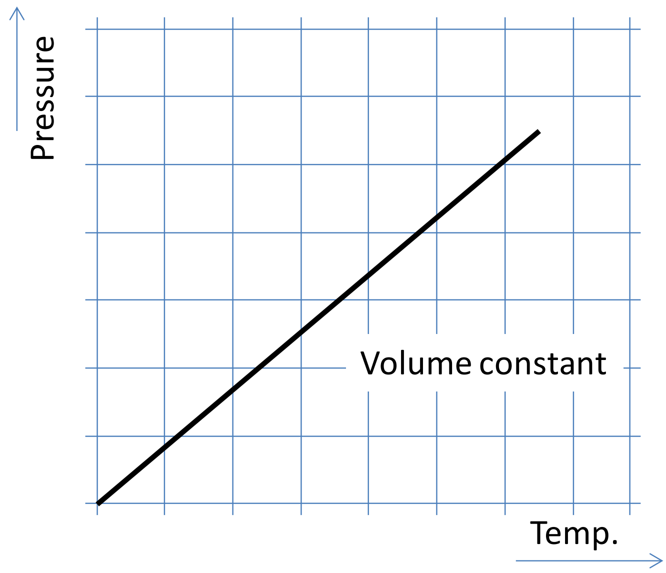
Pressure Law

Pressure Law states that for a fixed mass of gas at constant volume, the pressure is directly proportional to the temperature.

$p/T = C$

where p is the pressure, T is temperature and C is a constant

$p_1/T_1 = p_2/T_2$



Activity 2

Solution to Problems 1 to 6 is given below. Learners will need to be reminded to convert temperatures to degrees kelvin. Teachers may develop further problems for learners to solve.

Problem 1 requires the use of standard pressure (760.0 mmHg) and Problem 2 the use of standard temperature (0 °C or 273 K).

Problem 1
2 litres of a gas is at 740.0 mmHg pressure. What is its volume at standard pressure? (Boyle's Law)
Solution to Problem 1
This problem is solved by using Boyle's Law: $p^1V^1 = p^2V^2$ Learners will need to know that the value for standard pressure is 760.0 mmHg Use Boyle's Law: $(740.0 \text{ mmHg})\ (2.00 \text{ L}) = (760.0 \text{ mmHg})\ V_2$ Solve for $V_2 = [(740.0 \text{ mmHg})\ (2.00 \text{ L})]\ /\ (760.0 \text{ mmHg}) = \mathbf{1.947\ L}$

Problem 2
A 2.5 litre sample of gas is at standard temperature. When the temperature is raised to 273 °C and the pressure remains constant, what is the new volume? (Charles' Law)
Solution to Problem 2
This problem is solved using Charles' Law: $V^1/T^1 = V^2/T^2$ Learners will need to know that standard temperature is 0 °C or 273 K Convert 273 °C to kelvin = $273\ °\text{C} + 273\ °\text{C} = 546\ \text{K}$ Use Charles' Law: $2.5\ \text{L}\ /\ 273\ \text{K} = V_2\ /\ 546\ \text{K}$ Solve for $V_2 = (2.5\ \text{L x } 546\ \text{K})\ /\ 273\ \text{K} = \mathbf{5.0\ L}$

Problem 3
4.40 litres of a gas is collected at 50.0 °C. What will be its volume upon cooling to 25.0 °C? (Charles' Law)
Solution to Problem 3
Comment: 2.20 L is the wrong answer. Sometimes a student will look at the temperature being cut in half and reason that the volume must also be cut in half. That would be true if the temperature was in degrees kelvin. This problem is solved using Charles' Law: $V_1/T_1 = V_2/T_2$ Convert 50.0 °C to kelvin = $50.0\ °C + 273\ °C = 323\ K$ Convert 25.0 °C to kelvin = $25.0\ °C + 273\ °C = 298\ K$ Use Charles' Law: $V_1/T_1 = V_2/T_2$ $4.40\ L\ /\ 323\ K = V_2\ /\ 298\ K$ Solve for $V_2 = (4.40\ L \times 298\ K)\ /\ 323\ K = \mathbf{4.06\ L}$

Problem 4
A sealed syringe contains $10 \times 10^{-6}\ m^3$ of air at $1 \times 10^5\ Pa$. The plunger is pushed until the volume of trapped air is $4 \times 10^{-6}\ m^3$. If there is no change in temperature, what is the new pressure of the gas? (Boyle's Law)
Solution to Problem 4
This problem is solved by using Boyle's Law: $p_1V_1 = p_2V_2$ Use Boyle's Law: $(1 \times 10^5)\ (10 \times 10^{-6}) = p_2\ (4 \times 10^{-6})$ Solve for $p_2 = (1 \times 10^5)\ (10 \times 10^{-6})\ /\ (4 \times 10^{-6})$ $p_2 = \mathbf{2.5 \times 10^5\ Pa}$

Problem 5

In a sealed cylinder, the pressure of gas is recorded as 1.0×10^5 Nm-2 at a temperature of 0°C. The cylinder is heated further till the thermometer records 150°C. What is the pressure of the gas in pascals (Pa)?
(Pressure Law)

Solution to Problem 5

This problem is solved using the Pressure Law: $p_1/T_1 = p_2/T_2$

Convert 0 °C to kelvin = $0\,°C + 273\,°C = 273\,K$

Convert 150 °C to kelvin = $150\,°C + 273\,°C = 423\,K$

Use Pressure Law: $(1.0x10^5) / 273\,K = p_2 / 423\,K$

Solve for p_2 = $(1.0x10^5)\ (423\,K) / 273\,K =$ **$1.54x10^5\,Nm^{-2}$**

Convert answer to pascals (Pa): $1\,Nm^{-2} = 1\,Pa = 1.54x10^5\,Pa$

Problem 6

A car tyre contains air at 28 psi (pounds per square inch) when at a temperature of 10°C. Once the car has been running for a while the temperature of the air in the tyre rises by 40°C. If the volume of the tyre does not change what is the new pressure of the air in the tyre (present your answer in both psi and pascals)?
(Pressure Law)

Solution to Problem 6

This problem is solved using the Pressure Law: $p_1/T_1 = p_2/T_2$

Convert temperatures to degrees kelvin.

Convert 10 °C to kelvin = $10\,°C + 273\,°C = 283K$

Convert 50 °C to kelvin = $50\,°C + 273\,°C = 323\,K$

Use Pressure Law: $(28\,psi) / 283\,K = p2 / 323\,K$

Solve for $p_2 = (28\,psi)\,(323\,K) / 283\,K =$ **$32\,psi$**

Learners will need to know the conversion factor for psi to pascals.

Convert psi to pascal: (1 psi = 6 894.75729 pascals): 32 psi x 6894.75729
= **220632.2333 Pa (220.6 kPa)**

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