Q+A

Questions and Answers

NATIONAL PHYSICS

Unit 1 Thermal, Nuclear and Electrical Physics

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SET 1 The Kinetic Theory of Matter

1. What are the three major statements that summarise the kinetic particle theory?

2. What is our concept of temperature in the kinetic theory of matter?

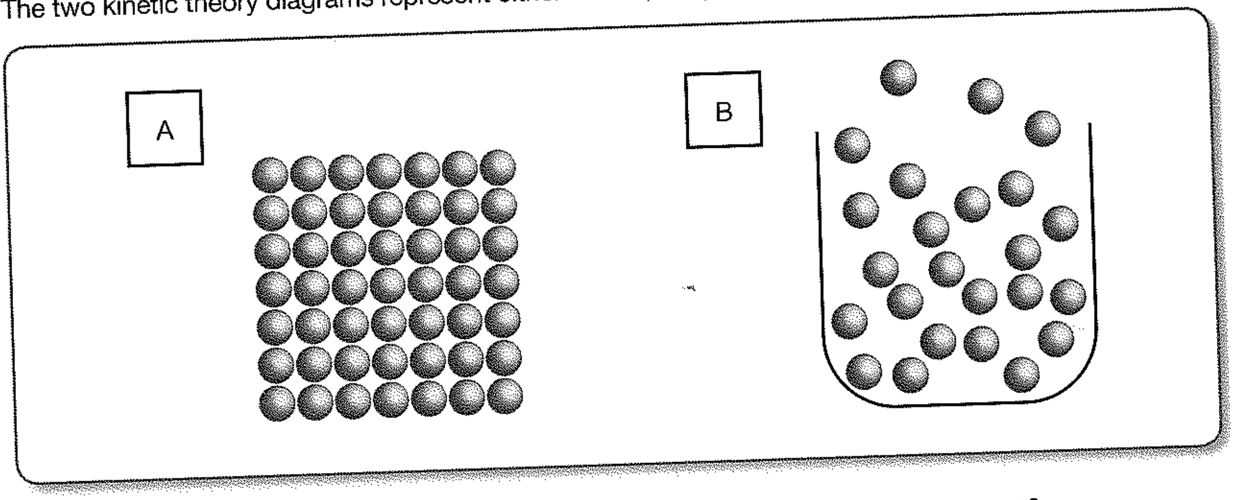
3. Explain why the kinetic theory of matter can only be considered a *theory*, or perhaps a *model* and not a series of statements of facts.

4. (a) What do we use the kinetic theory of matter for?

(b) Is the kinetic theory a good theory? Explain your answer.

(c) When will we need to change the kinetic theory of matter?

5. (a) The two kinetic theory diagrams represent either a solid, a liquid or a gas. Which represents which?



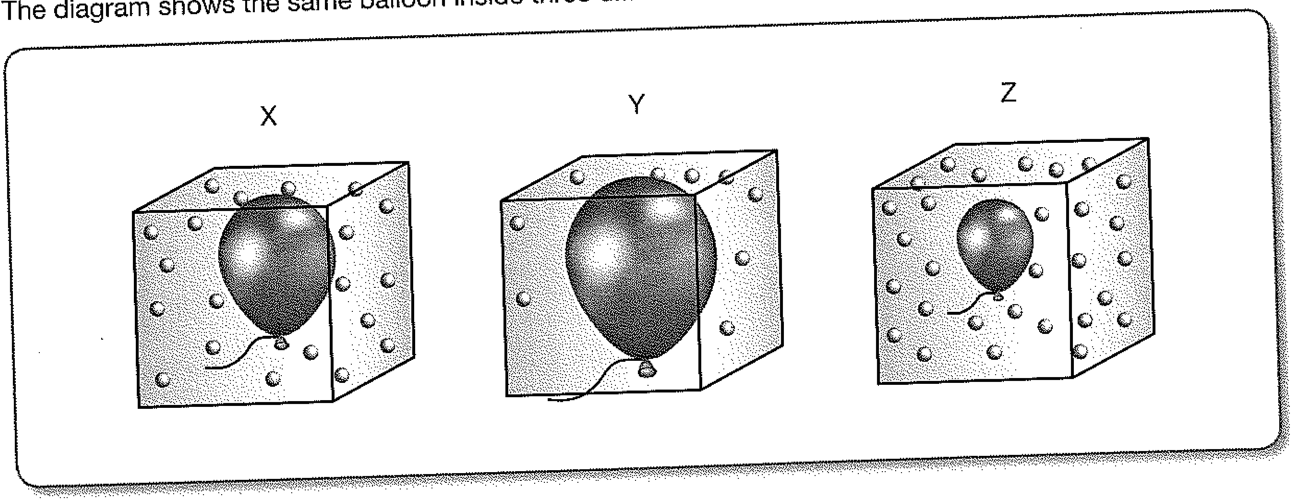
(b) What features in the diagram enable you to identify the state of matter they represent?

(c) How will the diagram for the third state of matter differ from these two diagrams?

(d) In what ways will the diagram for the third state of matter be similar to these two?

(e) Describe the movement of the particles in the three states of matter.

6. The diagram shows the same balloon inside three different containers.



(a) Account for the different sizes of the balloons inside each container.

(b) What property of the diagram allows you to answer (a)?

SET 2 Kinetic Theory and Properties of Matter

1. Complete the tables to list and explain how each kinetic theory diagram illustrates four properties of the solid, liquid or gas.

Solids	
Property	Feature of diagram

Liquids	
Property	Feature of diagram

Gases	
Property	Feature of diagram

2. Use the kinetic theory in the same way as the examples above to explain each of the following facts.

	Fact	Kinetic theory explanation
(a)	Concrete cannot be compressed.	
(b)	Glass does not diffuse.	
(c)	If a person is wearing perfume, we notice.	
(d)	A paper towel is used to mop up spillages.	
(e)	Drops of dye will spread through a glass of water.	
(f)	A metal bar can be bent without breaking.	
(g)	You can break a small branch from a tree, but not a metal rod the same diameter.	
(h)	Liquids diffuse into each other, solids don't.	
(i)	Gases fill their containers.	
(j)	It is easy to put lipstick on your lips.	
(k)	Compressed air pumps are used to blow up jumping castles.	
(l)	Cooking oil can be sprayed on the barbeque plate from a spray can.	
(m)	The bathroom mirror fogs up when you take a hot shower.	
(n)	Car tyres can blow out at fast speeds on a hot day.	

SET 3 Temperature and the Kinetic Theory

1. Copy and complete the following sentences.

(a) Temperature is a measure of how ....

(b) Temperature is a measure of the average ....

(c) The higher the temperature, the ....

(d) When matter is heated its particles absorb ....

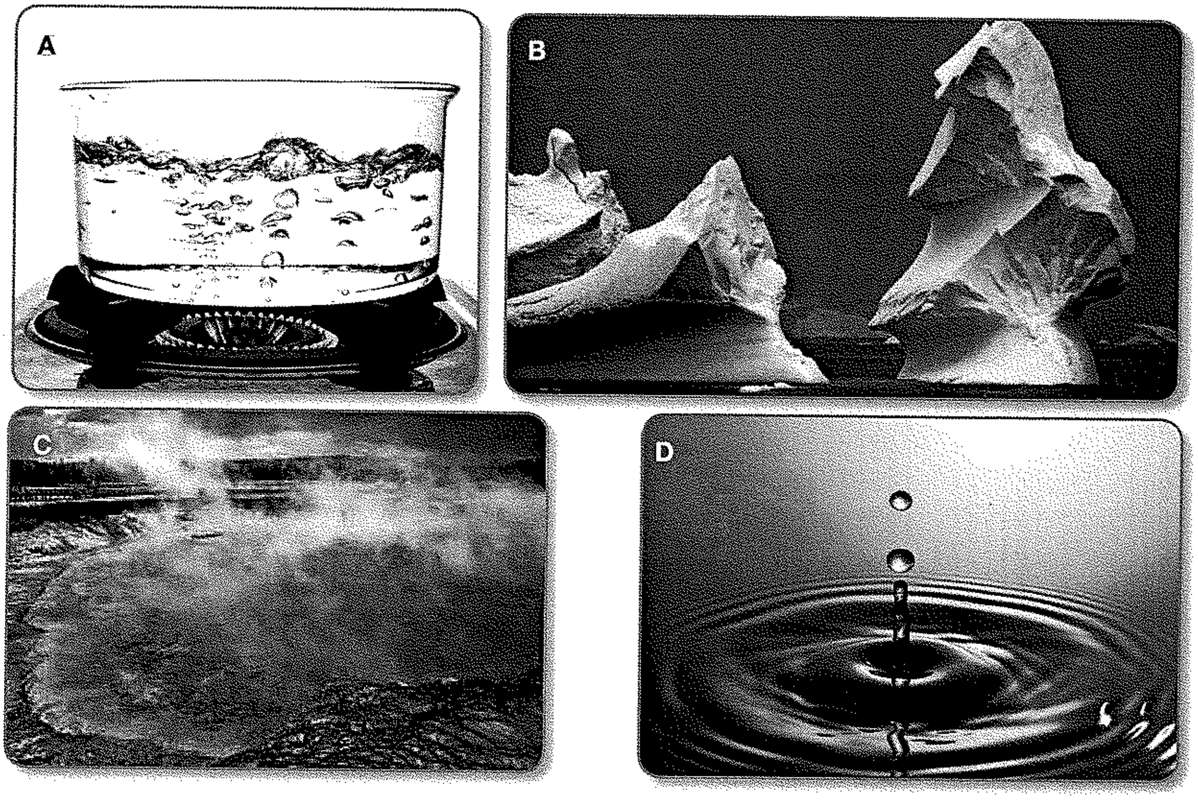
(e) When matter is cooled its particles ....

(f) Gas particles have more energy due to their state than ....

(g) Similarly, liquid particles have more energy than ....

(h) In both cases (f) and (g), this is due to the extra energy they have because ....

2. Consider the following photos which show a container of boiling water, icebergs, a boiling thermal pond with steam at 100°C, and water drops.



(a) In which picture will the water particles be moving most slowly? Justify your answer

(b) In which will the particles have the most kinetic energy? Justify your answer.

(c) Rank the particles in the four states of water in order from slowest to fastest.

(d) Steam at 100°C will actually cause more severe burns to a person than water at 100°C. Hypothesise why this is so.

3. (a) Explain how the kinetic theory of matter predicts an absolute zero temperature.

(b) What is the value of this absolute zero on the centigrade scale of temperature? (Research if needed.)

SET 4 Changes of State and the Kinetic Theory

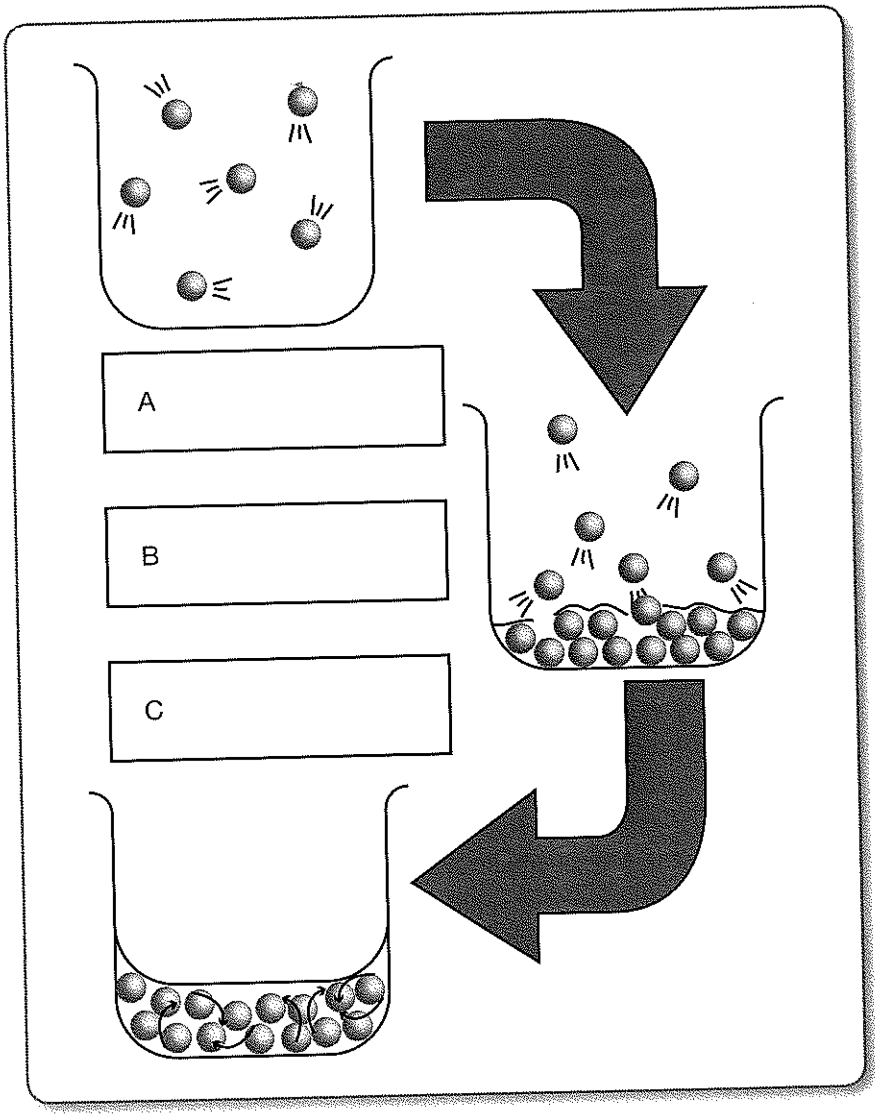
1. Match the sentences halves.

(a) As a solid is heated, its particles move faster
(b) As the particles absorb energy they start to
(c) Eventually, the particles have enough
(d) They then break away from their fixed
(e) At this stage the solid starts to
(f) As more energy is added, the particles in the liquid
(g) Eventually they have enough energy to overcome
(h) They then break away
(i) The liquid evaporates

A melt and become a liquid.
B and becomes a gas.
C and vibrate more violently.
D the forces holding them together.
E energy to totally overcome the forces holding them together.
F from each other and move freely.
G overcome the forces holding them together
H roll around faster and faster.
I positions and roll over one another.

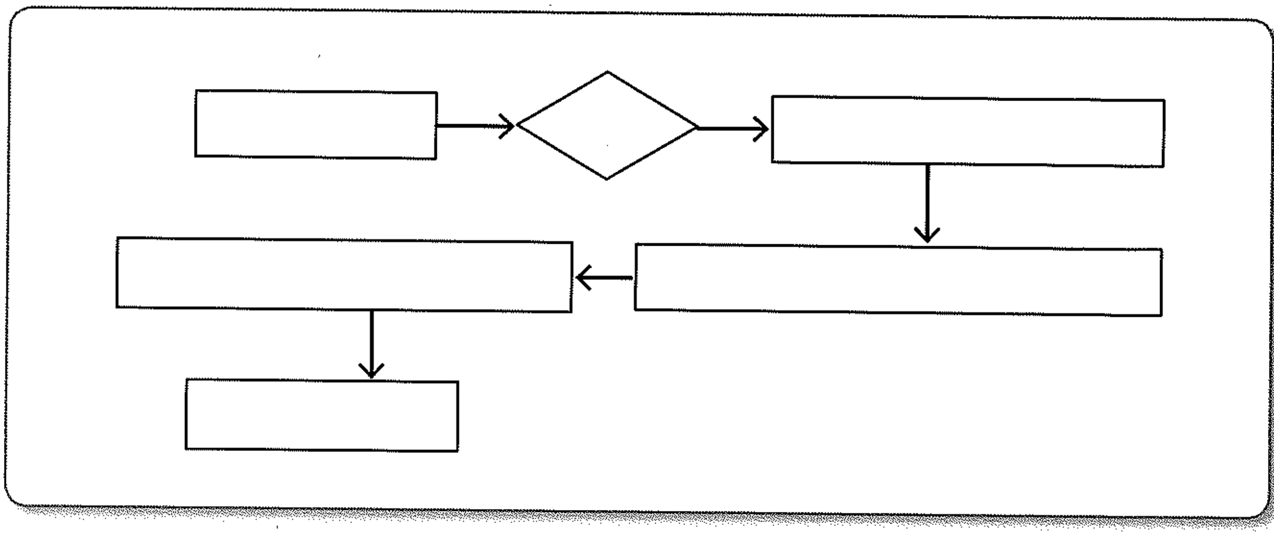
2. The diagram represents a change of state which is occurring at a constant temperature.

(a) Identify the change of state represented by the diagram.
(b) What is happening to the kinetic energy of the particles as this change of state happens?
(c) What is happening to the forces between particles as this change of state happens?
(d) In which of these diagrams do the particles have the least degree of freedom of movement?
(e) Compare the rate of movement of the particles in each of the situations represented in the diagram.
(f) Write an appropriate label for each beaker (A, B and C) in the diagram.



