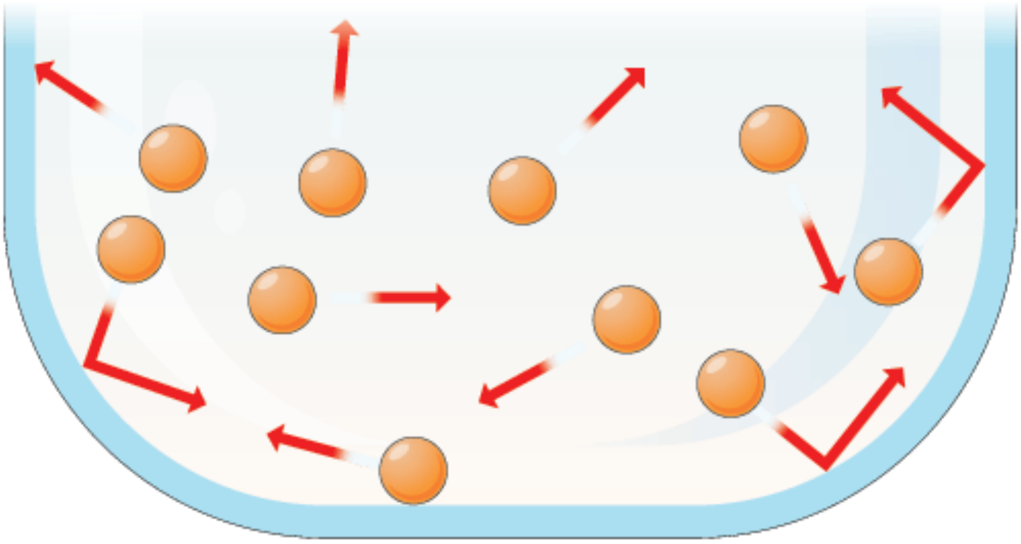
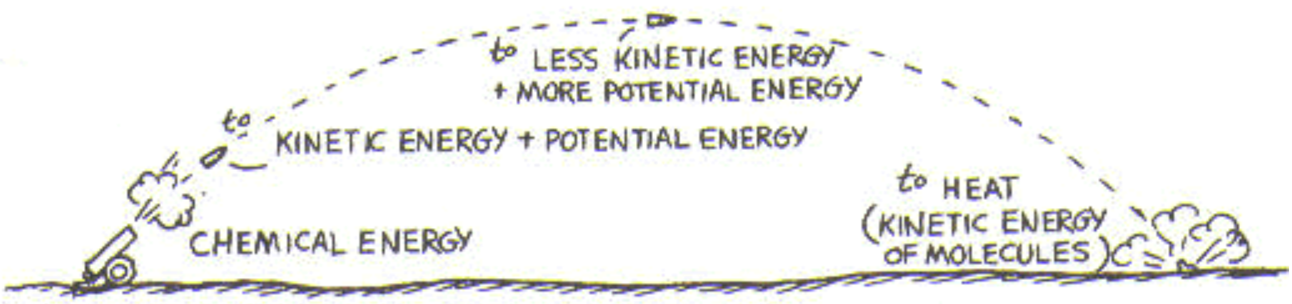
National 5 Physics

Energy





Energy Cannot Be Created or Destroyed

(It just changes forms)

Throughout the Course, appropriate attention should be given to units, prefixes and scientific notation.

tera	T	10^{12}	x 1,000,000,000,000
giga	G	10^{9}	x 1,000,000,000
mega	M	10^{6}	x 1,000,000
kilo	k	10^{3}	x 1,000
centi	c	10^{-2}	/100
milli	m	10^{-3}	/1,000
micro	µ	10^{-6}	/1,000,000
nano	n	10^{-9}	/1,000,000,000
pico	p	10^{-12}	/1,000,000,000,000

In this section the prefixes you will use most often are milli (m), micro (µ), kilo (k), and mega (M) and giga (G). It is essential that you use these correctly in calculations.

In Physics, the standard unit for time is the **second (s)** and therefore if time is given in milliseconds (ms) or microseconds (µs) it must be converted to seconds.

Example 1
An electronic system is now used and is able to perform the same experiment in 0.5 ms. How long is this?

0.5 ms = 0.5 milliseconds = 0.5 x 10^{-3} s = 0.5/1 000 = 0.0005 seconds.

In this unit we use the unit amperes, which is the unit of current. Often there will be currents which are measured in mA and µA.

Example 2
An ammeter reading shows that there are 54.2 µA of current in a circuit? How many amperes is this?

54.2 µA = 54.2 microamperes = 54.2 x 10^{-6} A = 54.2/1 000 000 = 0.0000542 amperes.

In this unit we use the unit for power – the Watt, W, this may be measured in kW and MW.

Example 3
A hairdryer is rated at 2 kW. How many W is this?

2 kW = 2 kilowatts = 2 x 10^{3} Hz = 2 x 1 000 = 2 000 watts.

National 5 Physics

Energy

Contents

Conservation of energy

1.1. Principle of 'conservation of energy' applied to examples where energy is transferred between stores.
1.2. Identify and explain 'loss' of energy where energy is transferred.
1.3. Calculations with potential and kinetic energy in situations involving conservation of energy

$$E_k = \frac{1}{2}mv^2$$

$$E_p = mgh$$

Conservation of Energy

It is difficult to state what energy actually is. We know that we need energy to do things, and we know that energy is changed from one type to another.

