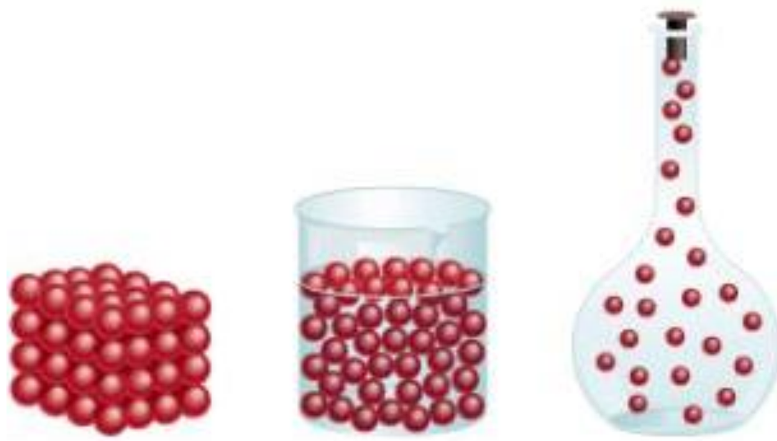
IGCSE Physics



Unit 3 – Solids, Liquids and Gases

Name: ……………………………………………………………

Class: ………… **Date:**……………………………

Summary

This topic looks at the particle theory of matter and how the movement of the particles determines the structure and properties of the substance. Density is determined by the mass of the particles and how tightly packed they are. The pressure of the substance is governed by the density, area and applied forces (usually gravity). We spend a great deal of time investigating the properties of gases – leading on to the famous and very useful gas laws. There are a lot of equations to learn in this topic!

Lesson	Objectives : Students will be assessed on their ability to
Density	• recall and use the relationship between density, mass and volume : $\rho = \frac{m}{V}$ • describe how to determine density using direct measurements of mass and volume
Pressure	• recall and use the relationship between pressure, force and area: $P = \frac{F}{A}$
Pressure in Fluids	• understand that the pressure at a point in a gas or liquid which is at rest acts equally in all directions • recall and use the relationship for pressure difference: $\Delta P = \rho g h$
States of Matter	• understand that a substance can change state from solid to liquid by the process of melting • understand that a substance can change state from liquid to gas by the process of evaporation or boiling • recall that particles in a liquid have a random motion within a close-packed structure • recall that particles in a solid vibrate about fixed positions within a close-packed regular structure
Specific Heat Capacity	• know that specific heat capacity is the energy required to change the temperature of 1 kg of mass by 1 °C • Be able to use the equation: $E = mc\Delta T$
Kinetic Theory	• understand the significance of Brownian motion • recall that molecules in a gas have a random motion and that they exert a force and hence a pressure on the walls of the container • understand that there is an absolute zero of temperature which is – 273 °C • describe the kelvin scale of temperature and be able to convert between the Kelvin and Celsius scales
Gas Laws: The Pressure Law	• understand that an increase in temperature results in an increase in the speed of gas molecules • understand that the Kelvin temperature of the gas is proportional to the average kinetic energy of its molecules • describe the qualitative relationship between pressure and kelvin temperature for a gas in a sealed container • use the relationship between the pressure and Kelvin temperature of a fixed mass of gas at constant volume: $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

Gas Laws: Boyle's Law	• use the relationship between pressure and volume of a fixed mass of gas at constant temperature $$P_1V_1 = P_2V_2$$
Gas Laws: Charles' Law	• describe the qualitative relationship between volume and kelvin temperature for a gas in a container that is free to expand or contract • use the relationship between the Volume and Kelvin temperature of a fixed mass of gas at constant pressure: $$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$
Gas Laws: Universal Law	• use the combined gas law relationship between the volume, pressure and Kelvin temperature of a fixed mass of gas: $$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

1 - Density

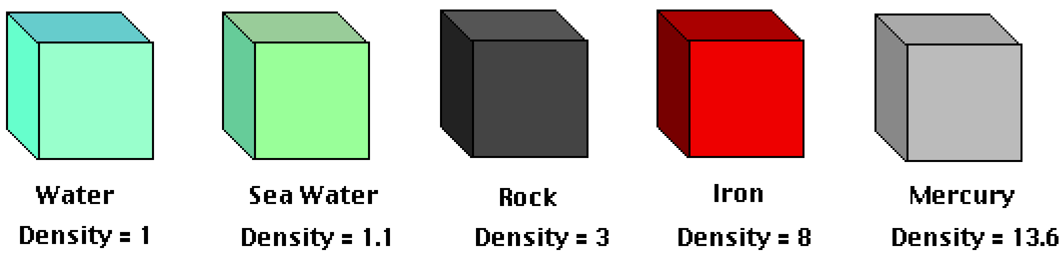
Objectives:

- recall and use the relationship between density, mass and volume :

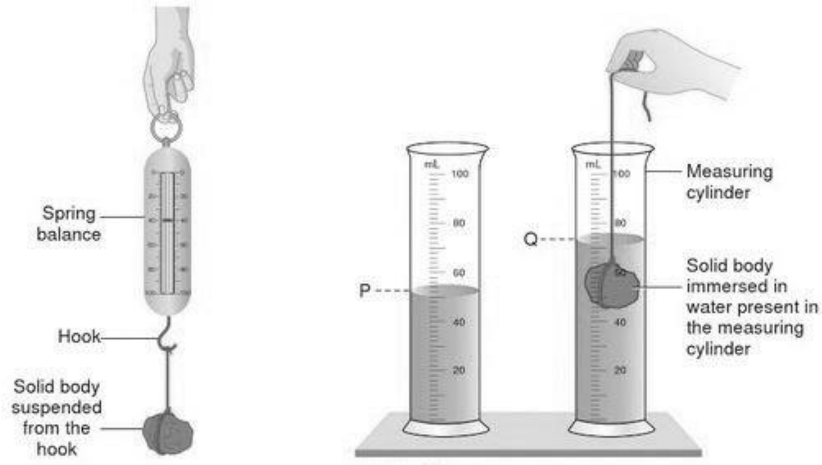
  Density = Mass / Volume

- describe how to determine density using direct measurements of mass and volume

Notes:



$$\rho = \frac{m}{V}$$


Spring balance
Hook
Solid body suspended from the hook
Measuring cylinder
Solid body immersed in water present in the measuring cylinder
P
Q
mL
100
80
60
40
20

LAB 3.1 – Measuring Density

Objective:

To calculate the mass, volume, and densities of both regular and irregular shaped objects.

Method:

To determine the density, one must measure both the mass and the volume of the object. Mass is easy – just weight it on a balance!

- To measure the volume of a regular object is easy, just multiply the length by the width by the height.
- To measure the volume of a liquid is easy – use a measuring cylinder.
- It is more problematic to measure the volume of an irregular object. The best way is to measure the volume of water that it displaces. This can either be in a measuring cylinder or using a Eureka Can.