3. Place the following labels in the flow chart.

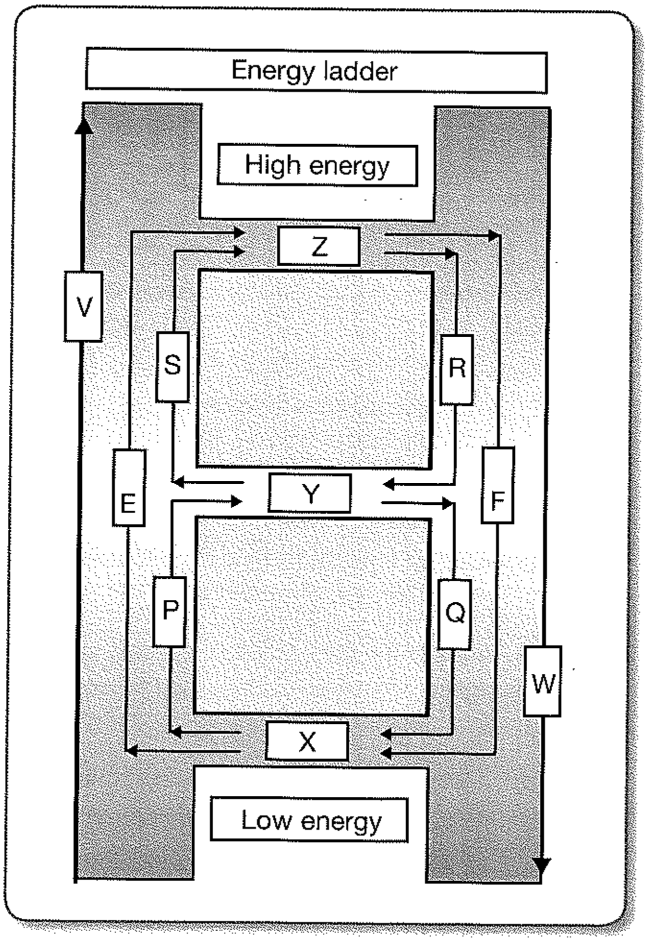
Cooling, Forces between particles pull them closer together, Particles collide with each other less violently, Particles slow down, Solid, Solid contracts



4. The diagram shown is commonly known as an energy ladder. You may have studied a diagram like this in junior school.

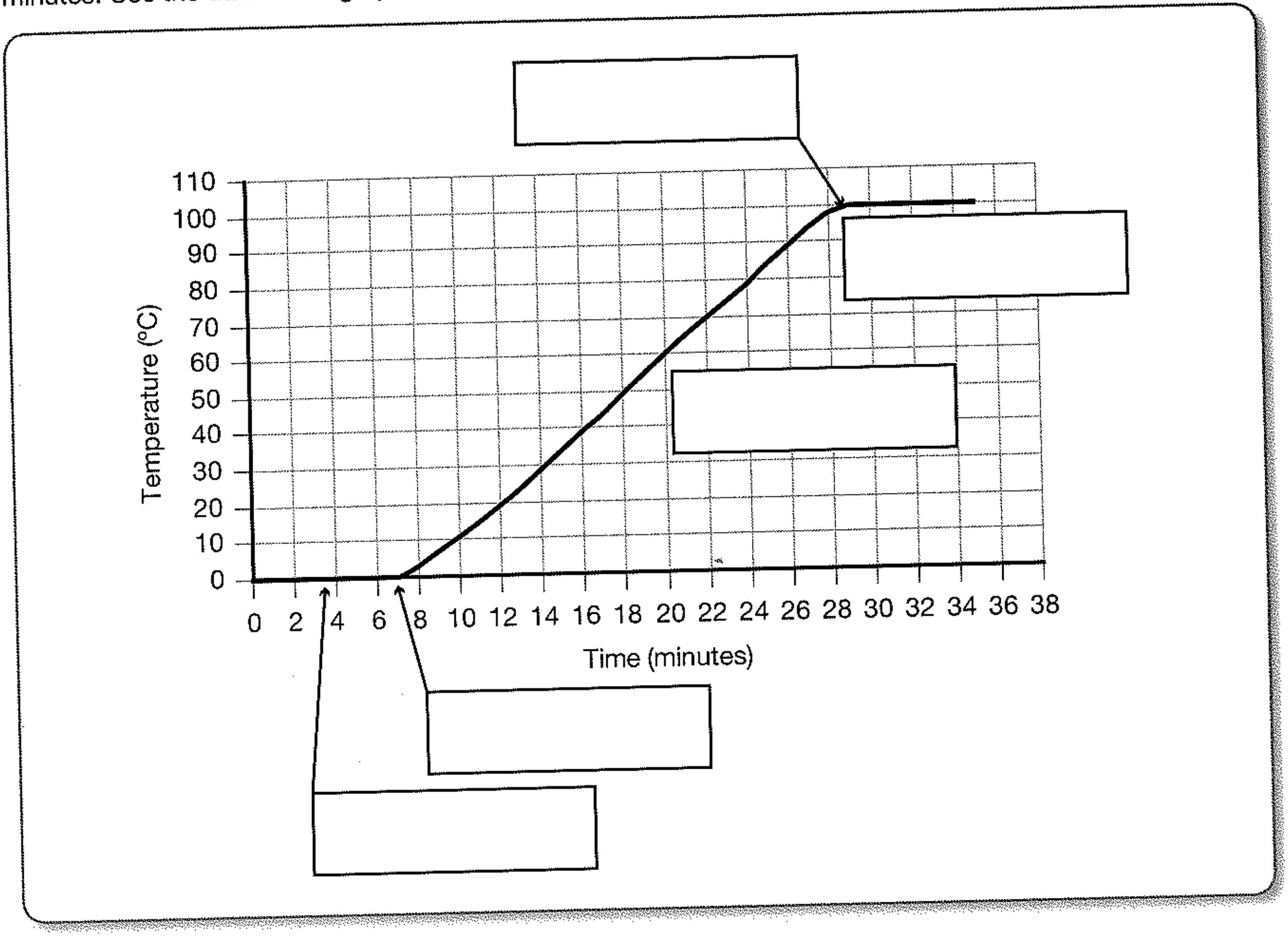
Suggest an appropriate label for each letter on the ladder.

State or process	Name of state or process
E	
F	
P	
Q	
R	
S	
V	
W	
X	
Y	
Z	



SET 5 Changes of State and Latent Energy

1. The graph shows the results of an experiment done by students who heated 100 g of ice gently until it turned into water and the water boiled and evaporated away. All the water had evaporated by time 35 minutes. Use the data in the graph to answer the questions that follow.



(a) Place these labels on the graph in the appropriate positions.
All ice has melted; Ice melting, temperature constant; Water heated, temperature rising; Water starts boiling; Water boiling, temperature constant

(b) During time 0 to time 7 minutes, the ice is being heated gently, but the temperature does not rise. Suggest a reason for this.

(c) During time 28 to time 35 minutes, the water is still being gently heated, but the temperature does not rise. Suggest a reason for this.

2. (a) Clarify the idea of latent energy, giving the units we usually use to measure it.

(b) Define latent heat of fusion, L_f.

(c) What does the energy involved in latent heat of fusion do?

(d) Define latent heat of vaporisation, L_v.

(e) What does the energy involved in latent heat of vaporisation do?

(f) Is latent heat involved in solidification? Explain your answer.

(g) Is latent heat involved in condensation? Explain your answer.

Use the following equations to answer the questions on this page.

When an object changes from solid to liquid, the total amount of energy involved, ΔH, is given by

$$\Delta H = \text{mass of solid} \times \text{latent heat of fusion of the solid} = m \times L_f$$

When an object changes from liquid to gas, the total amount of energy involved, ΔH, is given by

$$\Delta H = \text{mass of liquid} \times \text{latent heat of vaporisation of the liquid} = m \times L_v$$

When any object changes temperature, the total amount of energy involved, ΔH, is given by

$$\Delta H = \text{mass of object} \times \text{specific heat of object} \times \text{temperature change} = m \times c \times \Delta T$$

3. (a) If 12 000 J of energy is required to evaporate 150 g of a liquid, find the specific heat of vaporisation of the liquid.

(b) What volume of this liquid would 2500 J of energy evaporate?

(c) How much energy would be released if a kilogram of the liquid vapour was condensed?

4. (a) If the latent heat of fusion of ice is 334 kJ kg^{-1}, how much energy is requires to melt 200 g of ice?

(b) How much ice will 16 000 J of energy melt?

(c) How much energy would be released if a kilogram of water was frozen?

5. Energy is supplied at a uniform rate to 150 g of ice at 0°C. It melts totally in exactly 6 minutes. The latent heat of fusion of ice is 334 kJ kg^{-1}, and the latent heat of vaporisation of water is 2260 kJ kg^{-1}. The specific heat of water is 4.18 kJ kg^{-1} $°C^{-1}$. Find:

(a) The total energy required to melt the ice.

(b) The rate at which the energy is supplied to the ice.

(c) The additional energy needed to raise the temperature of the water to 100°C.

(d) How long this will take if energy is supplied at the same rate.

(e) The additional energy required to evaporate all the water once it is at 100°C.

(f) How long this will take if energy is supplied at the same rate.

6. An iceblock tray in a refrigerator holds 150 mL of water. It was filled with water from the tap at 15°C and placed in the freezer. 1.25 hours later the last of the water froze to complete the iceblocks. The latent heat of fusion of ice is 334 kJ $kg^{-1}$and the specific heat of water is 4.18 kJ kg^{-1} $°C^{-1}$.

(a) How much energy was removed from the water in this process?

(b) At what rate was the refrigerator removing energy from the water?

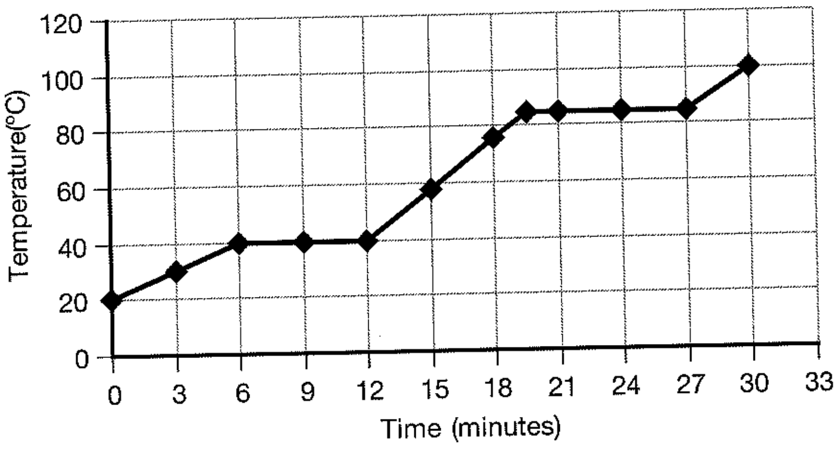
7. 1.5 L of water in a 2400 W electric jug is at 100°C. If the latent heat of vaporisation of water is 2260 kJ kg^{-1}:

(a) Find the energy required to evaporate all the water.

(b) Calculate how long this will take.

(c) How much energy would be released if this mass of water vapour was condensed?

8. The graph shows the temperature-time curve for a 90 g solid which was placed in a well insulated container and heated uniformly by a 1200 W heater. The container can be considered to have had zero mass.



(a) Suggest an aim for this experiment.

(b) Identify the dependent and independent variables in this experiment.

(c) What is the melting point of the solid?

(d) What was the total energy supplied by the heater from the start of the experiment until the last of the water was evaporated?

(e) If the heater was a 240 V heater, what current did it deliver to the heating coil?

(f) Without making any calculations, predict which is larger, the latent heat of fusion, or the latent heat of vaporisation of the substance. Justify your prediction.

(g) Calculate the latent heat of fusion of the substance.

(h) Calculate the latent heat of vaporisation of the substance.

(i) Calculate the specific heat of the liquid substance.

9. It is difficult to put out a fire on a crude oil tanker (or in fact, any oil fire) because each litre of oil releases 2.8×10^7 J of energy when burned.

(a) To illustrate this problem, calculate the amount of water needed to absorb the energy released when 1.00 L of crude oil is burned. Assume that the temperature of the water increases from 20°C to 100°C, before it boils and the resulting steam is heated to 300°C by the energy from the fire.

Take the specific heat of water as 4.18 kJ kg^{-1} $°C^{-1}$, the latent heat of vaporisation of water as 2260 kJ kg^{-1} $°C^{-1}$, and the specific heat of steam as 2.00 kJ kg^{-1} $°C^{-1}$.

(b) Identify additional complications in fighting an oil fire brought about by the fact that oil has a lower density than water.

10. Indigenous people sometimes cook in watertight baskets by placing hot rocks into water to bring it to a boil. What mass of 500°C rock must be placed in 4.00 kg of 15°C water to bring its temperature to 100°C, if 0.0250 kg of water escapes as vapour from the initial sizzle? Neglect the effects of the surroundings and take the specific heat of the granite as 0.79 kJ kg^{-1} $°C^{-1}$. The specific heat of water is 4.18 kJ kg^{-1} $°C^{-1}$ and the latent heat of vaporisation of water is 2260 kJ kg^{-1}.

SET 6 Transferring Heat Energy

In addition to the equations in Set 5, you will need to use the following equation to do the questions in this set.

$Q = mc\Delta T$ Where Q = amount of energy in joules

c = specific heat capacity of the substance involved (specific heat)

ΔT = temperature change effected

And, specific heat capacity, c = the amount of energy required to raise the temperature of 1.0 g of a material by 1°C (units for c = J g^{-1} K^{-1} or J kg^{-1} °C^{-1})

1. State the law of conservation of energy as it holds for heat energy transfers in closed systems.

2. Substance X has a specific heat of 3.6 J kg^{-1} °C^{-1}. Substance Y has a specific heat of 0.6 J kg^{-1} °C^{-1}.

(a) Equal masses of X and Y are heated by an identical source of energy for the same time. What difference will there be in the result? Justify your answer.

(b) Equal masses of X and Y are heated for the same time. At the end of this time they are both at the same temperature. What difference causes this result? Justify your answer.

(c) Masses of X and Y are heated by an identical source of energy for the same time. At the end of this time they are at the same temperature. What difference will there be in the result? Justify your answer.

3. 2500 J of heat energy was used to raise the temperature of 250 g of a metal from 18°C to 36°C. Find the specific heat of the metal.

4. A 250 g piece of metal is heated from 25°C to 150°C. If the specific heat of the metal is 156 J kg^{-1} °C^{-1}, how much heat energy has been absorbed by the metal?

5. 300 g of water at 80°C is mixed with 250 g of water at 60°C in a glass jug. Ignoring any energy transferred to the container and taking the specific heat of water as 4.2 kJ kg^{-1} °C^{-1}, what would be the final temperature of the water?

6. 200 mL of water at 75°C is added to 300 mL of water at 18°C. Taking the specific heat of water as 4.18 kJ kg^{-1} °C^{-1}, what will be the final temperature?

7. 40 mL of milk at 5°C was added to a 200 mL cup of coffee which was initially at 100°C.

(a) Ignoring any heat energy transferred to the cup, what would be the final temperature of the coffee?

(b) If the cup had a mass of 250 g, a specific heat capacity of 800 kJ kg^{-1} °C^{-1}, and was initially at the same temperature as the coffee, what would be the final temperature of the mixture and cup?

8. 400 g of water from the tap is at 20°C. Eight iceblocks, each with a mass of 10 g at 0°C are added. Ignoring any heat transferred to the container, and given that water has a specific heat of 4.2 kJ kg^{-1} °C^{-1}, and the latent heat of fusion of ice is 334 kJ kg^{-1} °C^{-1}, find the final temperature of the glass and the water.

9. A 300 g block of metal with a specific heat of 236 J kg^{-1} °C^{-1} is heated from 10°C to 80°C.

(a) How much heat energy is absorbed by the block?

(b) The hot block of metal is now put into an insulated container with 600 mL of oil at 20°C. The temperature of the oil rises to 55°C. The density of the oil is 0.75 g mL^{-1}. What is the specific heat of the oil?