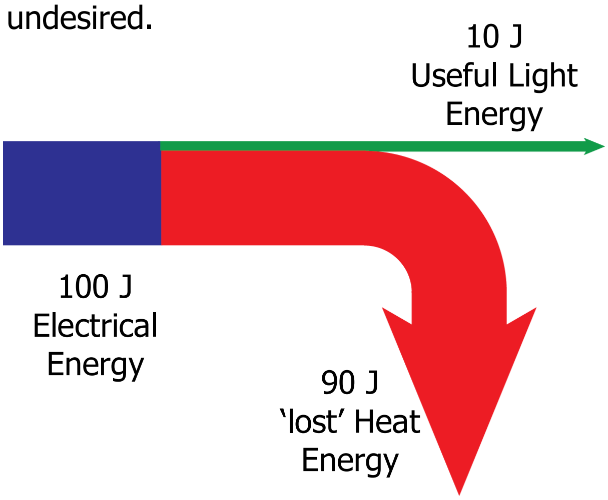
It is commonly stated that energy **cannot be created or destroyed, only transformed** from one type to another.

In order to increase the amount of one type of energy, we must transform it from a different type. A battery in a circuit stores chemical energy which is transformed in a circuit into electrical energy.

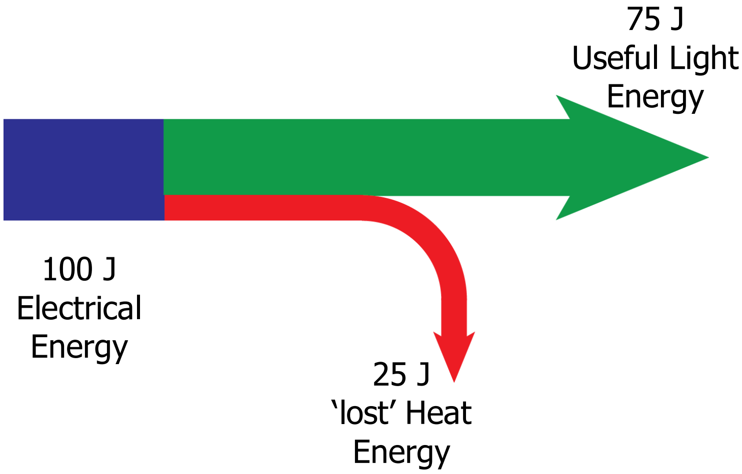
Energy is measured in joules (J). No energy can disappear in the change – all energy in a system is **conserved**. This means that if we start with 100 J, we must have 100 J of total energy after any change has taken place.

Energy 'loss'

We often talk about energy loss. As we have already discussed, energy cannot be destroyed but it can be changed. The problem is that it doesn't always change the way we want. A perfect example is a filament lamp. When we turn it on, the desired transformation is from electrical energy to light energy. This is the main transformation, but the lamp gets very warm when it is switched on. This transformation from electrical to heat energy is undesired.



This sankey diagram shows the energy transformation in a filament lamp.



This is a similar diagram but for an energy saving lamp. Very little energy is 'lost' as heat.

Any energy which is transformed into a form other than the one we want could be said to be 'lost' as it was not intended.

Friction will often cause energy loss too. If we want to move an object, we want to change potential energy into kinetic energy, but work done against friction will result in the surface of the object heating up. The temperature can't change if there isn't an increase in heat energy!

Calculations Using Conservation of Energy

We can use the conservation of energy in calculations. For example, we can calculate the change in gravitational potential energy when an object is dropped. Due to conservation of energy, this must be the same as the kinetic energy gained by the same object (if we ignore the effect of friction). As a result – we can calculate the velocity of the object.
Worked Example

A 0.50kg stone is dropped down a well. The distance from the top of the well to the water is 12.0 m. Calculate the speed of the stone as it hits the water, ignoring the effects of friction.

$h = 12$ m
$g = 10$ N/kg
$m = 0.5$ kg
$E_p = ?$
$v = ?$

$E_p = mgh$
$E_p = 0.5 \times 10 \times 12$
$E_p = 60$ J

$E_k = E_p = 60$
$E_k = \frac{1}{2}mv^2$
$60 = 0.5 \times 0.5 \times v^2$
$v^2 = 60/0.25$
$v = 15.5$ m/s

You may have noticed that it is possible to calculate the speed without the mass of the object. This is because, as Galileo discovered, the speed at which an object drops does not depend on the mass, only the gravitational field it is in. This is shown below.

$$E_k = E_p$$
$$1/2\, mv^2 = mgh$$
$$1/2\, v^2 = gh$$
$$v^2 = 2gh$$
$$v = \sqrt{2gh}$$

Calculating this for the above example

$h = 12$ m
$g = 10$ N/kg
$v = ?$

$v = \sqrt{2gh}$
$v = \sqrt{2 \times 10 \times 12}$
$v = \sqrt{240}$
$v = 15.5$ m/s

Specific heat capacity

1.4. The same mass of different materials requires different quantities of heat to raise the temperature of unit mass by one degree Celsius.
1.5. The temperature of a substance is a measure of the mean kinetic energy of its particles.
1.6. Explain the connection between temperature and heat energy.
1.7. Use appropriate relationships to carry out calculations involving mass, heat energy, temperature change and specific heat capacity.
1.8. Conservation of energy to determine heat transfer.

$$E_h = cm\Delta T$$

Specific Heat Capacity

Different materials sometimes feel warmer or colder to touch – even in the same room. This is because of the different amounts of energy required to 'heat them up.' Every kilogram of water, for example, requires 4180 J of energy to increase in temperature by 1 ^{0}C. The same mass of copper, 1 kg, only requires 385 J to increase the temperature by 1 ^{0}C.