Diagram (4):

Data and Observations (2):

Material	Mass (g)	Volume (cm^3)	Density (g/cm^3)	Comment
Iron				
Copper				
Wood				
Water				
Ethanol				
Aluminium				
Granite				

Questions

1. What measurements do you have to do in order to calculate density? (1)

....

2. What effect does size or shape have on density of the same material? (1)

....

3. Why do you need to use the water displacement method for some objects and not for others? (1)

....

4. Water has a density of 1 g/cm^3. If an object's density is less than this, will it sink or float? (1)

....

5. What objects in this lab would float on water? (1)

....

6. What would happen to the density of a substance whose mass was cut in half? (1)

....

CW 3.2 - Density

1. What is meant by the density of a substance? (1)

....

2. a) How many cm^3 are there in 1 m^3? (1)

....

b) How many cm^3 are there in a litre? (*WORK IT OUT! Do not guess*) (1)

....

c) How many ml are there in 1 m^3? *(DITTO!)* (1)

....

4. Aluminium has a density of 2700 kg/m^3.

a) What is the density in g/cm^3? (2)

....

....

b) What is the mass of 20 cm^3 of aluminium? (2)

....

....

c) What is the volume of 27 g of aluminium? (2)

....

....

5. What is the mass of air (ρ = 1.3 kg/m^3) in the physics lab? *Do not guess. Estimate lab dimensions.* (3)

....

....

....

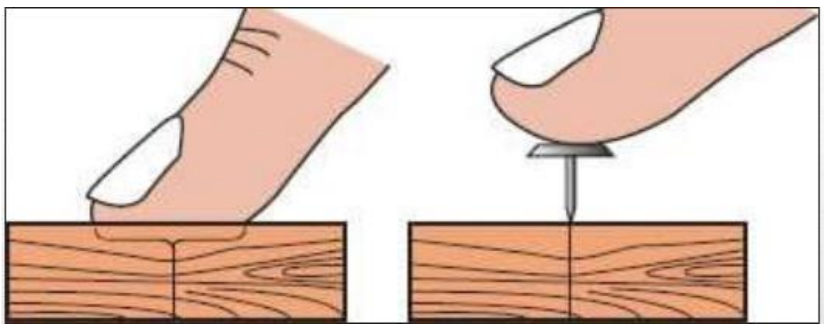
2 – Pressure

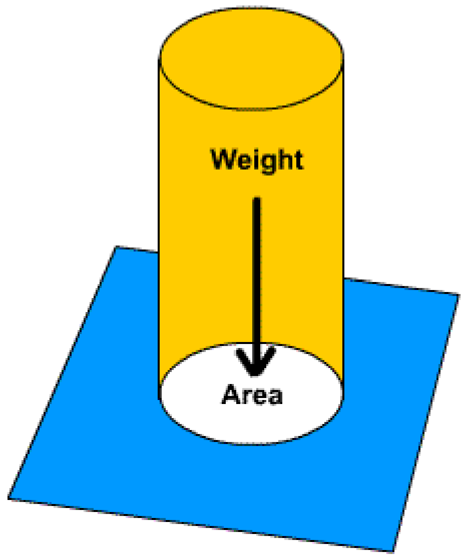
Objectives:

- recall and use the relationship between pressure, force and area:

$$pressure = \frac{force}{area}$$

Notes:




Weight
Area

CW 3.3 - Pressure

1. A force of 200 N acts over an area of 4 m^2.
   a) What pressure is produced? (2)

   b) What would the pressure be if the same force acted over half the area? (1)

2. What force is produced if:
   a) A pressure of 1000 Pa acts on an area of 0.2 m^2? (2)

   b) A pressure of 2 kPa acts on an area of 0.2 m^2? (2)

3. Explain why Farmer Wadson's tractor's big tyres stop it sinking in soft soil. (2)

4. A rectangular block of mass 30 kg measures 0.1 m by 0.4 m by 1.5 m.
   a) Calculate the weight of the block. (2)

   b) Draw diagrams to show how the block must rest on the ground to exert i) maximum pressure and ii) minimum pressure. (2)

   c) Calculate the maximum and minimum pressures in part b). (2)

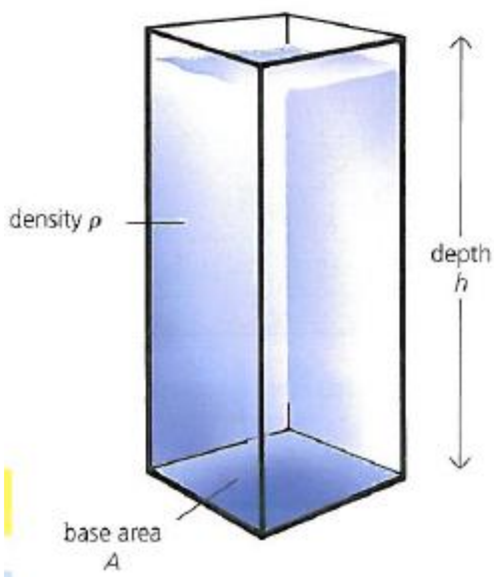
3 – Pressure in Fluids

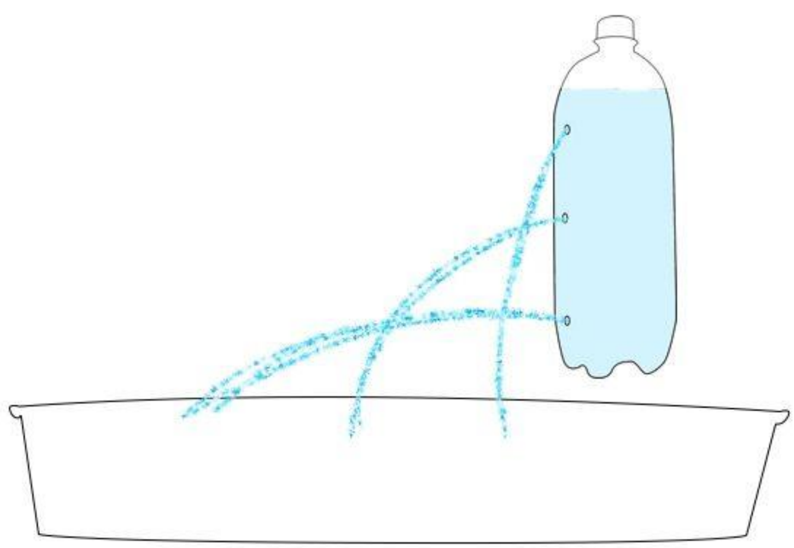
Objectives:

- understand that the pressure at a point in a gas or liquid which is at rest acts equally in all directions
- recall and use the relationship for pressure difference:

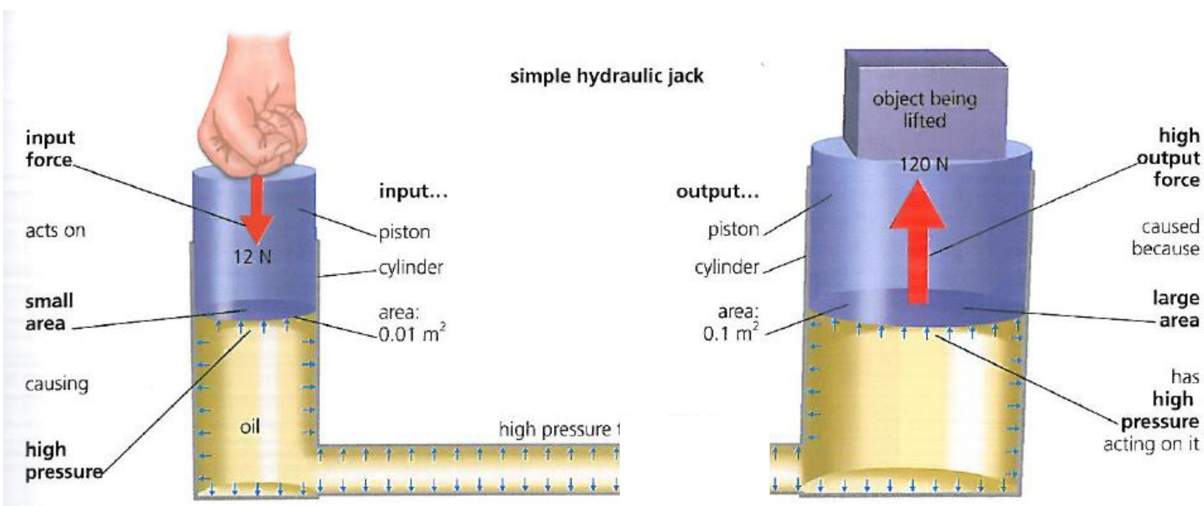
$$pressure\ difference = density \times g \times height$$

Hydrostatic Pressure





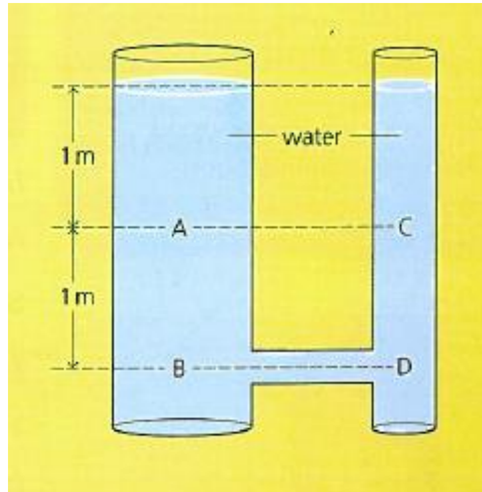
Pascal's Principle and Hydraulic Machines



CW 3.4 - Pressure in Fluids

Data: ρ_{water} = 1000 kg/m^3, $\rho_{paraffin}$ = 800 kg/m^3

1. In the diagram on the right:



a) How does the pressure at A compare to the pressure at B? (1)

b) How does the pressure at B compare to the pressure at D? (1)

c) How does the pressure at A compare to the pressure at C? (1)

d) If the water in the system were replaced with paraffin, how would this affect the pressure at B? (1)

2. A typical Bermuda water tank 6 m long by 5 m wide is filled to a depth of 4 m. Calculate:

a) The volume of water. (1)

b) the mass of the water. (2)

c) The weight of the water. (1)

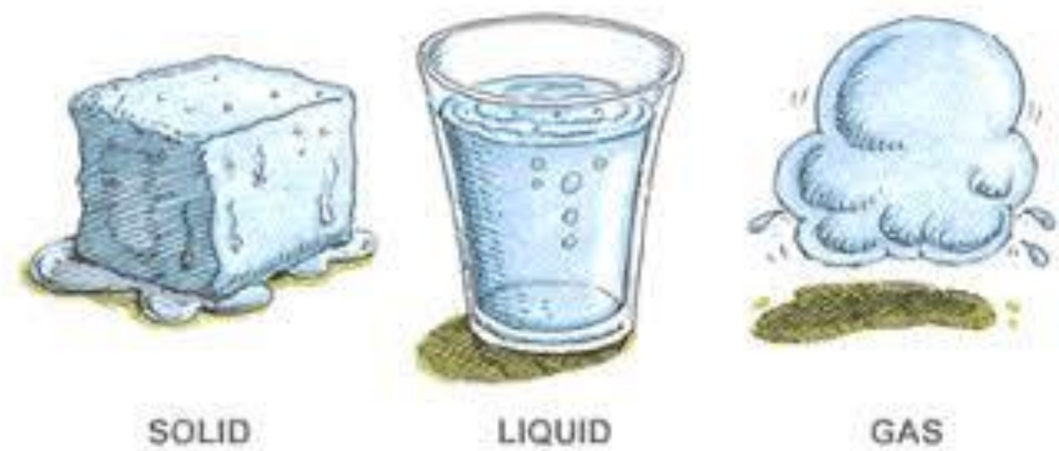
d) The pressure at the bottom of the tank of water. (2)

4 – States of Matter

Objectives:

- understand that a substance can change state from solid to liquid by the process of melting
- understand that a substance can change state from liquid to gas by the process of evaporation or boiling
- recall that particles in a liquid have a random motion within a close-packed structure
- recall that particles in a solid vibrate about fixed positions within a close-packed regular structure

Notes:



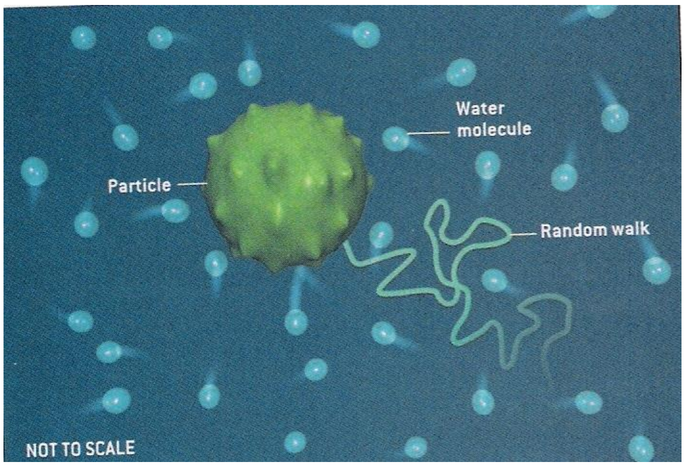
Solid	
Liquid	
Gas	

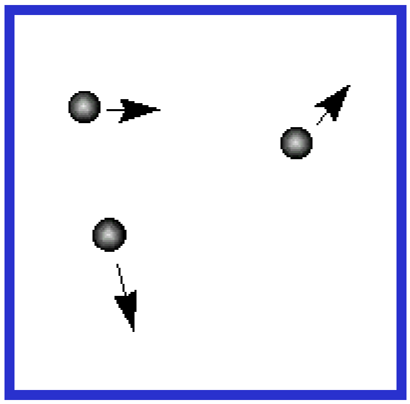
5 – Kinetic Theory and Temperature

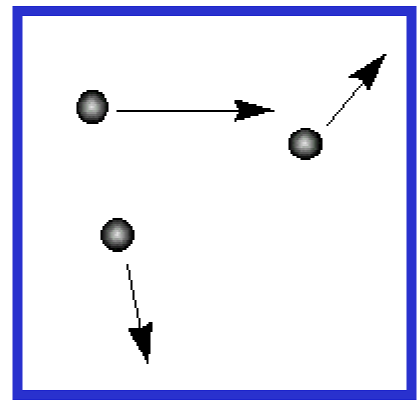
Objectives:

- understand the significance of Brownian motion
- recall that molecules in a gas have a random motion and that they exert a force and hence a pressure on the walls of the container
- understand that there is an absolute zero of temperature which is – 273 °Celsius
- describe the kelvin scale of temperature and be able to convert between the kelvin and Celsius scales

Notes:







6 - Specific Heat Capacity

Objectives:

- know that specific heat capacity is the energy required to change the temperature of 1 kg of mass by 1 °C
- Be able to use the equation:

$$E = mc\Delta T$$

LAB 3.5 - Finding the Specific Heat Capacity

Aim: To measure the specific heat capacity of a variety of materials.

Theory: Equal masses of different substances require different amounts of thermal energy to raise the temperature by the same amount. This is quantified by the term specific heat capacity, c. It is defined as the amount of energy required to heat 1.0 kg of mass by 1 °C. Obviously it is way to difficult to measure a 1.0 °C temperature rise, so we use maths!

The power rating of the heater is determined by multiplying the current by the voltage. Multiply this by the time (usually 5 mins = 300 sec) then we have the energy supplied to the heater.

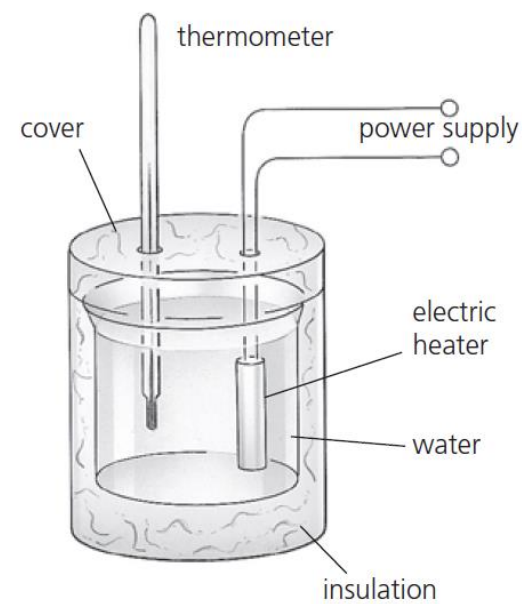
$$E = IVt$$

The specific heat capacity is then determined by:

$$c = \frac{E}{m\Delta T}$$

Method:

- Set up the apparatus as shown. If using water, measure out exactly 1000 ml and keep the heater from touching the sides – use a clamp stand.
- Record the initial temperature.
- Set the voltage to 12 V and start the timer.
- Record the mean values of the current and voltage (they may fluctuate a bit)
- At 5 mins, turn off the heater and record the temperature. If using water, stir the water first.



Substance	**Voltage (V)**	**Current (A)**	**Energy (J)**	**Temp before (°C)**	**Temp after (°C)**	**Temp increase (°C)**	**Specific heat capacity (J/kg°C)**	**Text book value!**
Water								
Aluminium								
Steel								
Sand								
Copper								

Conclusion and Evaluation:

1. Which substance was the easiest to heat up? (1)

2. Which substance was the hardest to heat up? (1)

3. Why is it important to insulate the substance? (1)

4. Did the pattern of your results match the textbook values? If not, were they too low or too high? Explain possible reasons for this. (3)

CW 3.6 - Specific Heat Capacity

$$E = mc\Delta T$$

1. Water has a very high specific heat capacity (c = 4200 J/kg°C). What effect does this have on the ocean that surrounds Bermuda? (2)

2. The specific heat capacity of sand is far lower, around 290 J/kg°C. Use this information to explain why Bermuda's beaches get really hot on a summer's day but cold at nighttime. (2)

3. The specific heat capacity of copper is 400 J/kg°C . Calculate how much heat energy is required to raise the temperature of a 5 kg block of copper by 20 °C? (2)

5. If a 10 kg block of copper cools from 100 °C to 20 °C, how much thermal energy was lost? (2)

6. If the heat energy from the copper block in Q5 was directly added to 20 kg of water at 20 °C, how hot would the water get (assuming no heat losses to the surroundings)? (3)

7. Challenging question: A 1500 W kettle contains 1 kg of water at 20 °C. How long would it take to boil? (3)

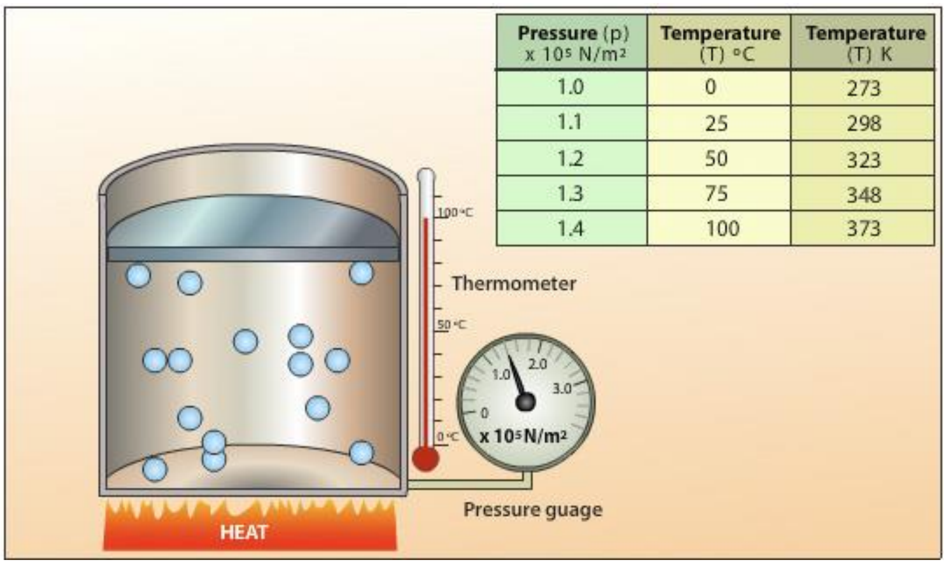
7 – The Gas Laws: Pressure Law

Objectives:

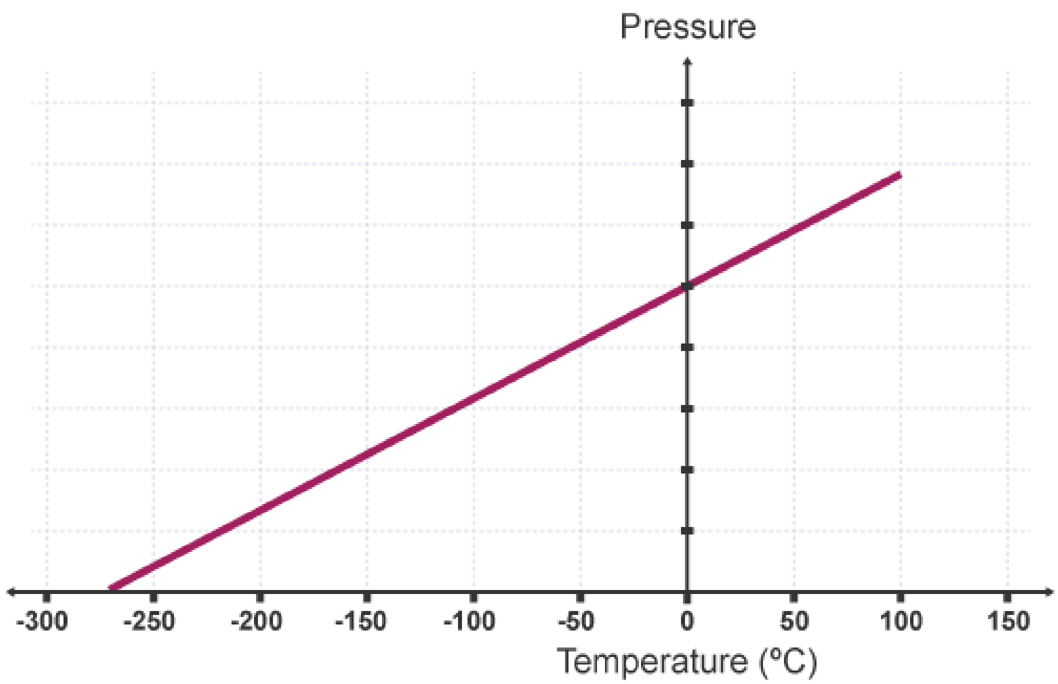
- understand that an increase in temperature results in an increase in the speed of gas molecules
- understand that the Kelvin temperature of the gas is proportional to the average kinetic energy of its molecules
- describe the qualitative relationship between pressure and kelvin temperature for a gas in a sealed container
- use the relationship between the pressure and Kelvin temperature of a fixed mass of gas at constant volume:

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Notes:



Pressure (p) x 10^5 N/m^2	Temperature (T) °C	Temperature (T) K
1.0	0	273
1.1	25	298
1.2	50	323
1.3	75	348
1.4	100	373


Pressure
-300
-250
-200
-150
-100
-50
0
50
100
150
Temperature (°C)

LAB 3.7 - Pressure Law

Aim: to show that the pressure and the absolute temperature of a fixed mass of gas are directly proportional.

Diagram: (2)	• Record the pressure and temperature of a known volume of gas. • Raise the temperature of the gas. • Leave sufficient time for the apparatus to obtain equilibrium, at this new temperature. • Record the new pressure and temperature. • Repeat for a range of temperatures. • Plot a graph of *P* against *T*. • The graph should be a straight line that intercepts at absolute zero.

Data (2)

Temperature (˚C)	**Pressure ( )**

It may be beneficial to use EXCEL to plot the graph. To find an estimate of the value of absolute zero, it is necessary to 'backward forecast' the trendline. (4)

Conclusion (4):

CW 3.8 – Pressure Law

DON'T FORGET TO CONVERT °C TO K (by adding 273)!!!

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Directions: Identify each variable and use the above formula to answer the following questions below.

---

1. According to the Pressure Law what happens to the pressure in a container when there is an increase in temperature? Why? Explain how the particles of gas are moving. (2)

2. According to the Pressure Law, what happens to pressure in a container when there is a decrease in temperature? Why? Explain how the particles of gas are moving. (2)

3. Define the Pressure Law and explain why it is critical the absolute temperature scale is used. (2)

5. A gas is collected at atmospheric pressure (1 atm) at 298K. What will be its pressure when the temperature decreases to 273K? (3)

6. A gas at 50.0°C has a pressure of 20,000 Pa. What will be its pressure upon cooling to 25.0°C? (3)

7. Calculate the increase in pressure when a gas at 30 psi at 20.0 °C is heated to 80°C. (3)

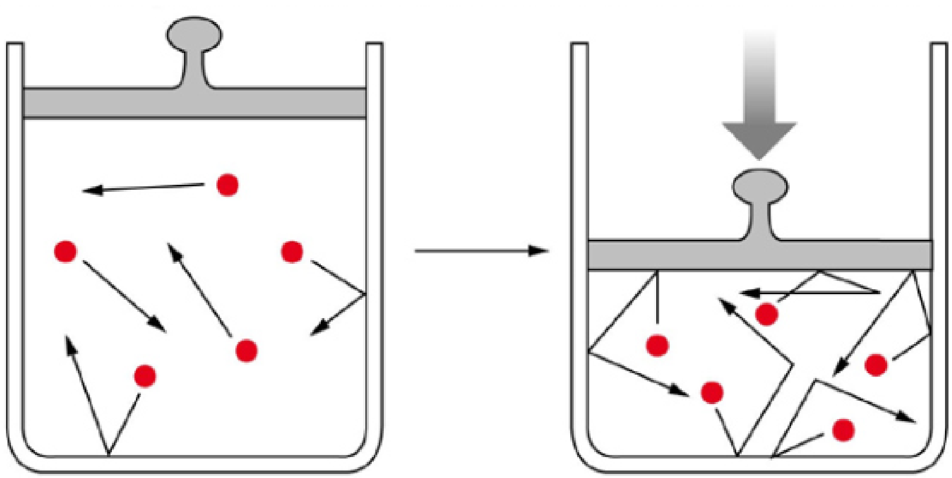
8 – The Gas Laws: Boyle's Law

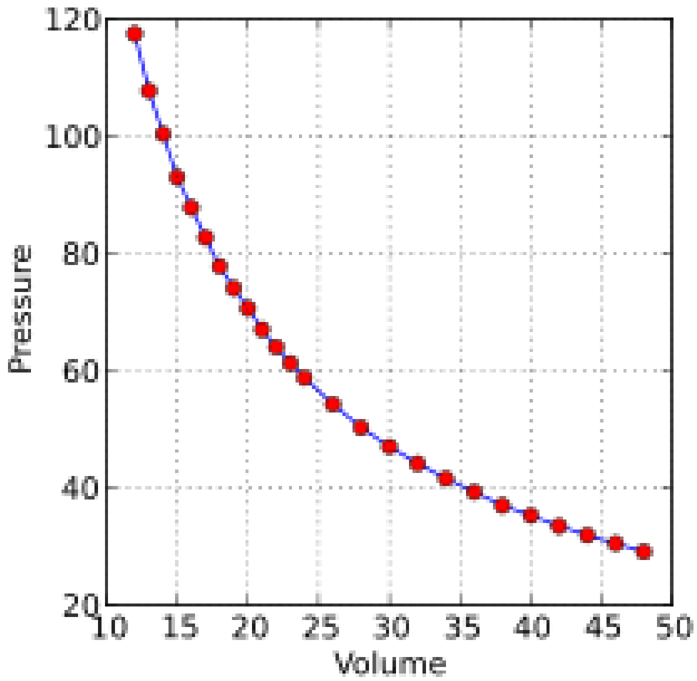
Objectives:

- use the relationship between pressure and volume of a fixed mass of gas at constant temperature

$$P_1V_1 = P_2V_2$$

Notes:

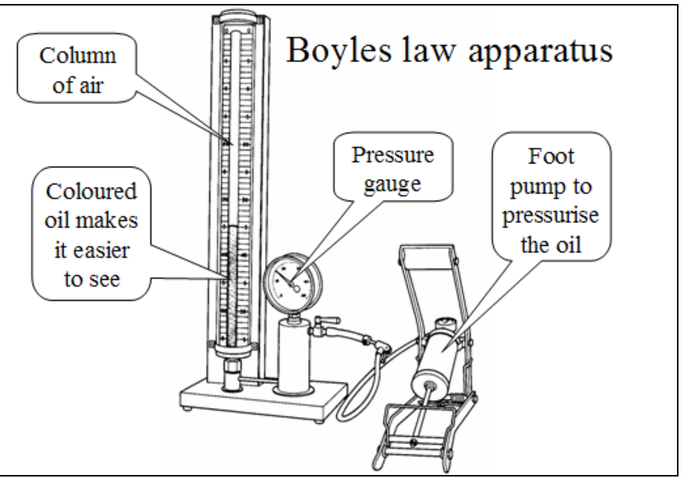



Pressure
Volume
120
100
80
60
40
20
10
15
20
25
30
35
40
45
50

LAB 3.9 - Boyle's Law

Aim: to show that the pressure and the volume of a fixed mass of gas are inversely proportional.

- Record the volume of a gas at a known pressure,
- Increase the pressure using the foot pump,
- Leave the gas for a time sufficient for the gas to reach thermodynamic equilibrium with its surroundings,
- Record the new volume and pressure,
- Repeat the procedure for a range of pressures by **slowly** releasing the air valve,
- Plot a graph of *P* against *V*,
- Graph should be a smooth curve.



Data (2)

Pressure ( )	**Volume ( )**

(4)

Conclusion (2):

CW 3.10 - Boyle's Law

$$P_1V_1 = P_2V_2$$

Directions: Identify each variable and use the above formula to answer the following questions below.

1. According to Boyle's Law what happens to the volume of a container when there is a decrease in pressure? (1)

2. According to Boyle's Law, what happens to volume of a container when there is an increase in pressure? (1)

3. Define Boyle's Law. (1)

5. A gas occupies 12.3 liters at a pressure of 40.0 mm Hg. What is the volume when the pressure is increased to 60.0 mm Hg? (3)

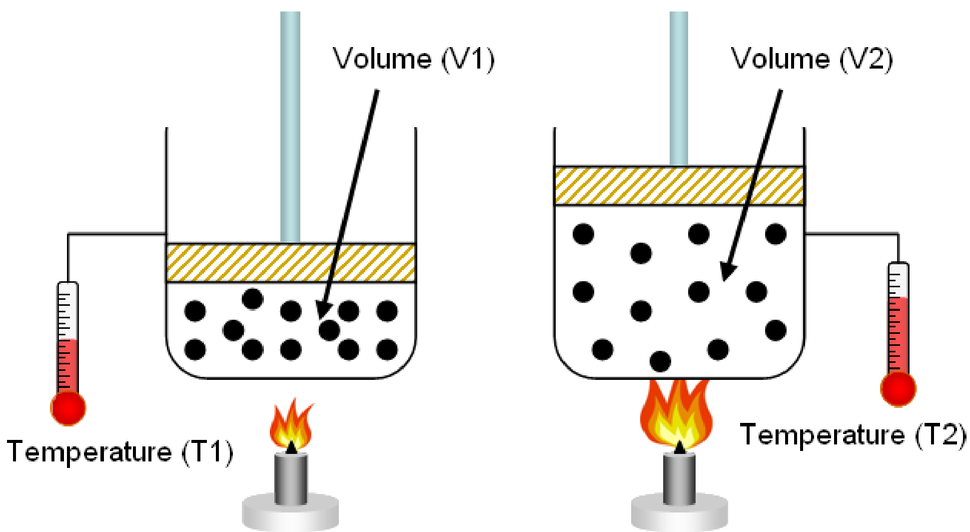
6. A gas occupies 1.56 L at 1.00 atm. What will be the volume of this gas if the pressure becomes 3.00 atm? (3)

7. A gas occupies 4.31 liters at a pressure of 0.755 atm. Determine the volume if the pressure is increased to 1.25 atm. (3)

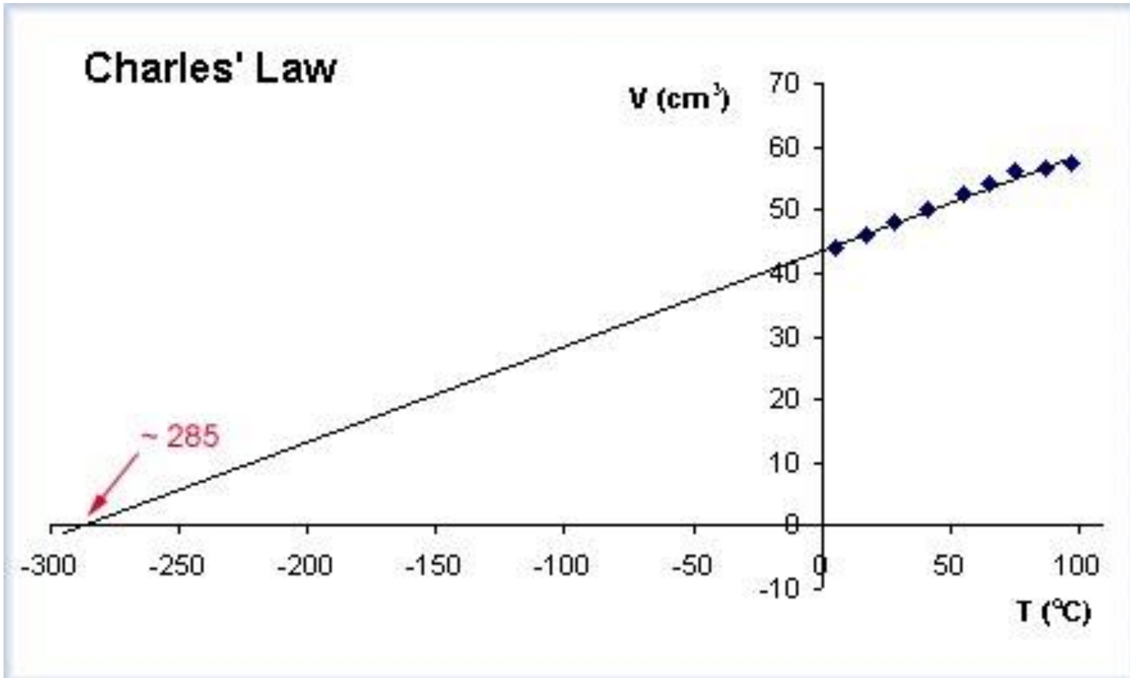
9 – The Gas Laws: Charles' Law

Objectives:

- understand that an increase in temperature results in an increase in the speed of gas molecules
- understand that the Kelvin temperature of the gas is proportional to the average kinetic energy of its molecules
- describe the qualitative relationship between volume and kelvin temperature for a gas in a container that is free to expand or contract
- use the relationship between the volume and Kelvin temperature of a fixed mass of gas at constant pressure:



$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$


Charles' Law
V (cm³)
70
60
50
40
30
20
10
0
-10
~ 285
-300
-250
-200
-150
-100
-50
0
50
100
T (°C)

LAB 3.11 - Charles' Law

Aim: to show that the volume of a fixed mass of gas is directly proportional to its absolute temperature.

- A thin capillary tube, closed at one end, is full of air. A small drop of concentrated sulphuric acid has been placed into the tube as a movable stopper,
- Place the tube into a water-bath at room temperature,
- Measure the length of the air column,
- Increase the temperature of the water. Measure the new length after thermal equilibrium has been reached,
- Repeat the procedure for a range of temperatures,
- Plot the data on a graph and extrapolate to find the temperature at which the length of the air column will be zero.

Data (2)

Temperature (˚C)	**Volume ( )**

It may be beneficial to use EXCEL to plot the graph. To find an estimate of the value of absolute zero, it is necessary to 'backward forecast' the trendline.

(4)

Conclusion (2):

CW 3.11 – Charles' Law

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

DON'T FORGET TO CONVERT °C TO K (by adding 273)!!!

Directions: Identify each variable and use the above formula to answer the following questions below.

---

1. According to Charles Law what happens to the volume of a container when there is an increase in temperature? Why? Explain how the particles of gas are moving. (2)

2. According to Charles Law, what happens to volume of a container when there is a decrease in temperature? Why? Explain how the particles of gas are moving. (2)

3. Define Charles Law. (1)

5. A gas is collected and found to fill 2.85 L at 298K. What will be its volume when the temperature decreases to 273K? (3)

6. 4.40 L of a gas is collected at 50.0˚C. What will be its volume upon cooling to 25.0˚C? (3)

7. Calculate the decrease in temperature when 6.00 L at 20.0 ˚C is compressed to 4.00 L. (3)

10 – The Gas Laws: The Universal Law

Objectives:

- use the combined gas law relationship between the volume, pressure and Kelvin temperature of a fixed mass of gas:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Remember: to increase the pressure of a gas:

1.

2.

3.

CW 3.12 – Universal Gas Law

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

DON'T FORGET TO CONVERT °C TO K (by adding 273)!!!

Directions: Identify each variable and use the above formula to answer the following questions below.

1. A gas balloon has a volume of 106.0 liters when the temperature is 45.0 °C and the pressure is 740.0 mm of mercury. What will its volume be at 20.0 °C and 780 .0 mm of mercury pressure? (3)

Hint: Why are there THREE marks here?

2. If 10.0 liters of oxygen at STP are heated to 512 °C, what will be the new volume of gas if the pressure is also increased to 1520.0 mm of mercury? (3)

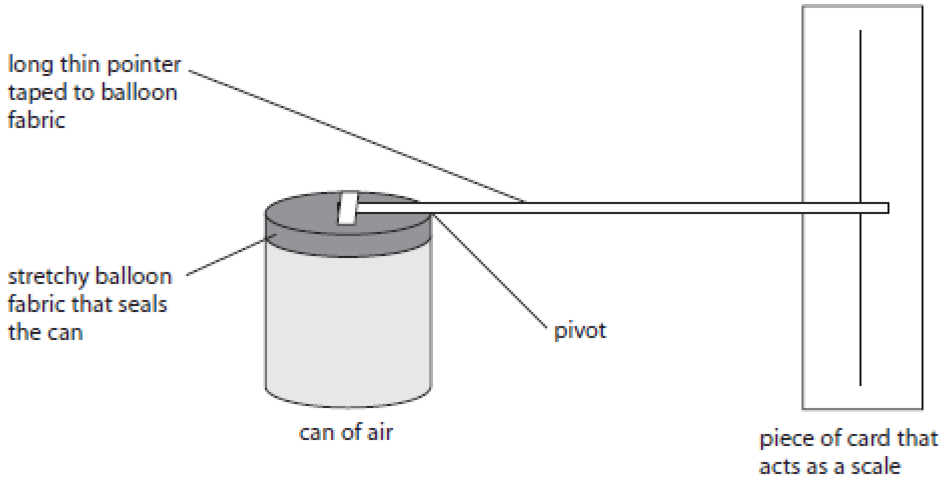
3. A gas is heated from 263.0 K to 298.0 K and the volume is increased from 24.0 liters to 35.0 liters by moving a large piston within a cylinder. If the original pressure was 1.00 atm, what would the final pressure be? (3)

4. The pressure of a gas is reduced from 1200.0 mm Hg to 850.0 mm Hg as the volume of its container is increased by moving a piston from 85.0 mL to 350.0 mL. What would the final temperature be if the original temperature was 90.0 °C? (3)

PAST IGCSE QUESTIONS

10 Aneroid barometers are used to measure air pressure.

A student makes a model aneroid barometer as shown.



(a) (i) The balloon fabric is attached to the can to stop the air escaping.

Explain how the air inside the can causes a pressure on the balloon fabric.
(3)

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This is a standard question that comes up EVERY year. You are expected to demonstrate a clear understanding of how particles move and cause the pressure on the walls of a container.

Hint: The pointer is a LEVER!

(ii) The balloon fabric is tight and flat.
The pointer is horizontal as shown.

Explain what happens to the different parts of the model when the atmospheric pressure increases. [You may assume that the temperature remains constant.]

(4)

(iii) Suggest two ways that the model could be altered to increase its sensitivity to changes in atmospheric pressure.

(2)

1

2

(b) The student heats the air in her can by placing the can in a water bath.

(i) State how this affects the reading shown by the pointer.