SET 7 Heat Conduction

1. Complete each of the following sentences by matching the halves.

(a) When we are cooking and need to stir food,
(b) A metal spoon would get hot because
(c) This happens because metals
(d) We use conductors when we want heat
(e) Because of this we use metals to make
(f) Non-metals, like wood,
(g) Non-conductors of heat are
(h) Heat energy does not pass
(i) Air is one of the
(j) Many substances that contain a lot of air, such as cork,
(k) We use insulators when we don't want
(l) So we use wood or plastic handles on saucepans, fibreglass

(A) to travel quickly through something.
(B) heat traveling through something.
(C) we usually use a wooden rather than a metal spoon.
(D) are non conductors of heat.
(E) are good conductors of heat.
(F) best insulators.
(G) lagging on hot water pipes, air cavities in the walls, and polystyrene in picnic baskets.
(H) heat energy from the food can transfer easily into it.
(I) saucepans, barbecue plates, kettles, radiators in cars.
(J) through insulators.
(K) polystyrene foam, fibre glass and wool, are therefore good insulators.
(L) also called heat insulators.

(a)	When we are cooking and need to stir food,
(b)	A metal spoon would get hot because
(c)	This happens because metals
(d)	We use conductors when we want heat
(e)	Because of this we use metals to make
(f)	Non-metals, like wood,
(g)	Non-conductors of heat are
(h)	Heat energy does not pass
(i)	Air is one of the
(j)	Many substances that contain a lot of air, such as cork,
(k)	We use insulators when we don't want
(l)	So we use wood or plastic handles on saucepans, fibreglass

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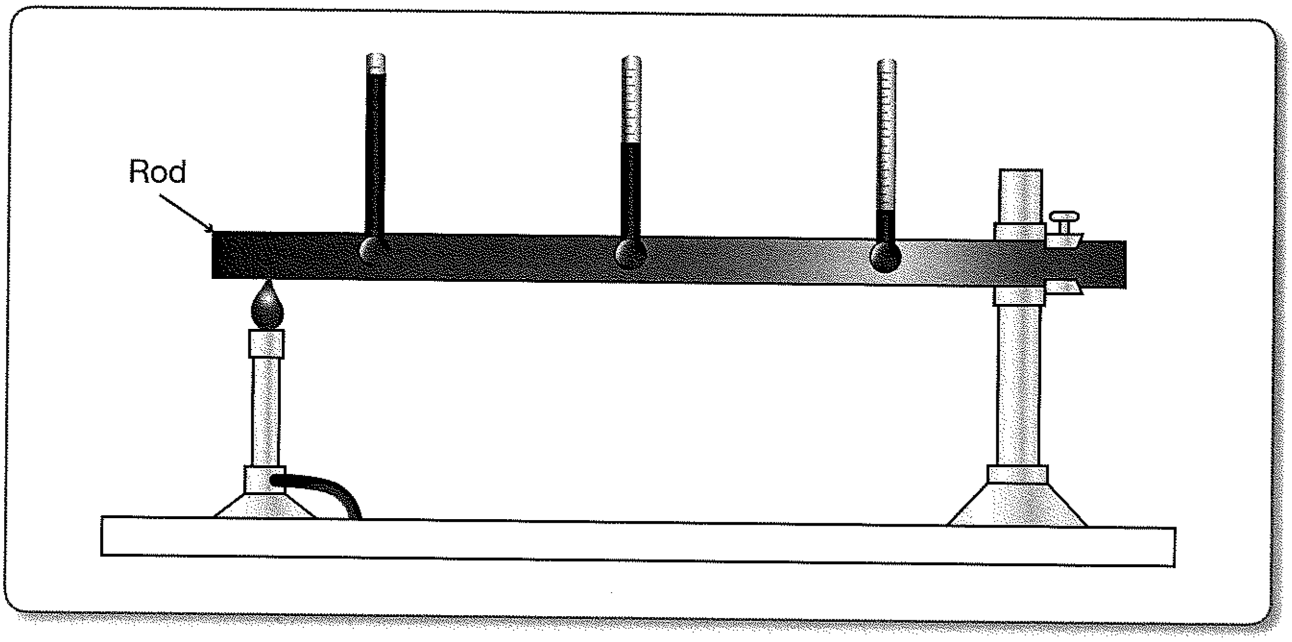
2. The diagram shows apparatus set up for an experiment.



(a) Suggest a purpose for this experiment.

(b) What are the results showing?

(c) What will be the composition of the rod? Justify your answer.

(d) According to this experiment, what is the relationship between the temperature of the rod and the distance from the Bunsen burner?

(e) In terms of the kinetic theory, explain how the heat energy is being transferred through the rod.

(f) How would these results differ if the rod was a glass rod? Explain your answer.

3. (a) One saucepan in the drawer has become tightly wedged inside a second, slightly larger saucepan. How can heat conduction be used to separate them?

(b) If you put your index finger in a cup of water at room temperature, and the index finger of your other hand in a beaker that just contains air, the finger in the water will feel cooler than the finger in the air despite the water and air being at the same temperature. Explain why.

(c) Place one hand flat on your desk, the other on a sheet of metal (or wrap it around the metal leg of a bench stool. Both the desk and the metal will be at the same temperature – the same as air temperature. Will they feel the same or will one feel cooler than the other. If so, which one will feel cooler and explain why.

4. Imagine that you have a glass ice cold orange juice on a picnic table in the shade of a tree. Your friend has an identical glass of iced orange juice on the same table, but this glass is sitting in the sun. You go for a short walk and come back 10 minutes later to find that both glasses have condensed water drops on the outside.

In terms of conduction predict which glass has the most water condensed on the outside of the glass and explain why.

5. Suggest a reason why metals are such good conductors of heat energy.

6. If an iceblock with a piece of copper wire wrapped around it is added to a test tube of water, the iceblock will sink to the bottom. If the water in the tube is now heated halfway up the tube, the water boils but the iceblock does not melt. Explain why.

SET 8 Heat Convection

1. The sentences below describe how a convection current forms. They are not in the correct order. Rewrite them in the correct order.

(a) As the water expands it becomes less dense.

(b) As the water cools down, it becomes denser.

(c) If water is heated, it moves with a circular motion called a convection current.

(d) The cooler, denser water sinks to the bottom of the container to take the place of the rising hot water.

(e) These processes repeat over and over setting up the convection current.

(f) At the top of the container this water cools down.

(g) The less dense water then rises to the top of the container.

(h) More rising hot water from the bottom pushes the cooling water to the side.

(i) Convection currents start because the water at the bottom of a container being heated expands.

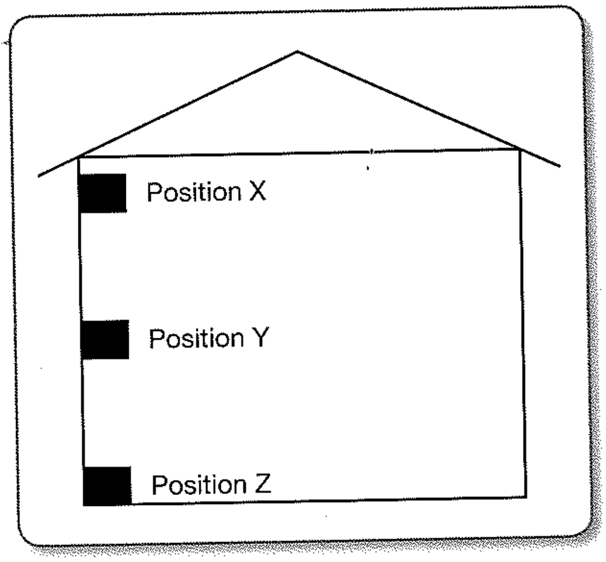
2. (a) In terms of the kinetic theory of matter, explain why convection currents can form in fluids but not in solids.

(b) In terms of the kinetic theory of matter, predict which will transfer energy more efficiently by convection, gases or liquids. Justify your answer.

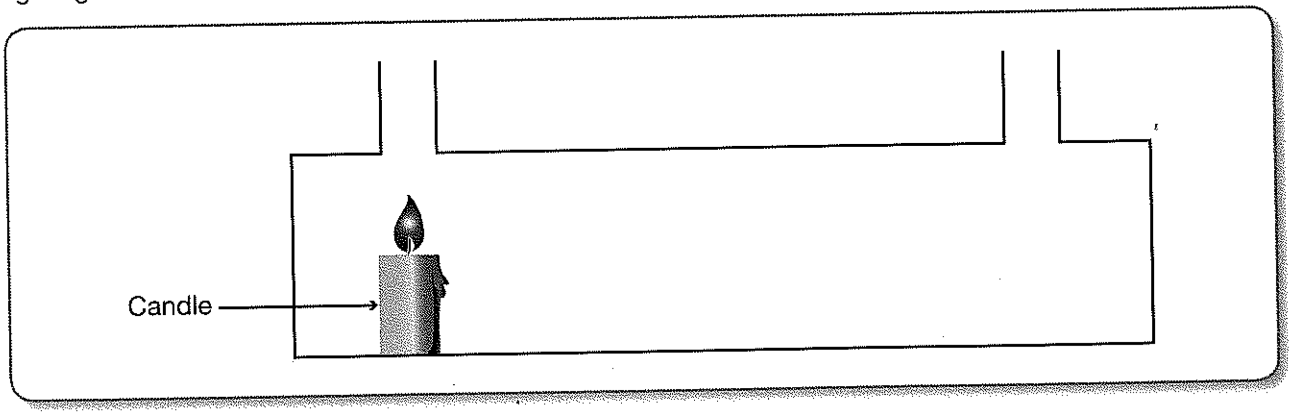
3. The diagram shows a room in a house. Three possible positions to mount a convection heater in the room are shown.

(a) Which position would result in the room being heated most efficiently? Explain your reasoning.

(b) Choose one of the other positions and explain why it would not be as good. Illustrate your answer with a simple, labelled diagram.



4. The diagram shows a simple convection heater. Complete it to show the circulation of air as a result of lighting the candle.



SET 9 Heat Radiation

1. (a) What is heat radiation?

(b) How does heat radiation occur?

(c) When you put your hands in front of a fire you can feel the heat energy from the fire. However, if you put your hands above the fire you feel much more heat energy. Why the difference?

2. (a) How do light coloured objects compare to dark coloured objects in their ability to absorb radiated heat energy?

(b) How do hot, light coloured objects compare to dark coloured objects in their ability to radiate heat energy?

(c) How do shiny objects compare to dull objects in their ability to absorb radiated heat energy?

(d) How do hot, shiny objects compare to hot dull objects in their ability to radiate heat energy?

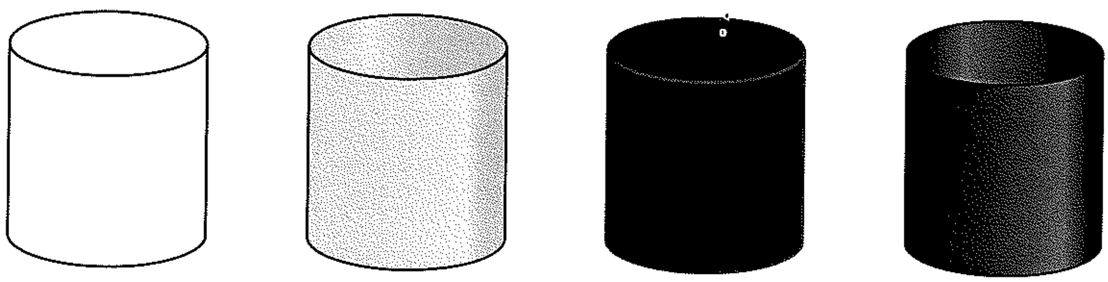
3. (a) Which band of the electromagnetic spectrum is responsible for radiate heat energy?

(b) What is the range of wavelengths of the radiation in this band?

(c) Why this band and not others?

4. Imagine a beaker of water sitting on a wire gauze on a tripod. A lit Bunsen burner is used to heat the water. Explain how heat conduction, heat convection and heat radiation are involved in this process.

5. Consider the following four containers which are each full of water at 80°C.



A Dull white B Shiny white C Dull black D Shiny black

(a) The containers are left to stand for 10 minutes. Rank them from hottest to coolest after the 10 minutes.

(b) The same containers are then filled with tap water at 20°C and placed at a uniform distance from a source of heat. Rank the temperature of the containers from hottest to coolest after 10 minutes of exposure to the heat.

6. (a) Explain why the handles of most saucepans and other containers used for heating substances are painted black.

(b) Why are houses often painted white in hot climates?

(c) What would be the best surface for a teapot in order to keep the tea hot for as long as possible. Explain why.

SET 10 An Experiment on Heat Radiation

The table shows the results a student obtained during an experiment studying an aspect of *heat energy transfer* in which the student placed two containers of water the same distance from an electric heater and measured the temperature of the water every 2 minutes. After 10 minutes, the heater was turned off.

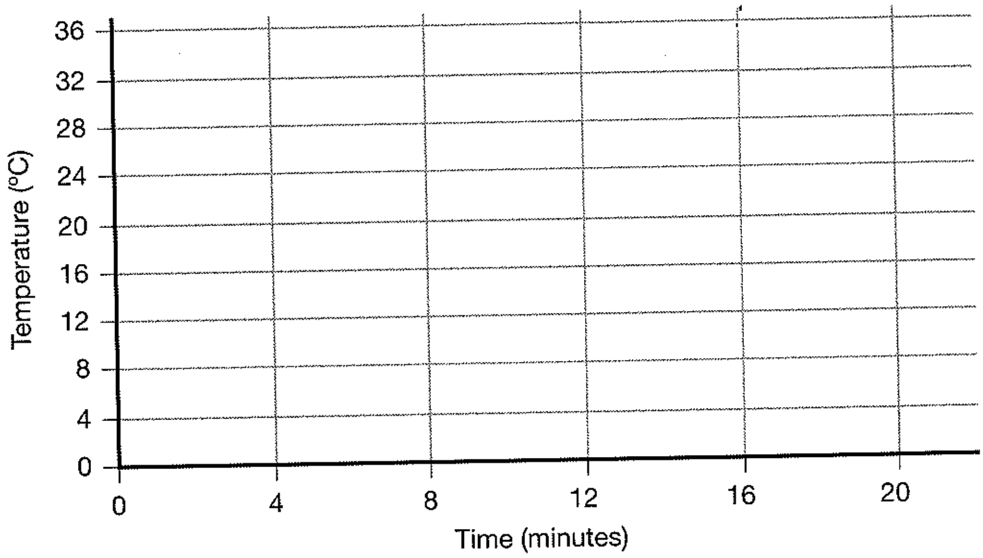
Equipment used

Two metal containers, water, thermometers, a ruler, a watch and an electric radiator.

One metal container had a bright shiny surface, the other was dark and dull.

Time (min)	Temperature of water in container A (°C)	Temperature of water in container B (°C)
0	16	16
2	18	17
4	20	18
6	23	20
8	27	22
10	32	24
12	28	23
14	25	22
16	22	21
18	20	20
20	18	19

1. Graph the two sets of results on the same set of axes provided.



2. For this experiment to have been a fair test, list three things that *must* have been kept constant.

3. Which container was the bright shiny one? Justify your answer.

4. Write a possible aim for the experiment.

5. Write a conclusion for the experiment.

6. Suggest four ways the experiment could be improved.

SET 11 Work Done and Internal Heat Energy

1. Given that $W = P\Delta V$, show that Pa m^3 = joule.

2. A balloon filled with gas is at a pressure of 1.8×10^5 Pa. The gas is heated and allowed to expand from a volume of 2.5 L to a volume of 5.0 L. Its temperature remains constant.

(a) What does the work in this system, the gas or an external source?

(b) How much work is done?

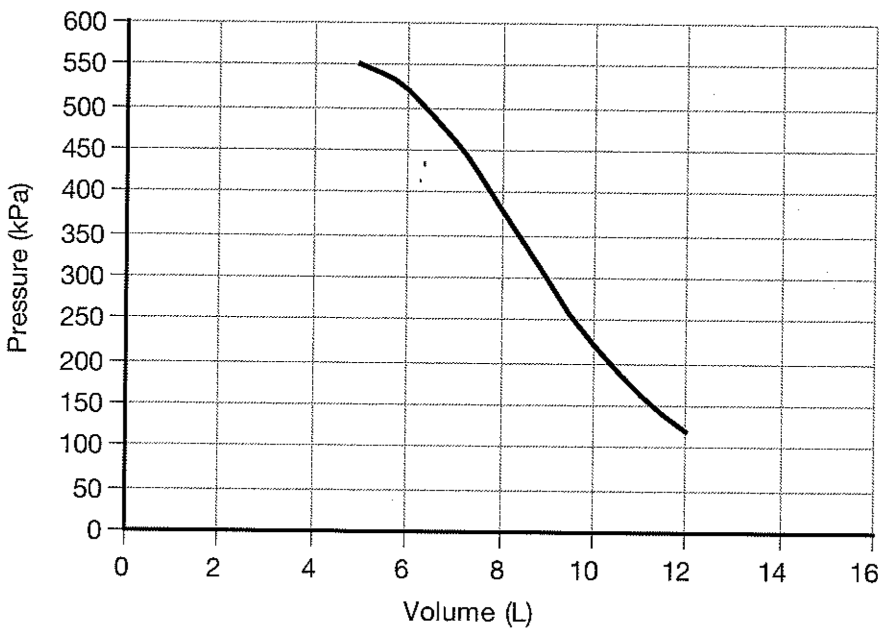
3. As a gas is cooled, the pressure on it is lowered so that its volume remains constant. During this process the pressure changes from 300 kPa to 180 kPa.