Each different material requires a different amount of energy to increase the temperature by 1 degree. We call this value the **Specific Heat Capacity.** It is measured in joules per kilogram degree Celsius, or J/kg^{0}C.

Some examples of specific heat capacities are shown below. You can see that metals require much less energy for their temperature to increase than many other materials.

Material	Specific Heat Capacity / J/kg^{0}C
Water	4180
Sea water	3900
Ethanol	2600
Oil	2500
Meths	2500
Ice	2100
Aluminium	900
Granite	800
Steel	500
Iron	440
Copper	400
Brass	390
Mercury	150
Lead	130

Heat and Temperature

Heat and temperature are related, but they are not the same. Temperature is a measure of the amount of heat energy that a material has. Heat energy is actually a type of kinetic energy. It increases as the movement of the individual particles of the material increases.

We state that **the temperature of a substance is a measure of the mean kinetic energy of its particles**.

The temperature of an object will increase as the heat energy increases.

Heat Energy

The change in heat energy of an object can be calculated when we know its mass, specific heat capacity and how much the temperature has changed.

$$E_h = cm\Delta T$$

Symbol	Name	Unit	Unit Symbol
E_h	Energy	joules	J
c	Specific Heat Capacity	joules per kilogram degree Celsius	J/kg°C
m	mass	kilograms	kg
ΔT	Change in Temperature	degrees Celsius	°C

This relationship allows us to calculate the change in energy when a material changes temperature. It is important to look at it as a change as the heat energy will increase if a material is getting warmer, but it will go down if the material cools down.

Worked examples

1. 2 kg of water is placed in a fridge to cool it to 5 ^{0}C. When it was placed in the fridge it was 25 ^{0}C. How much heat energy is removed from the water?

$m = 2$ kg
$T_1 = 25\ ^0C$
$T_2 = 5\ ^0C$
$\Delta T = T_1 - T_2 = 20\ ^0C$
$c = 4180$ J/kg^{0}C
$E_h = ?$

$E_h = cm\Delta T$
$E_h = 4180 \times 2 \times 20$
$E_h = 167200$
$E_h = 167$ kJ

2. A heating element is placed in a 3.6 kg block of lead. 18 kJ of energy are supplied to the heater. Assuming that all heat energy is absorbed by the lead, what is the increase in temperature?

$m = 3.6$ kg
$\Delta T = ?$
$c = 130$ J/kg^{0}C
$E_h = 18$ kJ $= 18000$ J

$E_h = cm\Delta T$
$18000 = 130 \times 3.6 \times \Delta T$
$\Delta T = 18000/468$
$\Delta T = 38.4\ ^0C$

3. A 160 kg sample of metal requires 35.2 kJ to increase its temperature by 5 ^{0}C. What type of metal is it?

$m = 160$ kg
$E_h = 35.2$ kJ $= 352000$ J
$c = ?$
$\Delta T = 5\ ^0C$

$E_h = cm\Delta T$
$352000 = c \times 160 \times 5$
$c = 352000/800$
$c = 440$ J/kg^{0}C

Matching to the table on p7, the metal is iron.

Conservation of Heat Energy

Earlier in this unit we learned about conservation of energy where an energy of one type can be transformed into another, but none can be created or destroyed. This includes heat energy, so in order to increase heat energy of a material, there must have been either an energy transformation, or a distribution of the total energy of a system.

When we are investigating conservation of energy, it is often stated that we can assume no energy 'loss.' In cases to do with heat energy, this is often because we must assume that no energy is 'lost' to the surrounding atmosphere – so for example if we are investigating how long it would take a kettle to boil 1 kg of water, we may assume that no heat energy is transformed into the surrounding area.

Worked example

1.5 kg of oil at 25 ^{0}C is mixed with 3.0 kg of oil at 55 ^{0}C. Assuming no heat energy is lost to the surroundings, what is the final temperature of all the oil?

Using conservation of energy the increase in heat energy of the colder oil must be the same as the decrease in heat energy of the warm oil.

$m = 1.5$ kg
$T_1 = 25\ ^0C$
$m_2 = 3.0$ kg
$T_2 = 55\ ^0C$
$c = 2500$ J/kg^{0}C
$\Delta T = ?$

$\Delta E_1 = \Delta E_2$
$cm_1\Delta T_1 = cm_2\Delta T_2$
$m_1\Delta T_1 = m_2\Delta T_2$
$1.5 \times \Delta T_1 = 3 \times \Delta T_2$
$\Delta T_1 = 2 \times \Delta T_2$

Therefore

$$25 + 2\Delta T_2 = 55 - \Delta T_2$$
$$3\Delta T_2 = 30$$
$$\Delta T_2 = 10\ ^0C$$

So the final temperature is 55 – 10 = 45^{0}C

The law of conservation of energy can be used with any type of energy, so it also allows us to investigate electrical appliances.