(1)

....

....

(ii) Explain why this happens.

(2)

....

....

....

....

(Total for Question 10 = 12 marks)

2 The photograph shows some large concrete cubes.

The mass of one of the concrete cubes is 1000 kg.

(a) State the weight of this concrete cube.

Give the unit.

(2)

weight of concrete cube = ... unit ....

(b) The density of this concrete cube is 2300 kg/m^3.

(i) State the equation linking density, mass and volume.

(1)

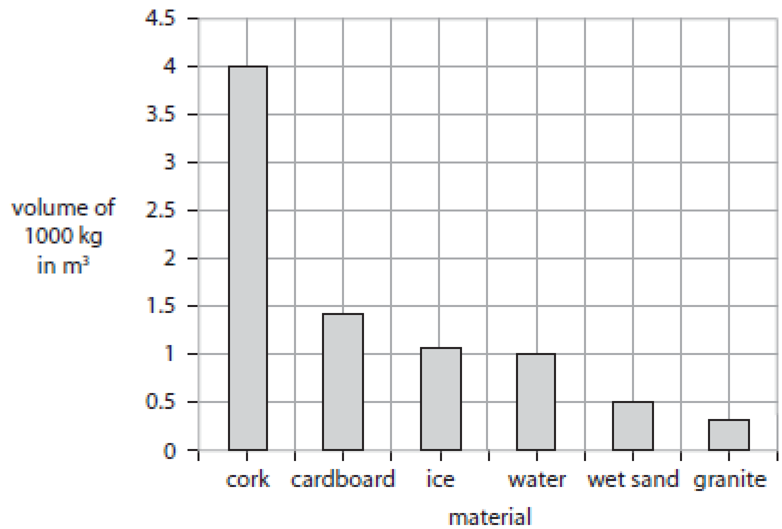
(ii) Calculate the volume of this concrete cube.

(2)

volume of concrete cube = ... m^3

Standard question

(c) The graph shows the volumes of 1000 kg of some other materials.



(i) State the type of graph shown.

(1)

....

(ii) Give a reason why a line graph is not an appropriate way to display this data.

(1)

....

....

....

(iii) Use information from the graph to compare the densities of cork and water.

(2)

....

....

....

....

(Total for Question 2 = 9 marks)

Part (iii). You would not believe how many students get this wrong!

8 All gases above absolute zero exert a pressure on the walls of their container.

(a) (i) State the value of absolute zero in °C.

(1)

absolute zero = ...°C

(ii) Explain, in terms of its molecules, how a gas exerts a pressure on the walls of its container.

(3)

....

....

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....

Oh look – it is that same question again!

(b) A pressure switch is used in a washing machine to control the flow of water. The water pushes on a flexible container and compresses some trapped air. When the pressure of this trapped air reaches 104 kPa, the pressure switch turns the water off.

The pressure of the trapped air is given by this relationship

$$\text{pressure of the trapped air} = \text{atmospheric pressure} + \text{pressure difference caused by water}$$

(i) State the equation linking pressure difference, height, density and g.

(1)

(ii) Calculate the height of water in the machine when the pressure of the trapped air reaches 104 kPa and the switch operates.

[atmospheric pressure = 100 kPa, density of water = 1000 kg/m^3]

(4)

Don't forget about the atmospheric pressure....

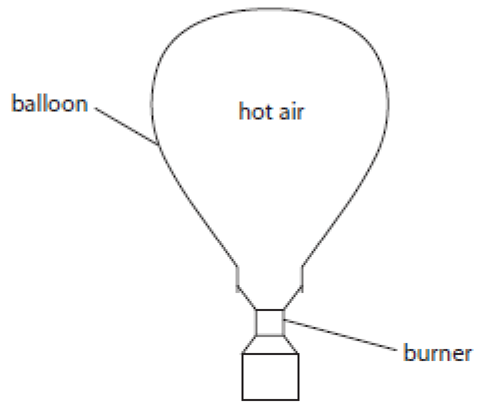
There are 4 marks for a reason.....

height of water = ...m

(Total for Question 8 = 9 marks)

8 A hot air balloon is filled with air through an opening.

The air is heated using a burner.



(a) Describe the effect of an increase in temperature on the average speed of the air molecules.

(1)

....

(b) The hot air causes a pressure on the inside of the balloon.

and again!

Use ideas about molecules to explain how the hot air causes this pressure.

(3)

....

....

....

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....

....

(c) Give a reason why the hottest air rises to the top of the balloon.

(1)

....

....

(d) The average density of the hot air in the balloon is 0.95 kg/m³.

The volume of this air is 2800 m³.

(i) State the equation linking density, mass and volume.

(1)

(ii) Calculate the mass of hot air in the balloon.

(3)

Rearrange the equation

Pretty standard question – only tough bit is e (ii)

mass of hot air = ... kg

(e) As the balloon climbs higher, the air pressure outside it decreases.

(i) Suggest a reason for this change in the outside air pressure.

(1)

....

....

....

(ii) Suggest how the decrease in air pressure outside the balloon affects the hot air inside.

(1)

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....

(Total for Question 8 = 11 marks)

Boyle's Law – pretty standard question.

Be sure to identify all the variables.

13 (a) A diver breathes air from a cylinder when he is under water.

(i) The cylinder contains 8 litres of air at 200 times atmospheric pressure.

The air is released from the cylinder at normal atmospheric pressure.

The diver needs 16 litres of air per minute.

Calculate the maximum amount of time that the diver can breathe under water using this cylinder.

(3)

time = ... minutes

(ii) When the diver breathes out, bubbles are released.

Suggest why the bubbles expand as they rise to the surface.

(2)

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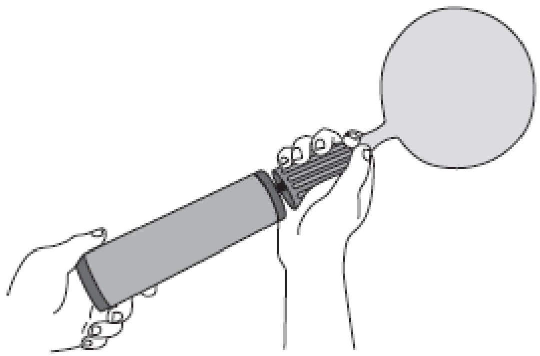
(b) A student wants to investigate how the volume of a balloon changes with pressure.



Lab question: really think hard about this, it is not easy!

(i) Suggest how the student could measure the volume of an inflated balloon.

(2)

....

....

....

....

....

(ii) The student plans to measure the pressure of the air in the balloon.

> To measure the pressure in the balloon I will count how many times I push the pump. The same amount of air goes into the balloon with each push.
>
> When there is twice as much air in the balloon the pressure will be twice as high, so the pressure will be proportional to the number of times I push the pump.

Explain why the student's plan will not work.

(2)

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(Total for Question 13 = 9 marks)