(a) Calculate the total work done by the gas in this process. Justify your answer.

The gas is then heated back to its original temperature and allowed to expand while the pressure is kept constant at 180 kPa. During this step, its volume changes from volume of 4.5 L to 8.3 L.

(b) Calculate the change in the heat energy of the gas in the second process.

4. The graph shows how the pressure and volume of 200 g of gas with a heat capacity of 1.75 kJ kg^{-1} $°C^{-1}$ changes over a period of time.



(a) How much work was done on this gas?

(b) If all the work done was converted into thermal energy, by how much did the temperature of the gas rise?

5. A cylinder with a frictionless, movable piston of negligible mass contains 0.7 m^3 of a gas. 4.0×10^5 J of work is done on the gas causing it to expand and push the cylinder upwards. The initial pressure of the gas was 2×10^5 Pa and its temperature at the end of the process is the same as its temperature at the start.

(a) What is the final volume of the gas?

(b) Draw a *P-V* graph to illustrate this process.

6. A gas is enclosed in a container which has a frictionless, movable piston. The system is heated until it has absorbed 605 J of energy. This causes the gas to expand and in doing so it does 375 J of work.

(a) In what way does the gas do work?

(b) What will be the increase in the internal energy of the gas?

(c) What will be the consequence of the increase in the internal energy of the gas?

(d) What additional information is needed in order to calculate the temperature increase of the gas?

7. The temperature of 125 g of water is raised from 2.5°C to 17.8°C. Given the specific heat of water as 4.18 J g^{-1} °C^{-1}, calculate the increase in the internal energy of the water.

8. The heat capacity of an 80 g ceramic cup is 0.82 J g^{-1} °C^{-1}. When it is filled with hot coffee its temperature rises from 21°C to 92°C.

(a) By how much does its internal energy increase?

(b) If the specific heat and density of the coffee is the same as that of water, what volume of coffee was added to the cup? Assume the water used to make the coffee was boiling at the time it was made.

9. 5.60 L of air is heated in a container with a piston which allows it to expand and maintain a constant pressure of 110 kPa. The final volume of the gas was 9.5 L. How much work was done on the air?

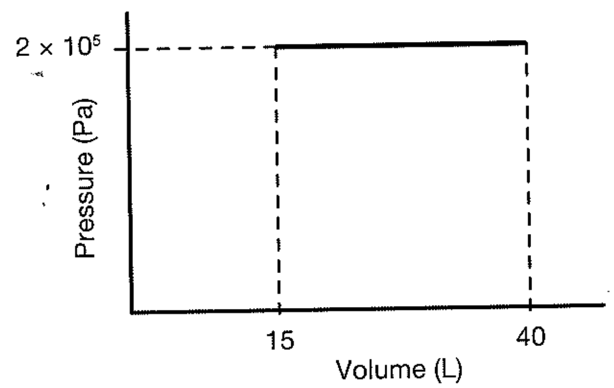
10. In an experiment, a 15 L sample of a gas is initially at 180°C and 2.0×10^5 Pa , and is contained in a cylinder with a freely moving piston. It was heated at constant pressure until its volume had increased to 40 L. The graph represents this experiment.

(a) What does the area under the graph represent?

(b) How much work is done by the gas in expanding?

(c) How much work would be done to compress it back to its original volume?

(d) Predict what happens to the temperature of the gas as it firstly expands and is then compressed again.



11. What will be the change in the internal energy of a system which has 2500 J of work done on it and then does 7500 J of work on its surroundings?

12. (a) An enclosed gaseous system loses 500 J of energy as it expands. How would this loss of energy be noticed by an observer?

(b) 1500 J of work is then done on the system by an external force. What two observations would indicate that this work had been done on the system?

(c) What is the overall change in the internal energy of the system?

13. A volume of gas in a container which has a freely moving piston is kept at a constant pressure of 80.0 kPa while its volume is decreased by 20 L.

(a) How much work is done on this system?

(b) What is the change in the internal energy of the system?

SET 12 The Development of Thermodynamics

1. Which of the following laws of physics becomes the foundation of thermodynamics?
(A) Newton's laws of motion.
(B) Law of conservation of energy.
(C) Law of universal gravitation.
(D) Law of conservation of momentum.

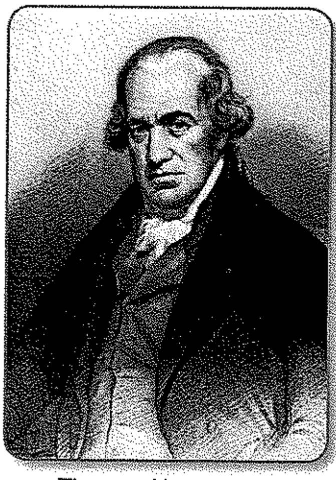
2. The word *thermodynamics* stems from two Greek words meaning:
(A) Conservation of heat.
(B) Interactions of heat.
(C) Study of heat.
(D) Movement of heat.

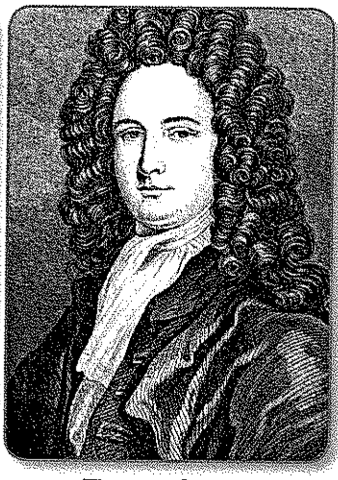
3. When heat is added to a system, all of the following may happen *except*:
(A) Increase in internal energy.
(B) Decrease in the system's temperature.
(C) External work is done by the system.
(D) Increase in the pressure in the system.

4. (a) What is thermodynamics?
(b) What was the main reason the science of thermodynamics started?

5. Four scientists involved in the invention and development of the steam engine were:
- Thomas Savery (1650-1715).
- Thomas Newcomen (1664-1729).
- Nicolas Leonard Sadi Carnot (1796-1832).
- James Watt (1736-1819).

Research the contribution of each of these scientists in this endeavour and write brief summary notes to outline their contributions.


Thomas Newcomen
(1664-1729)


Thomas Savery
(1650-1715)

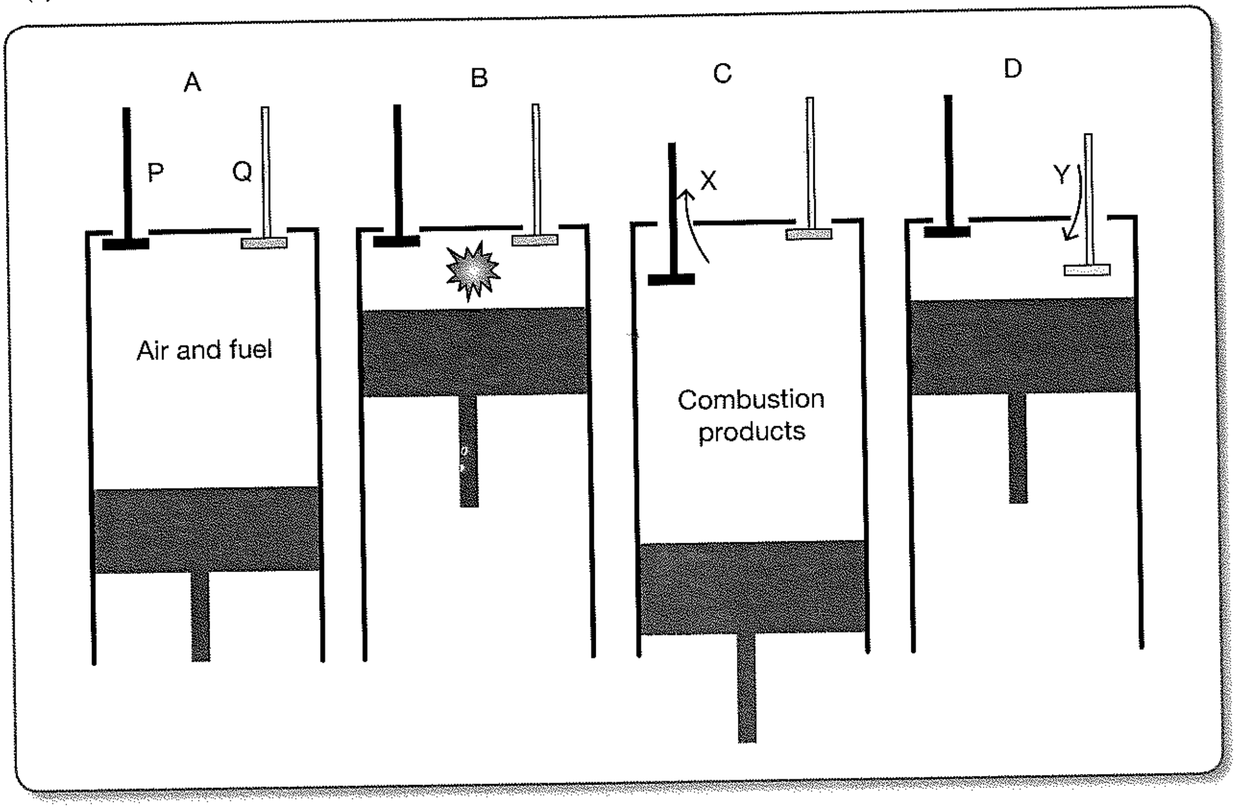

Nicolas Carnot
(1796-1832)


James Watt
(1736-1819)

SET 13 The Internal Combustion Engine

1. (a) What is an internal combustion engine?
   (b) What is a four stroke internal combustion engine?
   (c) List the four stages in a four stroke internal combustion engine.
   (d) Name four places where internal combustion engines are used.
   (e) Name four fuels used by internal combustion engines.

2. The diagrams show the four main stages of the four stroke internal combustion engine.
   (a) Match each diagram to the stage it represents. The four stages are given in your answer to Question 1 (c) above.



   (b) What is represented by the arrows X and Y?
   (c) Identify which way the piston in each stage is about to move and why.
   (d) What is P?
   (e) What is Q?
   (f) What is the difference in the positioning of P and Q in diagram C representing?
   (g) Why are P and Q both in the same position in diagrams A and B?
   (h) What would be the effect on the engine if P was open in diagram B?
   (i) Briefly describe what process occurs during each stage of the internal combustion engine.

SET 14 The Energy Balance of Earth

1. What is the greenhouse effect?

2. Why is this effect called a greenhouse effect?

3. (a) What is the main pollutant causing the greenhouse effect?

(b) Name two other pollutant gases contributing to the greenhouse effect.

4. Explain how the greenhouse effect works.

5. Name five consequences the greenhouse effect has already had on the Earth.

6. Why is there some debate or controversy amongst some people as to whether the greenhouse effect is responsible for global warming?

7. What is the ocean heat conveyor belt?

8. Why is it referred to as a conveyor belt?

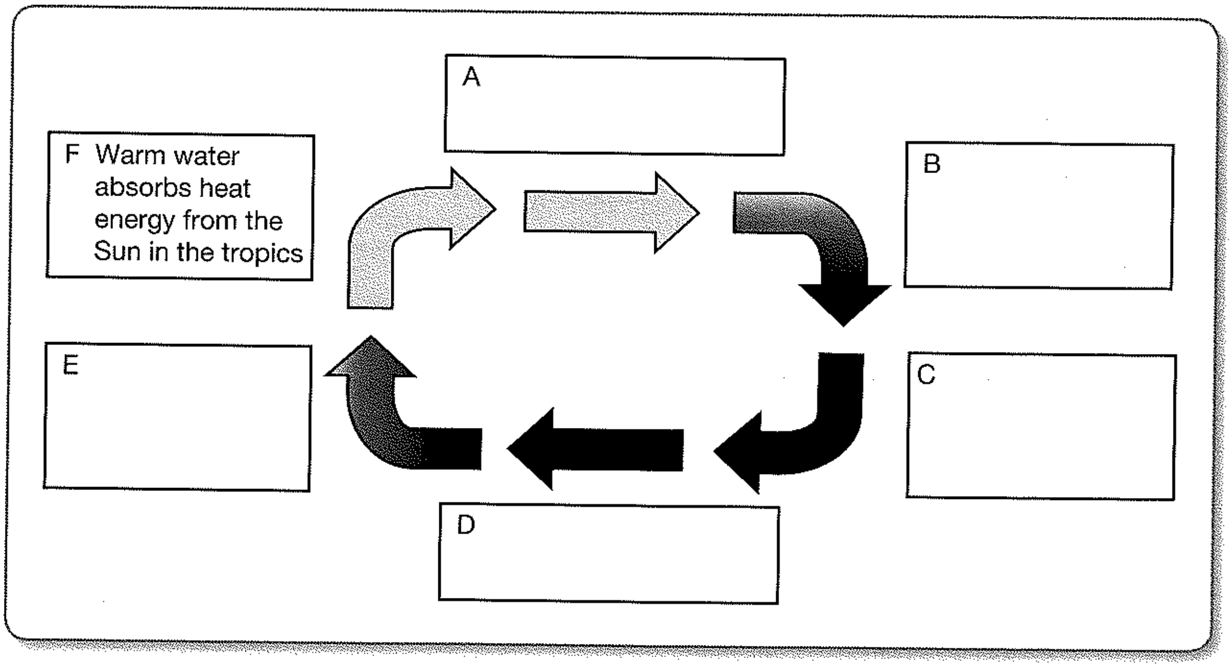
9. Explain the principle of heat transfer which drives the ocean heat conveyor belt.

10. What is the energy importance of the ocean heat conveyor belt?

11. What are scientists predicting about the ocean heat conveyor belt if global warming continues?

12. The flow diagram represents the heat energy exchange in the ocean heat conveyor belt. Place these labels on the diagram to complete it (they are not in correct order, and one has been done for you).

- Warm water absorbs heat energy from the Sun in the tropics.
- Cold water flows south, along the ocean floor.
- Warm water mixes with cold arctic water and becomes colder.
- Cold water mixes with warmer water and rises as it becomes warmer.
- Colder water sinks.
- Water moves north and gradually cools, releasing energy to the atmosphere.



SET 15 Energy Sustainability

1. (a) Explain what is meant by energy sustainability.

(b) What are our current three major sources of energy?

(c) Are these sustainable sources? Explain your answer.

(d) Which source of our energy is inexhaustible and therefore sustainable for all time?

(e) Give four reasons we do not use this source of energy as a major energy source.

(f) If the world is to have sustainable energy, what must the source of most of its energy be?

(g) Justify your answer to (d).

(h) List four other possible sources of energy that ultimately rely on this ultimate source.

2. (a) Name the seven forms of renewable energy.

(b) Which of these seven forms of renewable energy are powered by the Sun? Explain the role of the Sun in each.

(c) What are the other forms powered by?

3. In 1990 which form of energy had the most use?

(A) Nuclear.

(B) Coal.

(C) Natural gas.

(D) Oil.

4. What energy is projected to be the most used in 2030?

(A) Nuclear.

(B) Coal.

(C) Natural gas.

(D) Oil.

5. Which of the following is used as a renewable energy source by Japan?

(A) Doors opening and closing.

(B) Traffic noise in main streets.

(C) Passengers walking at Tokyo train stations.

(D) Leftover sushi rice.

6. The mass of the Sun is calculated to be 1.98855×10^{30} kg. In the nuclear reactions producing its energy it loses about 4.289×10^{9} kg of matter each second.

(a) What mass is lost each year?

(b) What is this mass loss expressed as a percentage of its current mass?

(c) According to this data, how long will the Sun last if the rate of fusion remains constant?

(d) The predicted lifetime of the Sun is 9×10^{9} years. What mass remains after this time?

(e) What percentage of its current mass does this represent?