Worked example

A kettle works on the UK mains (230 V) and a current of 12 A flows when it is switched on.

a. What is the power rating of the kettle?
b. How much energy would the kettle transform if it was switched on for 2 minutes?
c. What is the maximum mass of 20 ^{0}C water which could be heated to 99 ^{0}C in this time?
d. What assumptions did you make in part c?

a.

$V = 230\ V$
$I = 12\ A$
$P = ?$

$P = IV$
$P = 12 \times 230$
$P = 2760\ W$

b.

$P = 2760\ W$
$t = 2 \times 60 = 120\ s$
$E = ?$

$P = E/t$
$2760 = E/120$
$E = 120 \times 2760$
$E = 331200\ J$
$E = 331\ kJ$

c.

$m = ?$
$T_1 = 20\ ^0C$
$T_2 = 99\ ^0C$
$\Delta T = T_2 - T_1 = 79\ ^0C$
$c = 4180\ J/kg^0C$
$E_h = 331\ kJ = 331 \times 10^3\ J$

$E_h = cm\Delta T$
$331 \times 10^3 = 4180 \times m \times 79$
$m = 331 \times 10^3/330220$
$m = 1.002$
$m = 1\ kg$

d. Assuming all energy supplied to kettle heats the water, none is lost to the surroundings.

2. **Gas laws and the kinetic model**
   2.1. Pressure is the force per unit area exerted on a surface.
   2.2. Use an appropriate relationship to calculate pressure, force and area.
   2.3. Explanation of the relationship between the volume, pressure and temperature of a fixed mass of gas using qualitative kinetic theory.
   2.4. Use of appropriate relationship to calculate the volume, pressure and temperature of a fixed mass of gas.
   2.5. The relationship between kelvin, degrees Celsius and absolute zero of temperature.

$$P = \frac{F}{A}$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Gas laws and the kinetic model

Pressure

When an object exerts a force on another object, this force is spread across the entire surface area of contact. For example a wooden block sitting a table will exert a force on the table top due to the weight of the block. If the box is turned on its end, it will exert the same force but over a smaller surface area.

The amount of force exerted on a unit area is defined as pressure

$$P = \frac{F}{A}$$

Symbol	Name	Unit	Unit Symbol
P	Pressure	Pascal	Pa
F	Force	Newton	N
A	Area	Square Metre	m^2

The unit of pressure is the Pascal. One Pascal of pressure occurs when one Newton of force acts on an area of one square metre.

Worked example – Pressure, force and Area

An ice skater has a mass of 75 kg, when standing on one leg on the ice their skate has a surface area of 0.5 cm^2. What is the pressure exerted by the skater on the ice?

m = 75 kg
A = 0.5 cm^2 = 0.5 x 10^{-5} m^2
F = mg = 75 x 9.8 = 235 N
P = ?

P = 235/0.5 x 10^{-5}
P = 4.7 x 10^7 Pa

Pressure in everyday situations

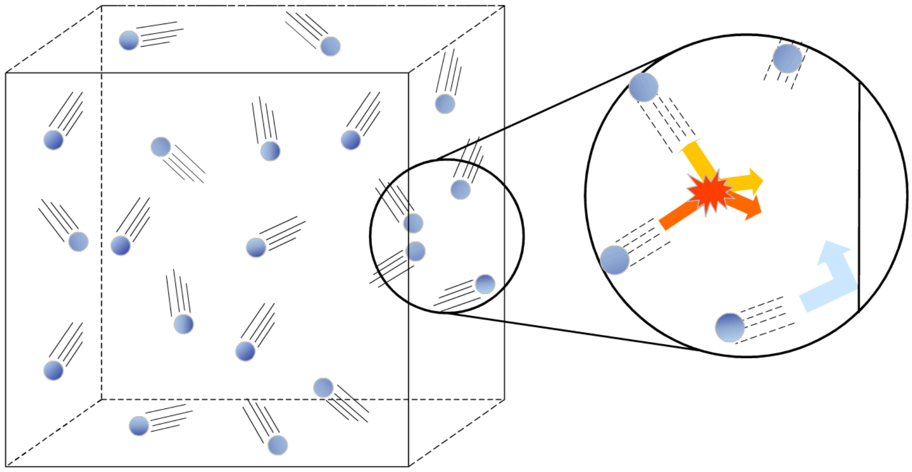
A knife has a very small surface area creating a large pressure. This allows food to be cut more easily.

An elephant has a large total foot surface area, preventing it from sinking into the Earth's surface.

Gas Pressure

A gas consists of very small particles, which are all very far apart and which all move randomly at high speeds. The study of gases by treating them as particles free to move in any direction is known as **Kinetic Theory**. These particles collide with one another and with anything else they come in contact with. Each time a particle collides with a wall of the container, it exerts a force on the wall. Thus with particle continuously bombarding the container walls, the gas exerts a pressure on the container.

Diagram showing gas particle collisions in a container.



http://www.docstoc.com/docs/113002286/Kinetic-Molecular-Theory---PowerPoint

Temperature, energy and the kinetic model

As discussed above, the temperature of an object is a measure of the mean kinetic energy of its particles. The most common everyday temperature scale is the Celsius scale (often referred to as the centigrade scale). This scale is based on the freezing (0 °C) and boiling point of water (100 °C). However the SI unit of temperature is the Kelvin (K). On the Kelvin scale, water freezes at 273 K and boils at 373 K. (Note that a temperature in Kelvin is written as, say, 300 K and not 300 °K.) Like the Celsius scale, the difference between the boiling and freezing points of water is 100 units on the Kelvin scale, which means that a **temperature *difference* of 1 K is equal to a temperature difference of 1 °C**. So the size of a temperature unit is the same on both scales. The scales differ in the point at which zero is defined, **0 K** is defined as the point at which the particles of a substance **have no kinetic energy.** 0 K is equivalent to -273 °C.

To convert between Kelvin and Celsius :-

$$\text{Temperature in K} = \text{Temperature in } ^{o}\text{C} + 273$$

To convert between Celsius and Kelvin :-

$$\text{Temperature in } ^{o}\text{C} = \text{Temperature in K} - 273$$

Pressure and Volume (Boyle's Law)

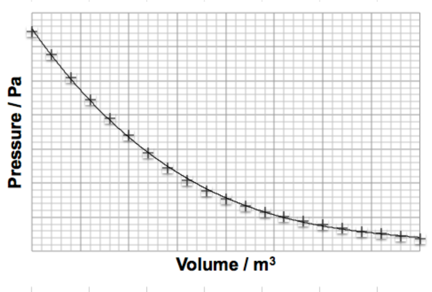
Using the apparatus below, the volume of a gas can be changed and any corresponding change in Pressure measured. The mass and temperature of the gas are fixed.

Syringe

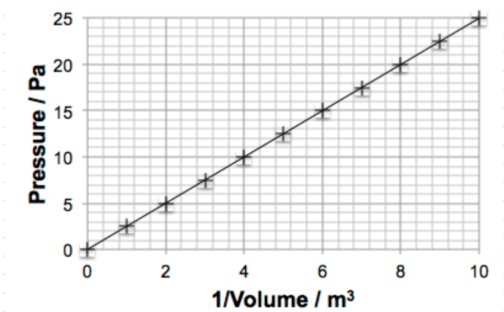
Pressure sensor connected to computer

As the syringe is pushed, the volume decreases, so the pressure increases. We can explain this in terms of the kinetic model. We have seen how the pressure exerted by the gas on its container arises from the collisions of molecules with the container walls. If we have the same number of molecules in a smaller container, they will hit the walls more frequently.

Graph of P versus V



Graph of P versus 1/V



We can state for a fixed mass of gas at constant temperature

$$P \propto \frac{1}{V}$$

or

$$PV = \text{constant}$$

so

$$P_1V_1 = P_2V_2$$

Temperature and Pressure

We will now look at the relationship between the temperature and pressure of a fixed mass of gas, with the volume of the container kept constant.

According to the kinetic theory, the average speed of the gas particles increases with increasing temperature. The hotter the gas, the faster the gas particles are moving. We stated earlier that when a particle collides with a wall of a container a force is exerted. The force exerted depends in the speed of the particle, so the faster the gas particles are moving, the greater the pressure exerted by the gas on the walls of the container.

For a fixed mass of gas at fixed volume,

$$\mathbf{P \propto T}$$

or

$$\mathbf{\frac{P}{T} = constant}$$

Therefore

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

Temperature must be given in Kelvin!

TEMPERATURE – PRESSURE LAW

The pressure of a fixed mass of gas at constant volume is directly proportional to its temperature in kelvin

TEMPERATURE – PRESSURE LAW :- Kinetic Theory Summary

- If the temperature of a sealed container full of gas is increased (and the volume stays the same), the kinetic energy and hence velocity of the gas molecules increases.
- The gas molecules therefore hit the walls of the container harder and more often (with a higher frequency) - so the pressure increases.

Volume and Temperature (Charle's Law)

Consider a fixed mass of gas trapped in a cylinder with a frictionless piston. If the gas is heated, the average speed of the gas particles increases. This means the force exerted on the piston when gas particles collide with it increases. It also means the number of collisions per second will increase. The increased force and rate of collisions act to push out the piston, increasing the volume inside the cylinder and hence the volume of the gas.

Once the piston has been pushed out, the rate of collisions will decrease, as particles now have further to travel between collisions with the piston or the walls. Thus the pressure remains the same - the effects of greater impulse and lower rate of collision balance each other out. The overall effect is that heating a gas causes it to expand, and the relationship between volume and temperature is

$$\mathbf{V \propto T}$$

or

$$\mathbf{\frac{V}{T} = constant}$$

Therefore

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

Temperature must be given in Kelvin!

VOLUME - TEMPERATURE LAW

The volume of a fixed mass of gas at constant pressure is directly proportional to its temperature in kelvin.

VOLUME - TEMPERATURE LAW :- Kinetic Theory Summary

- If the temperature of a sealed container full of gas is increased (and the pressure stays the same), the kinetic energy and hence velocity of the gas molecules increases.
- The gas molecules therefore hit the walls of the container harder and more often (with a higher frequency) - so the walls of the container are pushed outwards (volume increases).

The General Gas Equation

The gas experiment above gives three equations. These can be combined to create the general gas equation.

$$\mathbf{PV = constant}$$

$$\mathbf{\frac{V}{T} = constant}$$

$$\mathbf{\frac{P}{T} = constant}$$

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

Worked Examples

An air bubble at the bottom of the sea occupies a volume of 4.00×10^{-6} m^3. At this depth, the pressure is 2.50×10^7 Pa and the temperature is 275 K. Calculate the volume of the bubble when it has risen to a point where the pressure is 5.00×10^6 Pa and the temperature is 280 K, assuming the bubble contains a fixed mass of air.