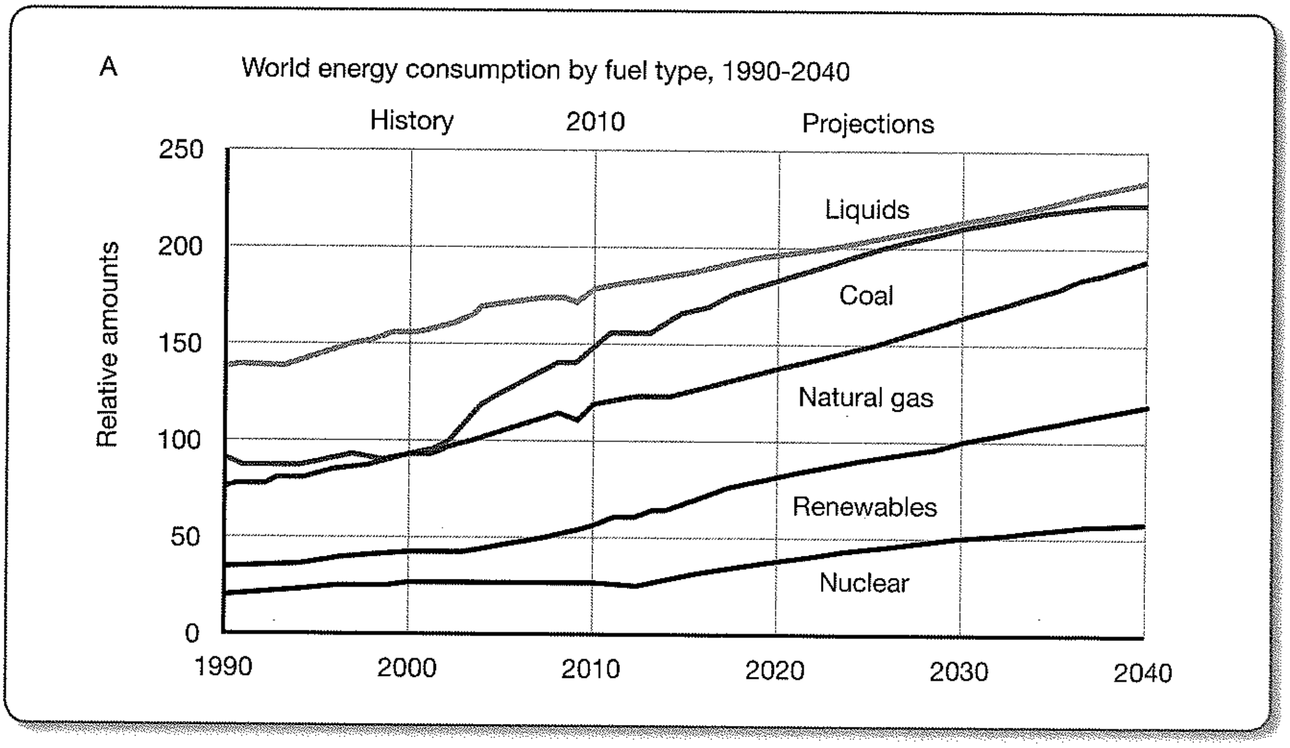
(f) Theory says the remaining life of the Sun is 5×10^{9} years. Calculation (c) tells us the Sun will last 1.47×10^{13} years. What is 5×10^{9} years as a percentage of 1.47×10^{13} years?

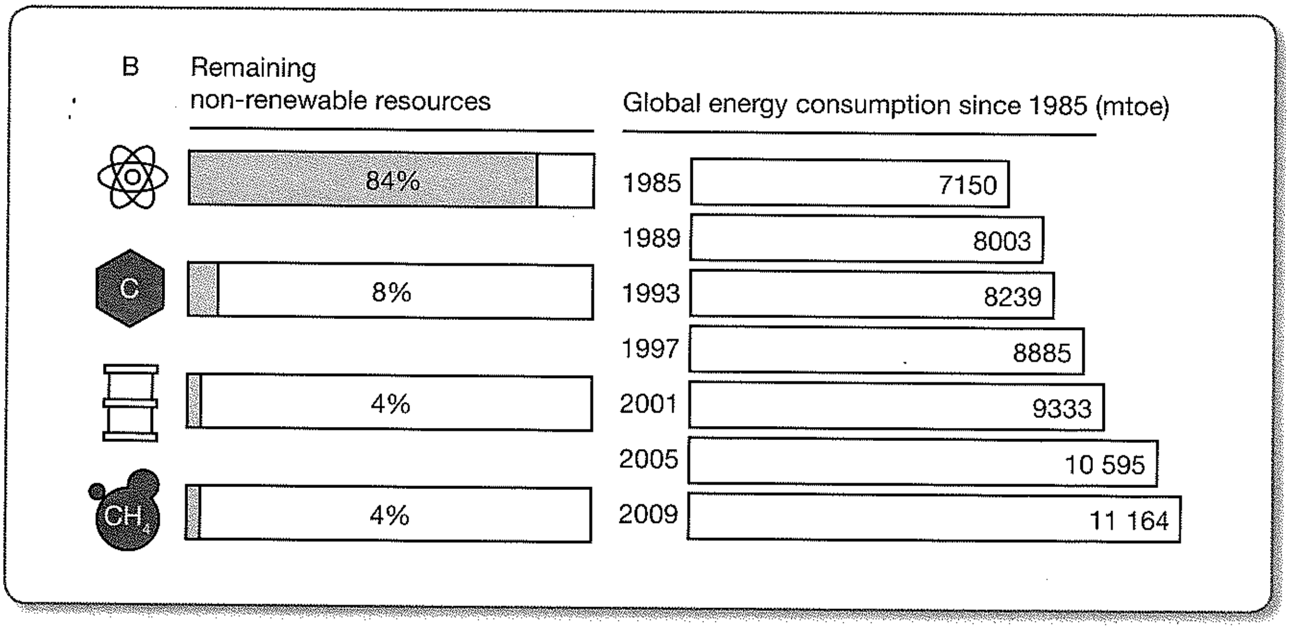
(g) What does your answer for (e) and (f) tell us?

(h) Rationalise this information (you may have to research this).

(i) What does this information tell us about the energy sustainability of the Sun?

7. Consider the following information about the world's energy use and predicted use.





(a) In figure B, what does *mtoe* mean?

(b) What percentage of world energy use in 2010 came from fossil fuels?

(c) What percentage of world predicted energy use in 2020 will come from fossil fuels?

(d) What does this suggest about the world's energy sustainability?

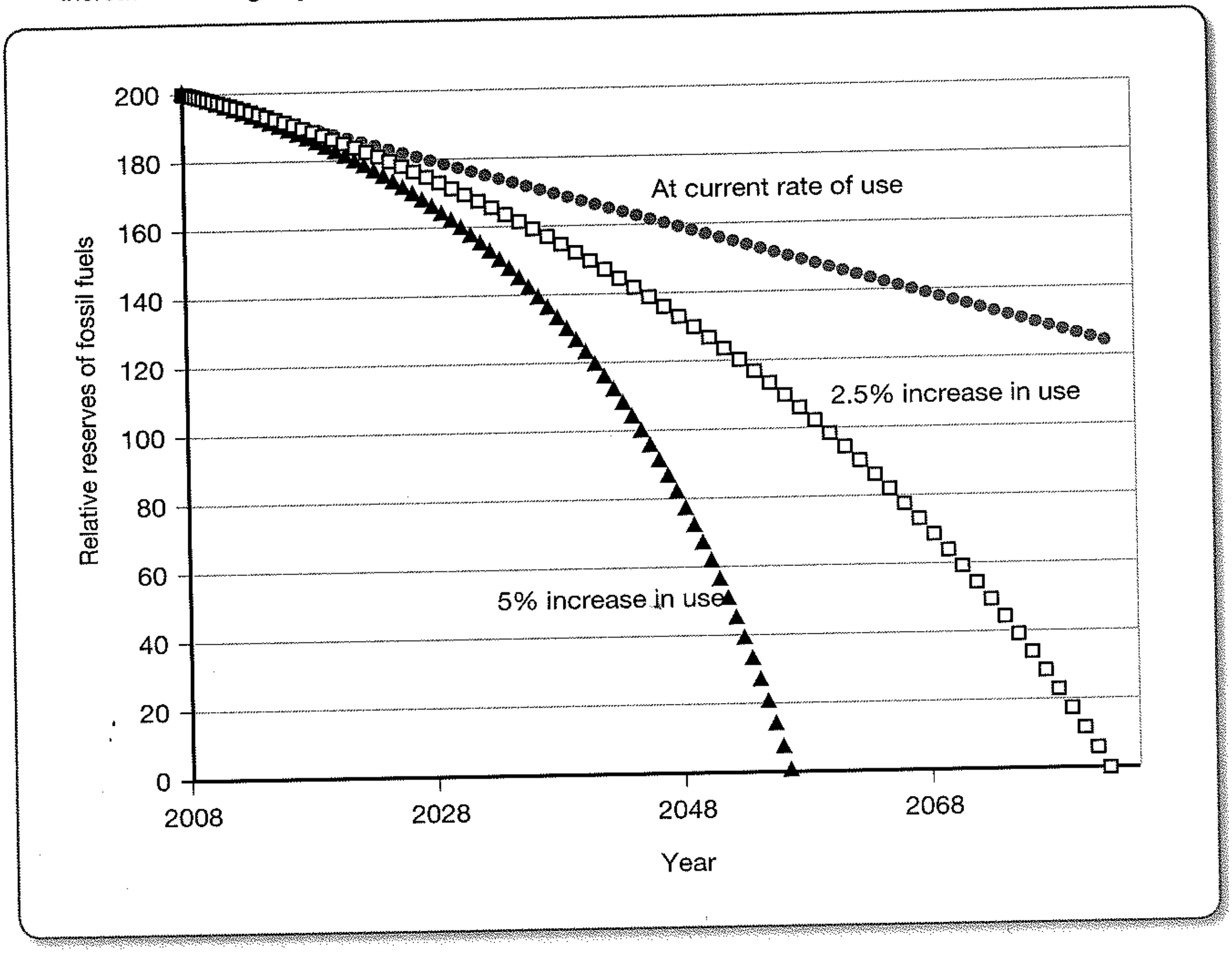
(e) Explain the four symbols used in the second figure.

(f) What does the information about remaining non-renewable resources suggest?

(g) What is needed before we can make a rational statement about these reserves of fossil fuels?

8. The graph shows one source of data about the remaining supplies of fossil fuels assuming:

- That we use than at the same rate as in 2008, or
- Increase our usage by 2.5% of the 2008 value per year, or
- Increase our usage by 5% of the 2008 value per year.



(a) Which of the three scenarios about use of fossil fuels is most likely? Give reasons for your answer.

(b) Consider the first graph in Question 7. What is the increase in the use of fossil fuels between 2010 and 2020 as a percentage of the 2010 figures?

(c) Consider the first graph in Question 7. What is the increase in the use of fossil fuels between 2020 and 2030 as a percentage of the 2020 figures?

(d) What do your answers to (b) and (c) suggest about the predictions in the graph given in this question?

(e) What does this data imply about the sustainability of the Earth's energy?

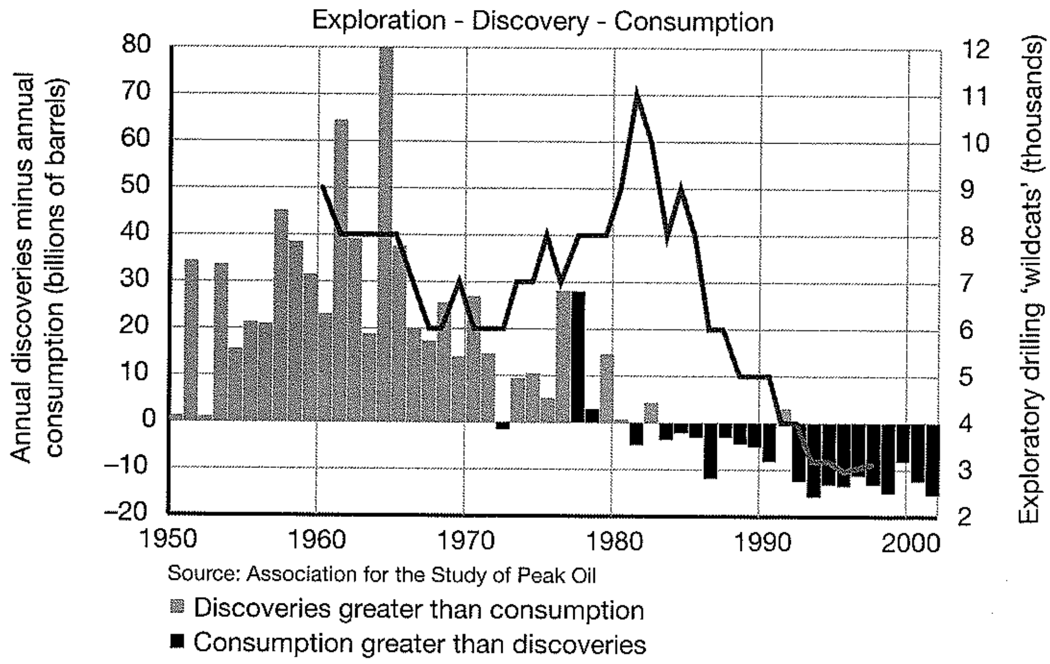
(f) What does this graph tell us about our need to develop alternate, renewable sources of energy?

(g) Comment on the reliability of predictive data like that shown in the graph in this question.

(h) Suggest at least three factors that might cause fossil fuels to be used more quickly than this data suggests.

(i) Suggest at least two factors that might cause fossil fuels to be used more slowly than this data suggests.

9. The diagram shows the extent to which the discovery of oil deposits exceeded or was less than consumption each year from 1950 to 2002.



(a) Is the message this information is giving us consistent with other sources of data?

(b) What is this message?

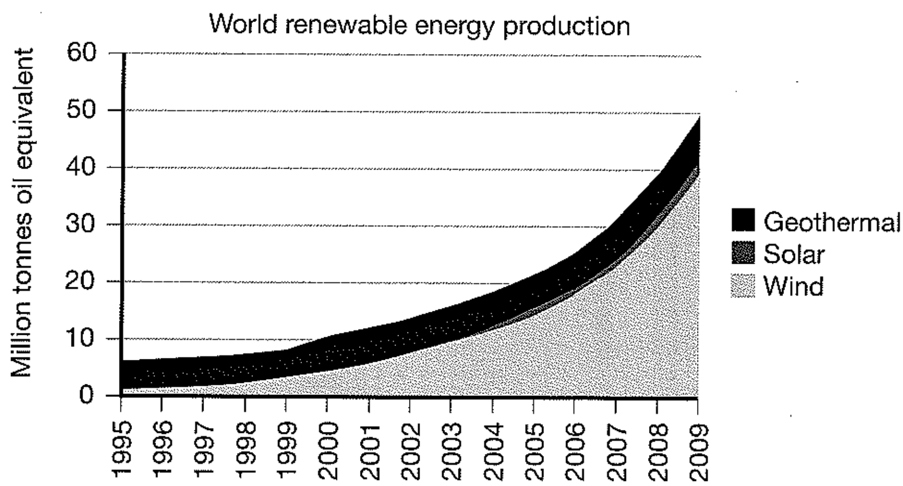
(c) Based on the four different sets of data considered here (Questions 6, 7 and 8) what can we say about the overall reliability of resource data like this?

(d) Given your answer to (c), suggest at least three reasons that more definite steps are not being taken by governments or manufacturers or people in general to tackle what seems to be an obvious problem for the future.

10. The graph shows how the production of three forms of renewable energy have changed from 1995 to 2009.

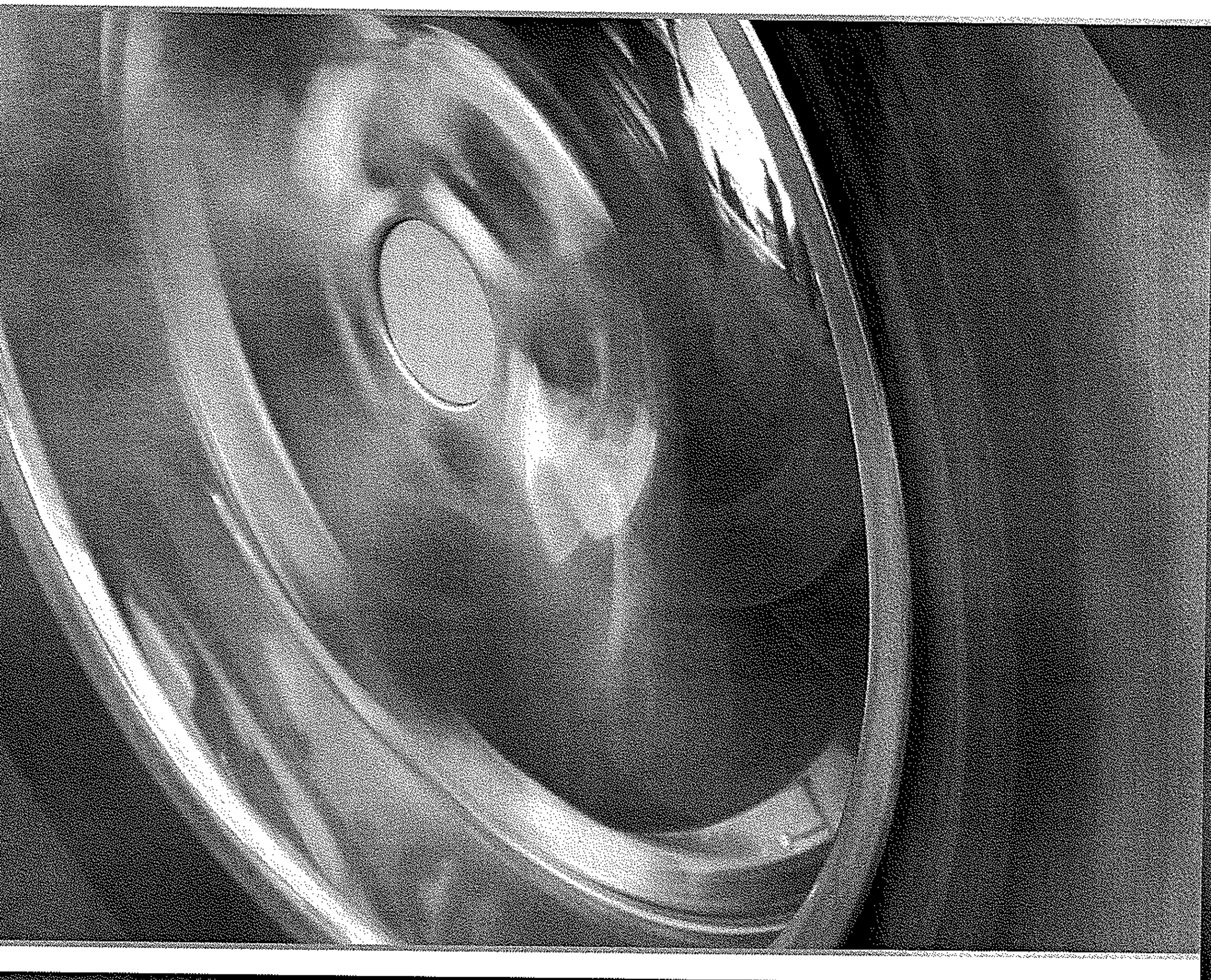
Despite the steep rise in the amount of renewable energy produced over this time, overall figures suggest little benefit from this.

Explain why this is the situation.



Questions and Answers

Ionising Radiation and Nuclear Reactions



SET 16 The Nuclear Model of the Atom

1. List five observations that were not able to be explained in the late 1800s that led scientists to rethink the model of the atom.

2. What is the basic idea in the concept of a nuclear model for the atom?

3. Rutherford's model was the first nuclear model of the atom.

(a) What experiment led Rutherford to propose his model of the atom?

(b) Who did this experiment?

(c) Explain why gold foil was used in this experiment.

(d) Describe Rutherford's model of the atom.

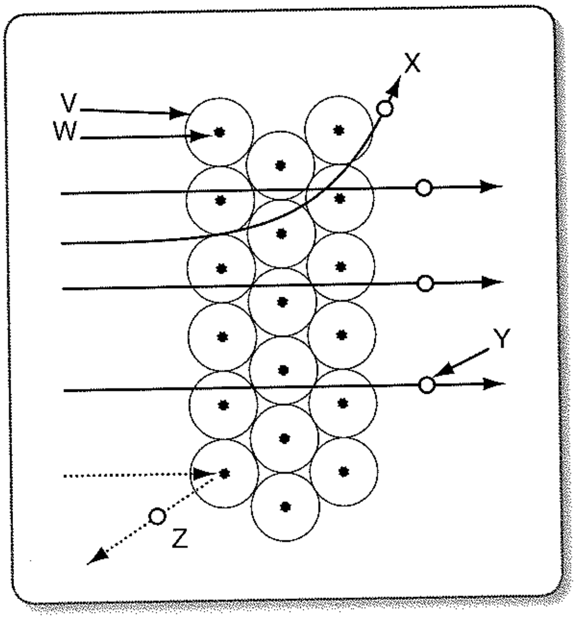
(e) What were the five limitations of Rutherford's model of the atom?

4. The diagram shows typical results of the experiment that led to Rutherford's model of the atom.

(a) Identify V, W, X, Y and Z labelled in this diagram.

(b) What are alpha particles? Give their atomic symbol.

(c) Explain how the different features of these results led to the different features in Rutherford's model of the atom. Be specific as to which result led to which feature of his model.



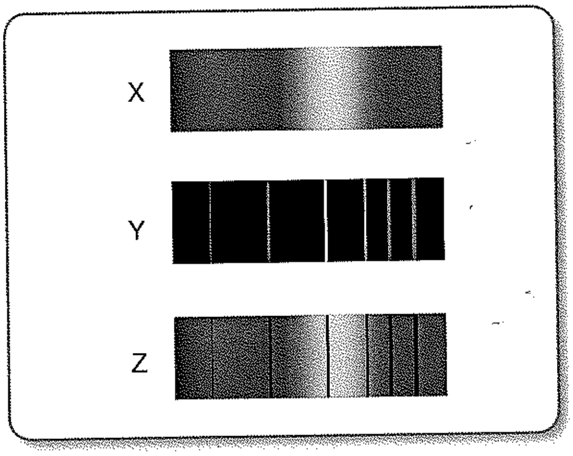
5. (a) The diagram shows three different types of spectra. Identity the continuous, emission and absorption spectra.

(b) Account for the structure of spectrum type X.

(c) Account for the structure of spectrum type Y.

(d) Account for the structure of spectrum type Z.

(e) Identify the low frequency end of each spectrum. Justify your answer.



6. Describe how atomic spectra provide evidence for the existence of atomic energy levels.

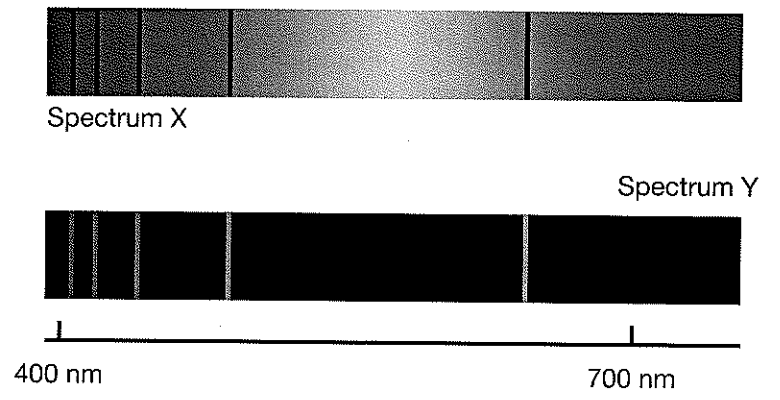
7. Outline the role of Max Planck in our understanding of energy levels in atomic structure.

8. What is the 'photon model of light' and how is this important to our idea of atomic structure?

9. Account for the hydrogen spectrum having many lines while its atom has one electron.

10. The continuous spectrum of the Sun has dark lines equivalent to the hydrogen absorption lines. Account for these lines.

11. The diagrams show absorption and emission spectra for hydrogen gas.



(a) Identify which spectrum is which.

(b) Compare the appearance of the two spectra.

(c) Account for the differences in the spectra.

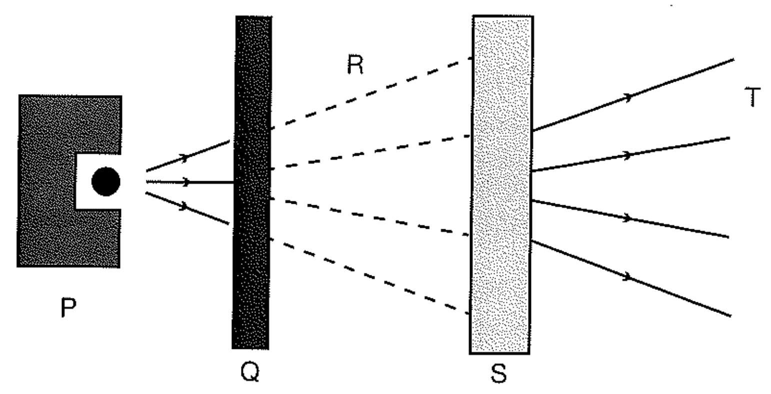
12. Account for elements having unique spectra.

13. When the hydrogen spectrum is examined using a particular piece of apparatus, brightly coloured lines are usually seen against a dark background.

(a) What type of spectrum is this?

(b) Explain how this forms.

14. The diagram summarises the experiment done by Chadwick in 1932.



(a) What was Chadwick's major contribution to atomic structure?

(b) Outline the experiment done by Chadwick, making sure you identify the labelled components in the diagram.

(c) Chadwick's discovery was not only a breakthrough on atomic structure, but would also become a essential part of further discovery in atomic structure. In what way?

SET 17 The Strong Nuclear Force

1. Calculate the gravitational force between two protons in a nucleus given that their average separation is 1.0×10^{-15} m and their mass is 1.673×10^{-27} kg.

2. Calculate the electrostatic force between two protons in the nucleus using the equation $F = \dfrac{kq_1q_2}{r^2}$.
Where k = electrostatic constant = 9×10^9
q_1 and q_2 = charge on the protons = $+1.6 \times 10^{-19}$ coulombs
r = distance between protons in the nucleus = 1.0×10^{-15} m

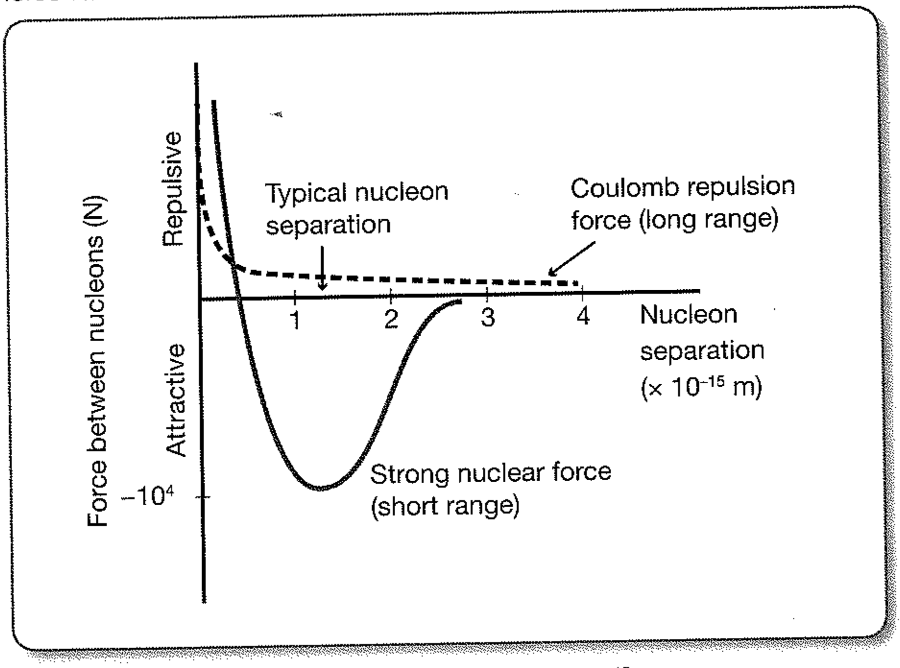
3. Calculate the ratio of the electrostatic force between two protons in a nucleus to the gravitational force between them.

4. Use the ratio to find the relative strength of the electrostatic force compared to the gravitational force.

5. Analyse the implications of this for the stability of a nucleus with two protons.

6. Compare this with the situation for a nucleus with many protons.

7. The graph shows how the nuclear force varies with the distance between nucleons in the nucleus of an atom.



(a) Describe how the nuclear force changes as the distance between nucleons changes.
(b) Explain why, in the absence of the strong nuclear force, large nuclei would be less stable than small nuclei.
(c) Describe the nature of the nuclear force if two nucleons are between 1.0×10^{-15} m and 2.3×10^{-15} m apart.
(d) Describe the nature of the nuclear force if two nucleons are more than 2.8×10^{-15} m apart.
(e) Describe the nature of the nuclear force if two nucleons are less than 1.0×10^{-15} m apart.
(f) Identify the distance at which the strong nuclear force stops acting.

8. (a) Account for the necessity of a strong nuclear force.
(b) Recall the four main properties of the strong nuclear force.

9. Compare the electrostatic force between two protons with that between:
(a) A proton and a neutron.
(b) Two neutrons.
(c) Two protons.
(d) Account for any differences in your answers.

SET 18 Isotopes

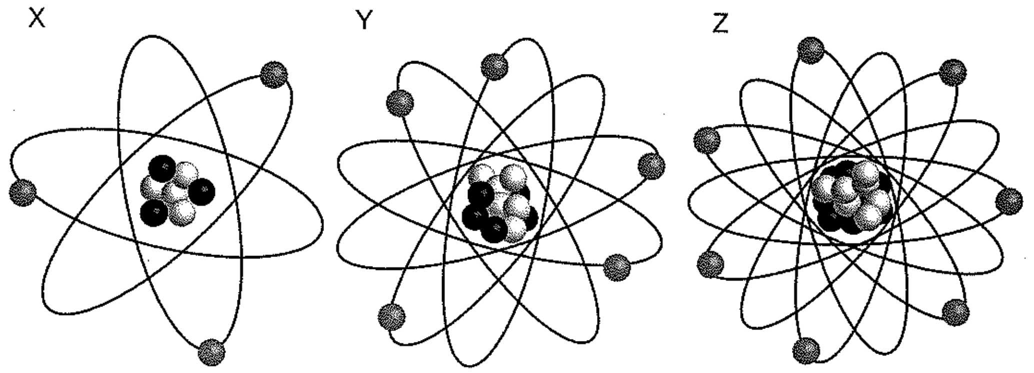
1. (a) What are isotopes?

(b) How does the existence of isotopes affect the atomic mass of an element? Explain your answer.

(c) How does the existence of isotopes affect the mass number of an element? Explain your answer.

(d) How does the existence of isotopes affect the atomic number of an element? Explain your answer.

2. Complete the table to summarise information about the elements represented by these diagrams.



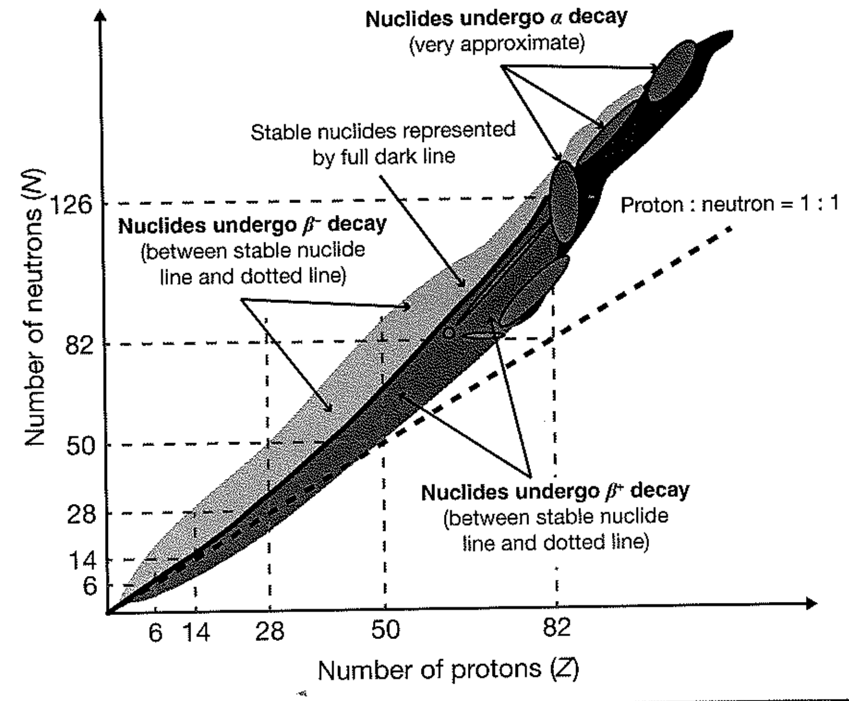
Element	Number of			Mass number	Atomic number	Name	Atomic symbol
	Protons	Neutrons	Electrons				
X							
Y							
Z							

3. Complete the table to show data for six of the 24 isotopes of chlorine.

Isotope	Number of protons in each nucleus	Number of neutrons in each nucleus	Number of electrons orbiting nucleus	Atomic number of element	Mass number of element
Chlorine-33					
Chlorine-34					
Chlorine-35					
Chlorine-36					
Chlorine-37					
Chlorine-38					

SET 19 Nuclear Decay

The graph shows the variation in the number of protons and neutrons in atomic nuclei as well as the position of a line if each atom had equal numbers of protons and neutrons. (Proton : neutron = 1 : 1.) The diagram also shows the type of decay each nuclide undergoes (approximations only).



1. (a) How many different elements have about the same number of protons and neutrons in their nuclei?

(b) What does the black line, approximately through the centre of the nuclide diagram represent?