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

$$\frac{2.50 \times 10^7 \times 4.00 \times 10^{-6}}{275} = \frac{5.00 \times 10^6 \times V_2}{280}$$

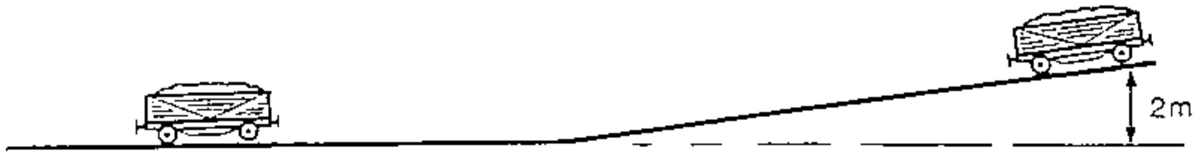
$$0.364 = 17857\ V_2$$

$$V_2 = 2.04 \times 10^{-5}\ m^3$$

Tutorial Questions

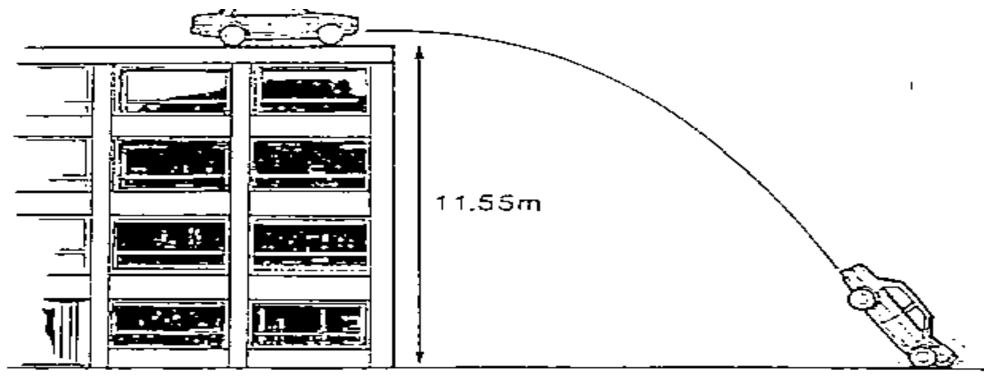
Conservation of energy

1. In a railway shunting yard, wagons are allowed to run down a slope as shown below. A wagon of mass 900 kg starts from rest and runs down the slope.



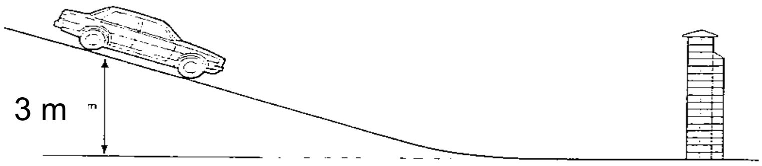
   a) Calculate the amount of gravitational potential energy it loses as it runs down the slope.
   b) Ignoring any energy losses due to friction, state its total gain in kinetic energy as it runs down to the bottom of the slope.
   c) Calculate its speed at the bottom of the slope.
   d) When the wagon is moving along the level part of the yard frictional forces slow it down. How much work will have to be done by friction to stop it?
   e) The wagon applies its brakes so that the total frictional force applied to it is 200 N. Calculate the distance required to stop the wagon.
   f) If frictional forces, such as air resistance, had not been ignored in parts (b) and (c) what would the effect be on the speed of the wagon at the bottom of the slope? Explain your answer.

2. In a TV advert to demonstrate the safety features of a car, the manufacturers drive it off the top of a building at a speed of 5 m s^{-1}, as shown in the diagram below. The mass of the car is 1000 kg and the height of the building is 11.55 m.



   a) Calculate the kinetic energy of the car as it drives off the roof.
   b) Calculate the gravitational potential energy that the car loses as it falls to the ground.
   c) What then will be its total kinetic energy as it hits the ground?

3. A 900 kg car is parked on a hill when its handbrake starts to slip. The car runs down the hill, crashing into a wall at 6 m s^{-1}.

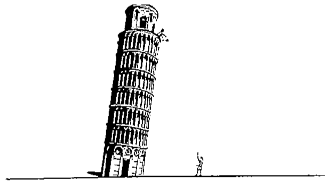


   a) How much gravitational potential energy did the car lose as it ran down the hill?
   b) What was the car's kinetic energy as it hit the wall?
   c) The slipping brake heated up as the car ran down the hill. How much heat energy was produced at the brake pads?

4. A part falls off a helicopter, at a height of 720 m. With what speed will it hit the ground?

5. When Galileo dropped metal spheres of different mass from the leaning tower of Pisa, he found that they hit the ground at the same time.

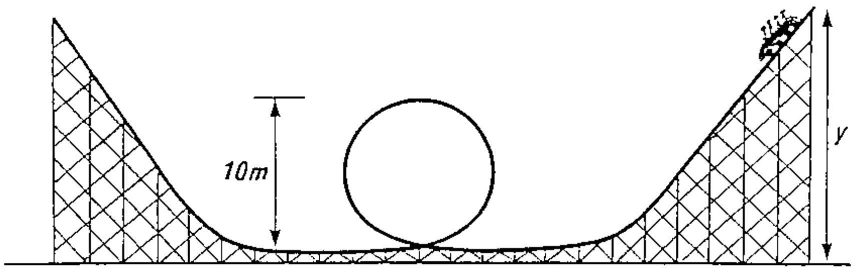
   How can his discovery be explained in terms of conservation of energy?