(c) Why does this line end at element number 82?

2. Consider the atomic nucleus $^{65}_{28}Ni$.

(a) How many protons in this nucleus?

(b) How many neutrons in this nucleus?

(c) Comment on its stability.

(d) Discuss the reason for its stability.

(e) Predict the nature of its radioactive decay and explain why this occurs.

3. Consider the atomic nucleus $^{48}_{27}Co$.

(a) How many protons in this nucleus?

(b) How many neutrons in this nucleus?

(c) Comment on its stability.

(d) Discuss the reason for its stability.

(e) Predict the nature of its radioactive decay and explain why this occurs.

4. (a) Assuming that it is radioactive, predict and explain the nature of the radioactive decay of a nucleus in which the number of neutrons is significantly greater than the number of protons.

(b) Assuming that it is radioactive predict and explain the nature of the radioactive decay of a nucleus in which the number of protons is greater than the number of neutrons.

(c) Explain why larger nuclei are likely to be less stable than smaller nuclei.

(d) What property of the strong nuclear force is the limiting factor in the stability of a nucleus?

5. An increase in the number of protons in a nucleus could contribute to the instability of that nucleus.

(a) What would be the cause of this increased instability?

(b) Assuming the nucleus remains stable, what also must increase?

(c) How can the strong nuclear force in a nucleus be increased without increasing forces of electrostatic repulsion?

6. List four types of radioactive decay.

7. Write a general equation (use the nuclide $^{A}_{Z}X$ as your example) for:

(a) Alpha decay of a nucleus.

(b) Beta decay of a nucleus.

(c) Positron decay of a nucleus.

8. (a) When are antineutrinos produced in nuclear decay reactions?

(b) When are neutrinos produced in nuclear decay reactions?

(c) When are gamma rays produced in nuclear decay reactions?

9. (a) From which part of an atom is energy released during a nuclear reaction?

(b) Where does the energy released by a radioactive substance come from?

10. (a) Give another term that means the same as transmutation as it is used in the phrase 'nuclear transmutation'?

(b) What was the first practical application of nuclear reactions?

(c) Which of the following best describes a nuclear transmutation?

(A) Elements emit radioactive particles to change into other elements.

(B) Elements react with each other to produce new elements.

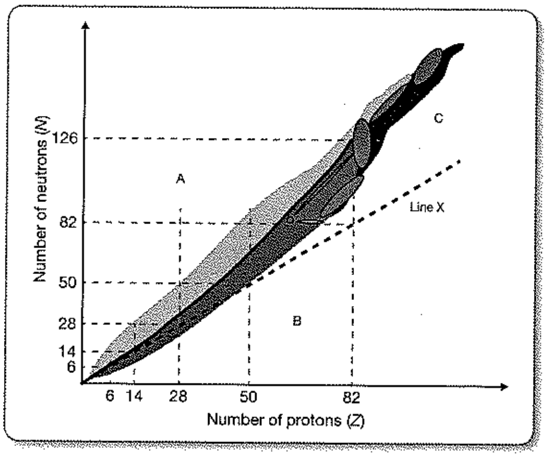
(C) Reactions which involve the release of enormous amounts of energy.

(D) Reactions in which elements combine to produce unknown elements.

(d) The discovery of nuclear transmutations led scientists to explain why atomic masses were not integral numbers. What is the explanation?

(e) Explain the concept of a nuclear transmutation.

11. The diagram plots atomic nuclei on the basis of the numbers of protons and neutrons they contain.



(a) What does the line X on this diagram represent?

(b) Nuclides in areas A, B and C undergo nuclear decay in different ways (in general). State the major type of decay the nuclei undergo in each area.

(c) According to this information, what is the relative neutron/proton ratio in nuclei which undergo alpha decay?

(d) According to this information, what is the relative neutron/proton ratio in nuclei which undergo beta decay?

(e) According to this information, what is the relative neutron/proton ratio in nuclei which undergo positron decay?

(f) Describe what happens to a nucleus which undergoes alpha decay.

(g) Describe what happens to a nucleus which undergoes beta decay.

(h) Describe what would happen to a nucleus if it underwent positron decay.

(i) All three types of nuclear decay discussed here increase the stability of the atomic nuclei concerned. In terms of the graph, justify this.

(j) Carbon-14 is a radioactive form of the element carbon, atomic number 12. Its nucleus consists of 6 protons and 8 neutrons. Where is carbon-14 relative to carbon-12 relative to the band of stability?

(k) What type of decay would stabilise an atom of uranium-238? The atomic number of uranium is 92. Justify your answer.

(l) A nuclide has 60 neutrons and 60 protons. What type of nuclear decay is this nuclide most likely to undergo? Justify your answer.

SET 20 The Stability of Nuclides

1. Some isotopes are radioactive and others are not. Explain, in terms of the structure of atoms and the forces that hold them together, how we can predict which ones will be radioactive.

2. While scientists don't really understand yet why some isotopes are more stable than others, the concept of entropy is sometimes used to generalise their ideas.
   (a) What is entropy?
   (b) How does entropy relate to the stability of isotopes?

3. (a) Outline the idea of neutron to proton ratio in trying to predict the stability of an isotope.
   (b) Atoms with more than 82 protons in their nuclei are all unstable. Explain why.
   (c) Scientists have found that one way to predict the stability of a nucleus is based on whether a nucleus contains an odd/even number of protons and neutrons. Complete the table to show this idea (you may have to research the information needed to complete the table).

Number of protons	Number of neutrons	Number of stable nuclides with this combination	Stability of these nuclides
Odd	Odd	4	
Odd	Even	50	
Even	Odd	57	
Even	Even	168	

4. (a) Scientists have also developed an idea of 'magic numbers' to predict nuclear stability. What are magic numbers?
   (b) What do scientists attribute the stability of nuclei with magic numbers to?
   (c) Complete the table to show the magic numbers of protons and neutrons.

Magic numbers of protons								
Magic numbers of neutrons								

   (d) Complete the table to show the effect of magic numbers on nuclei.

Nuclei has magic number of protons	Nucleus has magic number of neutrons	Tendency of nucleus to be stable
No	No	
Yes	No	
No	Yes	
Yes	Yes	

   (e) Which is the more stable nuclide? Give reasons for your answer.
      (i) ${}^{102}_{51}Sn$ or ${}^{101}_{51}Sn$.
      (ii) ${}^{62}_{31}Ge$ or ${}^{64}_{32}Ge$.

SET 21 Properties of Radioactive Particles

1. (a) What is radioactivity?

(b) Why is radioactivity a problem when considering commercial nuclear reactors?

2. Copy the table and complete it to summarise properties of alpha, beta and gamma radiations.

Radiation	Charge	Mass	Penetrating power	Ionising power	Path through electric field	Path through magnetic field	What is it?
Alpha							
Beta							
Gamma							

3. (a) What are alpha particles? Give their name, chemical formula and the common symbol used in nuclear reactions.

(b) What are beta particles? Give their name, chemical formula and the common symbol used in nuclear reactions.

(c) What is gamma radiation? Give the common symbol we use in equations for gamma radiation.

4. (a) Which radiation has the highest penetrating power?

(b) Which radiation has the highest ionising power?

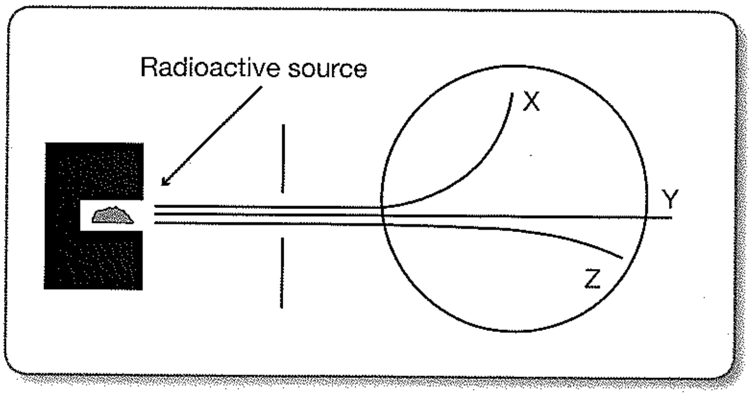
(c) Why are alpha particles more penetrating than beta particles?

(d) Why do gamma rays have low ionising power?

5. The diagram shows the path of alpha, beta and gamma rays through a magnetic field. Note that the direction of the magnetic field is not shown.

(a) Identify each type of radiation, X, Y and Z. Justify your answers.

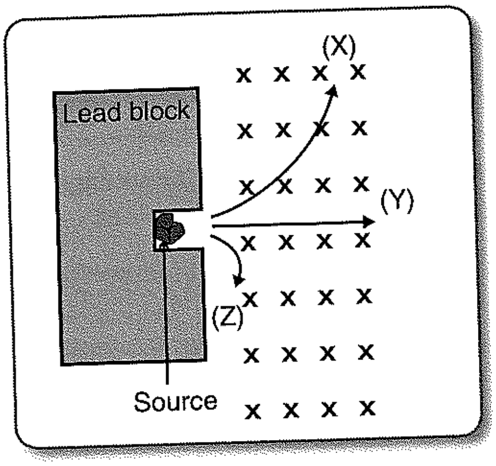
(b) Deduce the direction of the magnetic field.



6. The diagram shows the path of alpha and beta particles and gamma rays through a magnetic field.

(a) Identify each particle.

(b) Account for the difference in the *curvature* of the paths of the radiations.



7. Copy and complete the table, identifying the three nuclear radiations X, Y and Z and their properties.

Radiation	Charge	Penetrating power	Ionising power	Path through electric field	Path through magnetic field	What is it?
X		Very high				
Y	Positive					
Z						

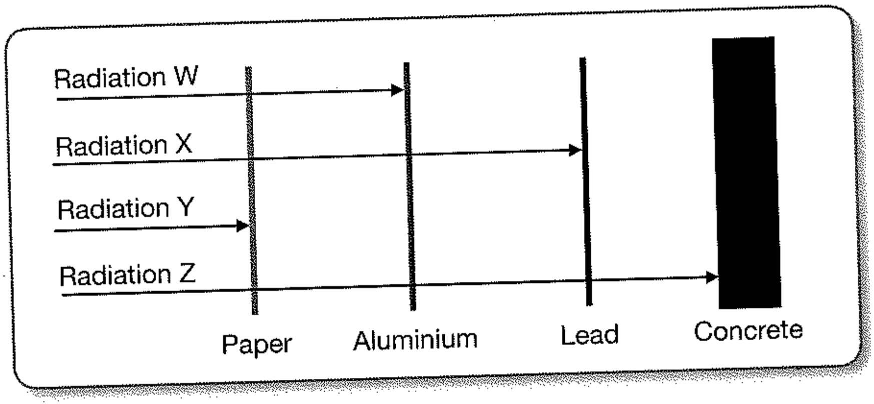
8. (a) What happens when matter is ionised by radiation?

(b) Why is ionisation dangerous to living tissue?

(c) Beta radiation does not cause as much ionisation in matter as alpha radiation. Why not?

9. When a negatively charged electroscope with a sheet of zinc on top of it has ultraviolet light shone on it, it discharges rapidly. Explain why this happens.

10. The diagram shows four types of nuclear radiations and their ability to penetrate several substances. Knowing that neutrons are more penetrating than gamma radiation which is stopped by a thin sheet of lead, and that alpha radiation is the least penetrating, which choice correctly identifies each type of radiation?



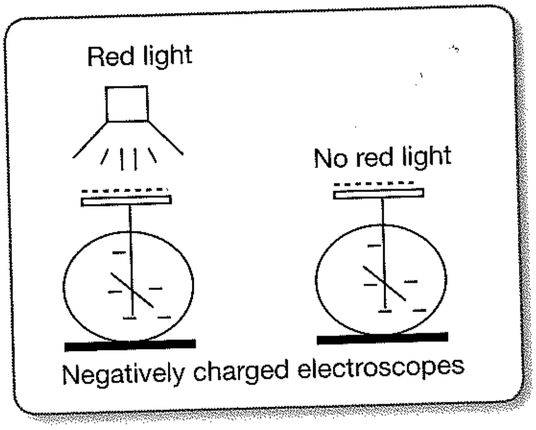
11. In an experiment to study ionisation, a student set up two negatively charged electroscopes as shown in the diagram.

He hypothesised that the electroscope under the red light would discharge more quickly than the other electroscope. It didn't.

(a) What was the student assuming in this experiment?

(b) Explain why the experiment did not work.

(c) What change in method might make this experiment work? Explain your answer.



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SET 22 Writing Equations for Nuclear Decay Reactions

1. (a) Write a general equation for alpha decay.

(b) Write a general equation for beta decay.

(c) What always accompanies the release of beta particles in a nuclear decay?

(d) When is gamma radiation emitted during a nuclear decay process?

2. (a) X-212 undergoes alpha decay to form Y. How will an atom of Y differ from an atom of X?

(b) Element X undergoes alpha particle emission to form element Y. Where will element Y be on the periodic table of elements compared to element X?

(c) If an atom of polonium emits an alpha particle, what element will be formed?

(d) If an atom of bismuth emits a beta particle, what element will be formed?

3. (a) Thorium-235 undergoes two successive beta decays. What element is formed?

(b) U-238 undergoes a series of alpha and beta decays to form Pb-210. How many of each decays occur? Justify your answer.

(c) Element Y undergoes beta decay then alpha decay to form element X. Compare the atomic number and atomic mass of an atom of X to those of an atom of Y. Justify your answer.

4. (a) Write the equation for the reaction between beryllium and alpha particles to produce a neutron.

(b) Consider ${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}X + {}^{0}_{-1}e + Z$. What is Z?

(c) What is the correct identification for element Y in the reaction below?

$${}^{A}_{Z}Y \rightarrow {}^{222}_{86}Rn + {}^{0}_{-1}e + {}^{0}_{0}\bar{v}$$

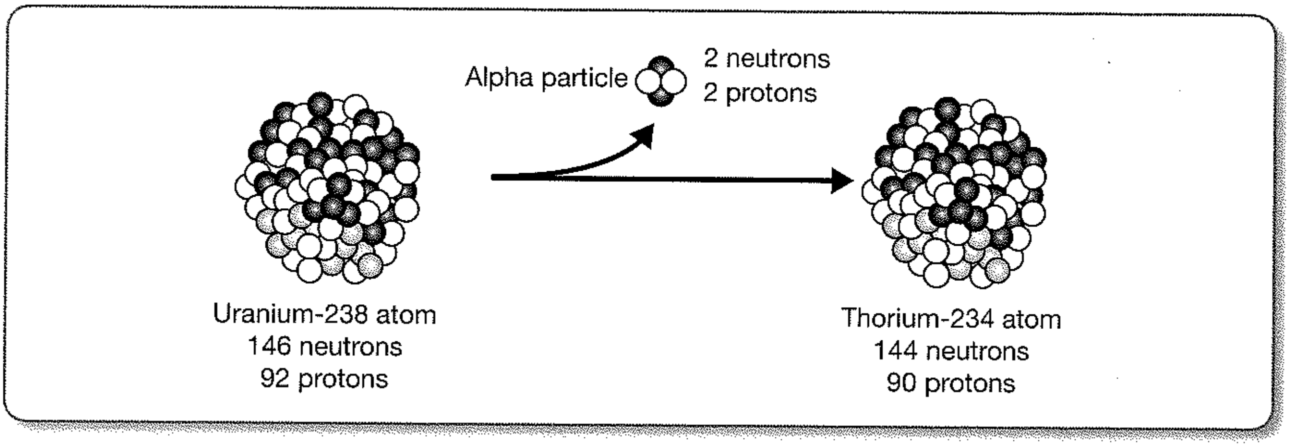
(d) What is the correct identification for element X in the reaction below?

$${}^{211}_{83}Bi \rightarrow X + {}^{4}_{2}He$$

(e) What is the ${}^{0}_{0}\bar{v}$ shown in the reaction below?

$$Y \rightarrow Z + {}^{0}_{-1}e + {}^{0}_{0}\bar{v}$$

5. The diagram shows the nuclear decay of a uranium-238 atom into a thorium-234 atom by releasing an alpha particle. Use it, and the periodic table at the back of the book, to answer this question.



(a) Write an equation to represent this nuclear decay.

(b) Thorium is also radioactive. Suppose an atom of thorium released an alpha particle. How many protons and neutrons would be in the nucleus of the atom formed?

(c) What element would be formed if thorium decayed by releasing an alpha particle?

6. Use the information in the table to answer this question. The table shows some of the successive steps in the decay of an atom of U-238 to lead-206.