6. A 50 kg girl on a 15 kg bicycle is moving at a constant speed of 5 m s^{-1}. She applies her brakes and comes to rest in 2 seconds.

   a) What is the kinetic energy of the girl plus her bicycle before she brakes?
   b) What becomes of this kinetic energy during the braking?
   c) Calculate the power of the brakes in watts.

7. A fun ride is being designed so that a carriage with 20 people in it will be raised to a height of y metres, be released and then will go round a loop and stop going up another slope. The carriage has to reach a speed of 7.07 m s^{-1} at the top of the 10 m high loop. The carriage and passengers are expected to have a total mass of 2500 kg.



   a) Calculate the kinetic energy of the full carriage at the top of the loop.
   b) Calculate its gravitational potential energy at the top of the loop.
   c) What will be its total kinetic energy as it enters the loop?
   d) What will be its total gravitational potential energy at height y?
   e) Calculate the height y.
   f) Calculate the maximum speed the carriage will reach during the ride.

Specific Heat Capacity

Use the table of specific heat capacities page 7 to help you with these questions.

1. Define heat and temperature and explain the difference between them.

2. Using the **table of specific heat capacities,** answer the following:
   a) Do liquids or solids have higher specific capacities?
   b) Which category of solids has the lowest specific heat capacities?
   c) Which materials will be best at storing heat?
   d) Explain the effect on weather of being a country surrounded by the sea?

3. What is meant by the term "Specific Heat Capacity"?

4. What is the heat energy required to heat 4.5 kg of oil from 25 °C to 95 °C?

5. A 2 kg block of iron is heated to 200 °C, it is then left to cool to 50 °C. How much heat energy has been dissipated to the surrounding area?

6. What mass is a block of lead if its temperature increases by 4 °C when it gains 1800 J of heat energy?

7. An 0.5 kg block of an unknown material is found to increase in temperature by 10 °C when the heat energy increases by 400 J. What is the material?

8. Fill in the following table

Change in Heat Energy / J	Specific Heat Capacity / J/kg°C	Mass /kg	Change in temperature /°C
a)			
	b)		
		c)	
			d)

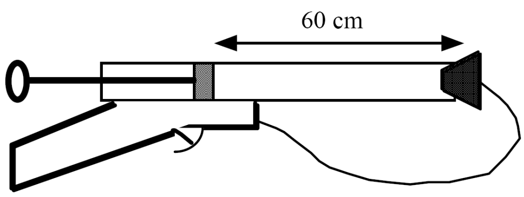
Pressure and volume (constant temperature)

1. 100 cm^3 of air is contained in a syringe at atmospheric pressure (10^5 Pa). If the volume is reduced to a) 50 cm^3 or b) 20 cm^3 without a change in temperature, what will be the new pressures?

2. If the piston in a cylinder containing 300 cm^3 of gas at a pressure of 10^5 Pa is moved outwards so that the pressure of the gas falls to 8×10^4 Pa, find the new volume of the gas.

3. A weather balloon contains 80 m^3 of helium at normal atmospheric pressure of 10^5 Pa. What will be the volume of the balloon at an altitude where air pressure is 8×10^4 Pa?

4. The cork in a pop-gun is fired when the pressure reaches 3 atmospheres. If the plunger is 60 cm from the cork when the air in the barrel is at atmospheric pressure, how far will the plunger have to move before the cork pops out?



5. A swimmer underwater uses a cylinder of compressed air that holds 15 litres of air at a pressure of 12000 kPa.
   a) Calculate the volume this air would occupy at a depth where the pressure is 200 kPa.
   b) If the swimmer breathes 25 litres of air each minute at this pressure, calculate how long the swimmer could remain at this depth (assume all the air from the cylinder is available).

Pressure and temperature (constant volume)

1. Convert the following Celsius temperatures to Kelvin.
   a) -273 °C b) -150 °C c) 0 °C d) 27 °C e) 150 °C

2. Convert the following Kelvin temperatures to Celsius.
   a) 10 K b) 23 K c) 100 K d) 350 K e) 373 K

3. A cylinder of oxygen at 27 °C has a pressure of 3×10^6 Pa. What will be the new pressure if the gas is cooled to 0 °C?

4. An electric light bulb is designed so that the pressure of the inert gas inside it is 100 kPa (normal air pressure) when the temperature of the bulb is 350 °C. At what pressure must the bulb be filled if this is done at 15 °C ?

5. The pressure in a car tyre is 2.5×10^5 Pa at 27 °C. After a long journey the pressure has risen to 3.0×10^5 Pa. Assuming the volume has not changed, what is the new temperature of the tyre?

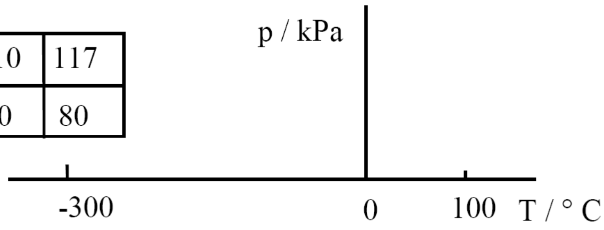
6. A compressed air tank which at room temperature of 27 °C normally contains air at 4 atmospheres, is fitted with a safety valve which operates at 10 atmospheres. During a fire the safety valve was released. Estimate the average temperature of the air in the tank when this happened.

7.
   a) Describe an experiment to find the relationship between the pressure and temperature of a fixed mass of gas at constant volume. Your answer should include:

i. A labelled diagram of the apparatus
ii. A description of how you would use the apparatus
iii. The measurements you would take.

b) Use the following results to plot a graph of pressure against temperature in °C using axes as shown below.

Pressure / kPa	91	98	104	110	117
Temperature / ° C	0	20	40	60	80



i. Explain why the graph you have drawn shows that pressure does not vary directly as Celsius temperature.
ii. Explain how the graph can be used to show direct variation between temperature and pressure if a new temperature scale is introduced.
iii. Use the graph to estimate the value in °C of the zero on this new temperature scale.

c) Use the particle model of a gas to explain the following:
i. Why the pressure of a fixed volume of gas decreases as its temperature decreases
ii. Why the pressure of a gas at a fixed temperature decreases if its volume increases
iii. What happens to the molecules of a gas when Absolute Zero is reached?

Volume and temperature (constant pressure)

1. Describe an experiment to find the relationship between the volume and temperature of a fixed mass of gas at constant pressure. Your description should include:
   a) A diagram of the apparatus used
   b) A note of the results taken
   c) An appropriate method to find the relationship using the results.

2. 100 cm^3 of a fixed mass of air is at a temperature of 0 °C. At what temperature will the volume be 110 cm^3 if its pressure remains constant?

3. Air is trapped in a glass capillary tube by a bead of mercury. The volume of air is found to be 0.10 cm^3 at a temperature of 27 °C. Calculate the volume of air at a temperature of 87 °C.

4. The volume of a fixed mass of gas at constant temperature is found to be 50 cm^3. The pressure remains constant and the temperature doubles from 20 °C to 40 °C. Explain why the new volume of gas is not 100 cm^3.

General gas equation questions

1. Given, for a fixed mass of gas, $p \propto T$ and $p \propto 1/V$, derive the general gas equation.

2. Find the unknown quantity from the readings shown below for a fixed mass of gas.

   a) $p_1 = 2 \times 10^5$ Pa $V_1 = 50$ cm^3 $T_1 = 20$ °C
   $p_2 = 3 \times 10^5$ Pa $V_2 = ?$ $T_2 = 80$ °C

   b) $p_1 = 1 \times 10^5$ Pa $V_1 = 75$ cm^3 $T_1 = 20$ °C
   $p_2 = 2.5 \times 10^5$ Pa $V_2 = 100$ cm^3 T2 = ?

   c) $p_1 = 2 \times 10^5$ Pa $V_1 = 60$ cm^3 $T_1 = 20$ °C
   $p_2 = ?$ $V_2 = 80$ cm^3 $T_2 = 150$ °C

   d) $p_1 = 1 \times 10^5$ Pa $V_1 = 75$ cm^3 $T_1 = ?$
   $p_2 = 2.5 \times 10^5$ Pa $V_2 = 50$ cm^3 $T_2 = 40$ °C

3. A sealed syringe contains 100 cm^3 of air at atmospheric pressure 10^5 Pa and a temperature of
   27 °C. When the piston is depressed the volume of air is reduced to 20 cm^3 and this produces a temperature rise of 4 °C. Calculate the new pressure of the gas.

4. Calculate the effect the following changes have on the pressure of a fixed mass of gas.
   a) Its temperature (in K) doubles and volume halves.
   b) Its temperature (in K) halves and volume halves.
   c) Its temperature (in K) trebles and volume quarters.

5. Calculate the effect the following changes have on the volume of a fixed mass of gas.
   a) Its temperature (in K) doubles and pressure halves.
   b) Its temperature (in K) halves and pressure halves.
   c) Its temperature (in K) trebles and pressure quarters.

6. Explain the pressure-volume, pressure-temperature and volume-temperature laws qualitatively in terms of the kinetic model.

Numerical Answers

Conservation of Energy

1. a) 18 000J b) 18 000 J c) 6.3 m/s d) 18 000 J e) 90 m f) –
2. a) 12 500 J b) 115 500 J c) 128 000 J
3. a) 27 000 J b) 16 200 J c) 10 800 J
4. 120 m/s
5. -
6. a) 812.5 J b) transferred to heat c) 406 W
7. a) 62 500 J b) 250 000 J c) 312 500 J d) 312 500 J e) 12.5 m f)15.8 m/s

Pressure and volume (constant temperature)

1. a) 2 $x10^5$ Pa b) 5 $x10^5$ Pa
2. 375 cm^3
3. 100 m^3
4. 40 cm
5. a) 900 litres b) 36 minutes

Pressure and temperature (constant volume)

1. a) 0K b) 123K c) 273K d) 300K e) 423K
2. a) –263°C b) –250°C c) –173°C d)77°C e) 100°C
3. 2.73 $x10^6$ Pa
4. p = 4.6 $x10^4$ Pa
5. T = 87 °C.
6. T = 477 °C.
7. –

Volume and temperature (constant pressure)

1. -
2. 300 K
3. 0.012 cm3
4. –

General gas equation questions

1. -
2. a) 40 cm^3 b) 977 K c) 2.2×10^5 Pa d) 188 K
3. 5.1×10^5 Pa
4. -
5. -
6. -