Element	Symbol	Atomic number	Mass number
Uranium	U	92	238
Thorium	Th	90	234
Protactinium	Pa	91	234
Uranium	U	92	234
Thorium	Th	90	230
Radium	Ra	88	226
Radon	Rn	86	222
Polonium	Po	84	218
Lead	Pb	82	214
Bismuth	Bi	83	214
Thallium	Tl	81	210
Lead	Pb	82	210
Bismuth	Bi	83	210
Polonium	Po	84	210
Lead	Pb	82	206

(a) What radioactive particles are emitted when thallium-210 decays to form polonium-210?

(b) What is the total number of alpha particles emitted in this decay sequence?

(c) What is the total number of beta particles emitted in this decay sequence?

(d) Write a nuclear equation for the decay of thallium-210 into lead-210.

(e) Write a nuclear equation for the decay of thorium-230 into radium-226.

(f) Write a nuclear equation for the decay of bismuth-210 into polonium-210.

(g) Write a nuclear equation for the decay of polonium-210 into lead-206.

(h) How many alpha and beta particles are emitted in the decay from radium-226 to bismuth-210?

(i) How many alpha and beta particles are emitted in the decay from polonium-218 to lead-210?

7. Using information from the periodic table, write equations for the following nuclear transformations.

(a) Polonium-214 emits an alpha particle.

(b) Thallium-210 emits a beta particle.

(c) Lead-212 decays to form bismuth-212.

(d) Bismuth-212 emits a beta particle.

(e) X emits an alpha particle to form lead-208.

(f) Y emits a beta particle to form nitrogen-14.

(g) Uranium-232 emits an alpha particle.

(h) Sodium-24 emits a beta particle.

(i) X emits an alpha particle to form radon-222.

(j) Y emits a beta particle to form barium-137.

(k) X emits a beta particle to form magnesium-24.

(l) Y emits an alpha particle to form a second alpha particle.

(m) Alpha decay of Bi-211.

(n) Beta decay of the product from (m).

(o) U-239 undergoes beta decay.

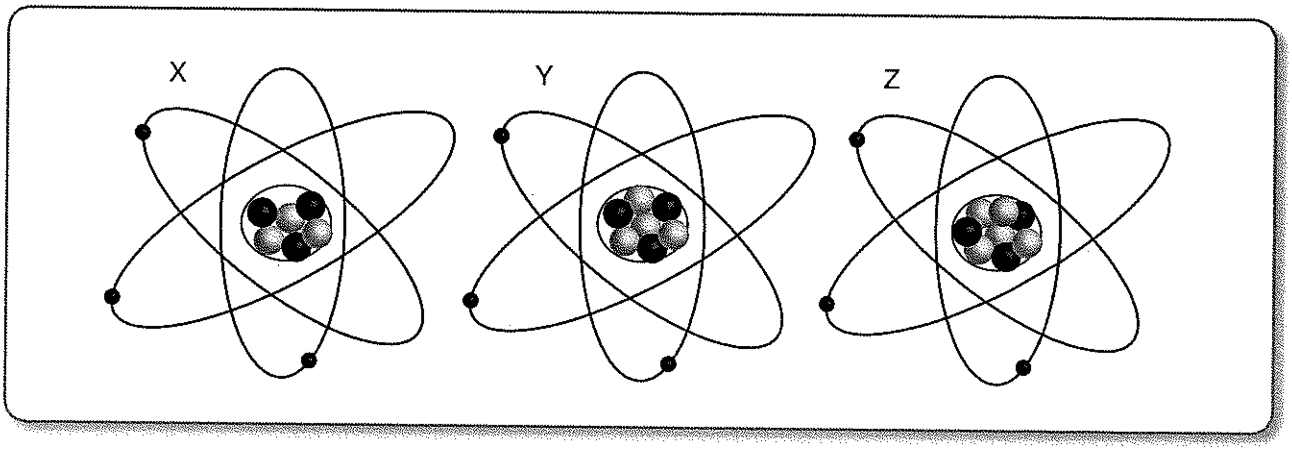
(p) The product from (o) undergoes another beta decay.

(q) Thorium-235 undergoes two successive beta decays.

SET 23 The Half-life of Nuclides

1. (a) What is a nuclide?
(b) What is the difference between isotopes and nuclides?
(c) How do isotopes of an element differ from one another?
(d) Are all nuclides radioactive?
(e) Are all isotopes radioactive?

2. The diagram shows three atoms. Assume that all nuclear particles are visible.



(a) Explain whether these nuclides represent atoms of different elements or isotopes of the same element.
(b) Use the periodic table to identify the element(s) represented by these diagrams.

3. Explain how we can predict when a particular radioactive nucleus will decay.

4. Explain why the rate of radioactive decay is proportional to the number of radioactive atoms in the sample.

5. Explain why the rate of radioactive decay decreases with time.

6. State and sketch the shape of a radioactive decay rate curve.

7. Define the term radioactive half-life.

8. Strontium-90 (Sr-90) has a half-life of about 20 years. Californium-251 (Cf-251) has a half-life of about 10 years. A nuclear researcher starts with a mass of each that has an activity of 200 counts per minute.
(a) What would be the activity of the Sr-90 after 5 half-lives?
(b) How much time is represented by 5 half-lives for SR-90?
(c) What would be the activity of the Cf-251 after 5 half-lives?
(d) How much time is represented by 5 half-lives for Cf-251?
(e) The researcher measured the activity of each sample after the same period of time. Which nuclide would be the most radioactive after this time?

9. The half-life of radioactive caesium-137 is about 30 years. This means that after 30 years the mass of a sample of caesium-137 will have halved, regardless of its starting mass. If 40 grams of radioactive caesium-137 is stored in concrete, how many years will it take for its mass to decrease to 2.5 grams?

10. The half-life of plutonium is 88 years. Explain why over a period of six months the activity of a sample of plutonium-238 may be considered to be constant.

11. Thorium-227 (Th-227) has a half-life of 18 days to form radium-223 (Ra-223). A sample of Th-227 has an initial activity of 3.2×10^5 Bq. Determine the activity of the remaining thorium after 50 days.

12. The table lists some common radioactive elements and their half-lives.

Radioisotope	Half-life
Carbon-14	5930 years
Cobalt-60	5.26 years
Iron-59	46.3 days
Uranium-235	710 million years
Sodium-24	15 hours
Polonium-216	0.16 seconds

(a) Nuclear reactors use uranium-235 as a source of fuel. In terms of its half-life, what is the benefit of using uranium-235 as a fuel?

(b) What is the main problem with using and producing radioisotopes with long half-lives?

(c) Sodium-24, an alpha emitter, is used by doctors to diagnose diseases of the circulatory system. Cobalt-60, a gamma emitter, is used to treat cancer. Suggest a reason why each of these particular radioisotopes are used for these specific purposes.

(d) Some foods are treated with radiation before storing them. Why is this done?

13. A nuclear scientist was investigating the properties of a radioisotope, X. Before starting the experiment she measured the background radiation and gained the results shown in the table.

Time (s)	Number of counts
60	45
60	52
60	47
60	46
60	40

(a) Calculate the average background radiation in counts per minute.

(b) Why is it necessary to measure this background radiation before starting the experiment?

The scientist then placed a sample of X near the counter and measured the radiation each Monday for seven weeks, counting the first week as week 0, the starting week. Her results are shown in the table.

Week	Total radiation counts recorded (counts min^{-1})	Radiation due to X (counts min^{-1})
0	1031	
1	848	
2	698	
3	566	
4	476	
5	395	
6	328	

(c) Copy the table and complete it by writing in the values for the third column.

(d) Plot the results to show the relationship between time and the radiation of X.

(e) Use your graph to determine the number of days for the radiation count from X to halve, that is, the 'half-life' of X.

(f) Predict the radiation in counts min^{-1} of X for day 10.

(g) Predict the radiation in counts min^{-1} of X for day 75.

14. (a) Carbon-14 is a radioactive isotope and is produced in the atmosphere by neutron bombardment of nitrogen. The equation for this reaction is shown below. Identify the particle X.

$$^{14}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C + X$$

Living trees contain atoms of carbon-14. The activity per gram of carbon from a living tree is 9.6 disintegrations per minute. The activity per gram of carbon in burnt wood (charcoal) found at an ancient campsite is 2.1 disintegrations per minute.

(b) A living tree continuously takes in carbon dioxide from the atmosphere. Suggest why the activity of the carbon from the charcoal is less than that of the living wood.

(c) The half-life of carbon-14 is 5730 years. Calculate the decay constant for carbon-14 and use this value to estimate the age of the carbon found at the campsite.

(d) Suggest one reason why radioactive dating of carbon samples that are more than 70 000 years old is unreliable.

15. The half-life of Zn-71 is 2.4 minutes. If one had 100.0 g at the beginning, how many grams would be left after 9.6 minutes has elapsed?

16. Os-182 has a half-life of 21.5 hours. How many grams of a 200.0 g sample would have decayed after five half-lives?

17. U-238 has a half-life of 4.46×10^9 years. How much remains in a 2.0 g sample after 2.5×10^9 years?

18. The half-life of W-187 is 23.9 hours. How much of an original 10 g sample will remain after one day? Two days? Seven days?

19. How long does it take for a sample of H-3 to lose 75% of its radioactivity? (Half-life = 12.26 years.)

20. Pd-100 has a half-life of 3.6 days. A sample has 6.02×10^{23} atoms. How many remain after 20.0 days?

21. A 128.0 mg isotope decays to 2.00 milligrams in 24 days. What is the half-life of the isotope?

22. How long will it take for a 40.0 gram sample of I-131 (Half-life = 8.040 days) to decay to 0.4 g?

23 Fermium-253 has a half-life of 0.334 seconds. A radioactive sample is considered to be completely decayed after 10 half-lives. How much time will elapse for this sample to be considered gone?

24. How much time will have passed if a 100 gram sample of an isotope with a half-life of 36 hours has decayed to 5.00 grams?

25. Rn-222 has a half-life of 3.82 days. How long will it take a sample to decay to 1/16 its original mass?

26. A sample of Se-83 registers 10^{12} disintegrations per second when tested. What would be the disintegration rate 3.5 hours later, if the half-life is 22.3 minutes?

27. Iodine-131 has a half-life of 8.040 days. How much of a 40.0 gram sample will remain after 24.0 days?

28. If a sample contains 2.97×10^{22} atoms of molybdenum-99 (half-life = 65.94 hours), how many atoms will remain after one week?

29. The isotope H-3 has a half-life of 12.26 years. What fraction of a sample will remain after 49 years?

30. How long will it take for 64.0 g of Rn-222 (half-life = 3.8235 days) to decay to 8.00 g?

SET 24 Effects of Radiation

1. (a) What do radioactive substances give off that makes them dangerous?

(b) Distinguish between initial and residual radiation as it relates to a nuclear incident.

2. Clarify each of the following terms.

(a) Radioactivity.

(b) Absorbed dose.

(c) Dose equivalent.

(d) Exposure.

3. (a) Complete the table to show the different radiation units used. Write in the names and the symbols for each.

	Radioactivity	Absorbed dose	Dose equivalent	Exposure
Common unit				
SI unit				

(b) What is a becquerel?

(c) How does the curie relate to the becquerel?

(d) What is the relationship between the gray and the rad?

(e) How does the sievert relate to the rem?

(f) Define the C kg^{-1} in terms of the roentgen.

4. Why is the frequency of the radiation a factor in determining its effect on matter?

5. What is the difference between absorbed dose and dose equivalent?

6. Why are older people less sensitive to radiation damage that younger people?

7. X-rays of the same intensity as a beam of red light are considered to be more dangerous. Why?

8. (a) A nuclear scientist is in an area for 15 minutes and the reading on his survey meter is 5 mR/h. What dose of radiation does the technician receive?

(b) A technician wants to receive no more than a 0.75 mR dose in the above conditions. What is the maximum time the technician can stay in the area?

9. Two of the more common industrial gamma ray sources are iridium-192 and cobalt-60. These isotopes emit radiation in two or three discreet wavelengths as shown in the table.

	Energy of radiations emitted (MeV)		
Iridium-192	0.31	0.47	0.6
Cobalt-60	1.17	1.33	-

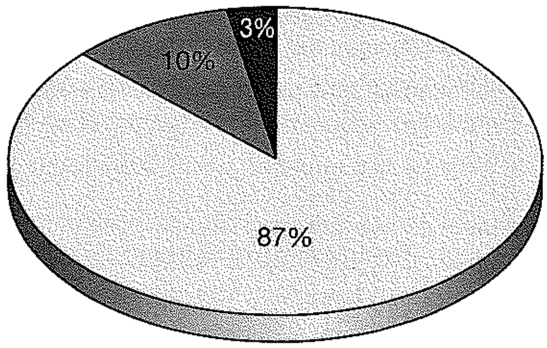
Discuss the shielding implications this data has for nuclear technicians working with these nuclides.

10. The pie chart shows the sources of nuclear radiation we receive annually. A dose of about 1000 mSv of radiation can cause radiation sickness. This would take about 500 years to absorb through background radiation.

(a) According to this information, how many units of background radiation do we absorb in an 80 year lifetime?

(b) How many units of radiation from other sources do we receive in this time?

(c) Suggest two possible sources of background radiation.



11. Discuss the factors below which determine the effect ionising radiation can have on human tissue.

(a) Type of radiation involved.

(b) Size of dose received.

(c) Rate at which the dose is received.

(d) Part of the body exposed.

(e) The age of the individual.

12. Discuss the effect of ionising radiations on human tissue with specific reference to direct and indirect action of this radiation.

13. The depth of penetration for a given photon energy is dependent upon the material density (atomic structure). The more subatomic particles in a material (higher *Z* number), the greater the likelihood that interactions will occur and the radiation will lose its energy.

The *half-value layer* (HVL) is the thickness of a given material that is necessary to reduce the exposure rate from a particular source to one half that at the unshielded surface of the material.

In an experiment to determine the half-value layer of lead for two different nuclides, some nuclear technicians obtained the following results when they placed the shield one metre from the source of the radiation.

Thickness of lead shielding (mm)	0	1	2	3	4	5	6	8	10	12
Activity of nuclide X	660	560	490	425	380	330	280	210	165	122
Activity of nuclide Y	1196	1020	900	800	720	650	580	455	360	292

(a) Graph these results on the same set of axes.

(b) From your graph, determine the HVL for the radiation from each nuclide.

(c) Comment on the relative intensities of the radiation emitted by the nuclides.

14. A 20 kg child and a 100 kg adult each receive a dose of 120 J of radiation energy from gamma rays.

(a) Who has the higher absorbed dose? Justify your answer.

(b) Who receives the higher dose equivalent? Justify your answer.

(c) If the adult had received 120 J of energy from alpha radiation and the child 260 J of gamma radiation, who now would have the largest absorbed dose? Explain.

(d) Who, in this situation would have the higher dose equivalent? Justify your answer.

15. The table shows the weighting or quality factors for different types of radiations. Use the information to answer this question.

Radiation weighting factors		
Type of radiation	**Energy range of radiation**	**Weighting factor**
Electromagnetic photons	All	1
Beta particles	All	1
Slow neutrons	Less than 10 keV	5
	10 keV to 100 keV	10
Fast neutrons	100 keV to 2 MeV	20
	2 MeV to 20 MeV	10
Very fast neutrons	Greater than 20 MeV	5
Protons	Greater than 2 MeV	5
Alpha particles	All	20

(a) According to this information, what type(s) of radiation are most damaging to humans?

(b) Suggest a reason for the difference in the radiation weighting factor for different energy neutrons.

(c) Suggest a reason for the relatively low radiation weighting factors for gamma rays (electromagnetic photons) and beta particles.

(d) An individual absorbs a fast neutron dose of 0.1 Gy. What equivalent dose has he received?

(e) What dose of X-rays would a person have to receive to absorb the same equivalent dose?

(f) What equivalent dose has an individual absorbed if he has absorbed 1 mGy of slow neutrons?

(g) What would be the total biological dose absorbed by a person if they were to absorb 0.3 mGy of slow neutrons, 6.0 mGy of gamma rays and 0.1 mGy of alpha particles?

The next few questions may require you to research the answers.

16. What is the danger of dental X-rays?

17. What is the danger of mobile cellular phones and can they cause cancer of the face or brain?

18. (a) What are the three ways in which radioactivity can be taken into the body, known as 'internal exposure'?

(b) What is 'external' radioactivity'? Give an example.

19. (a) What radiation dangers were there in watching a cathode ray tube television?

(b) How did cathode ray tubes produce radioactivity?

(c) What type of levels of radiation have been measured from TVs?

20. (a) What is radiation therapy?

(b) How does radiation therapy kill cancer cells?

(c) Does radiation therapy kill only cancer cells?

(d) Does radiation therapy make a patient radioactive?

21. (a) Why is food irradiated?

(b) Does irradiating food make it radioactive?

(c) Does eating irradiated food constitute a health risk?

(d) Does irradiation cause chemical changes in food?

SET 25 Nuclear Reactions

1. What principle governs nuclear reactions?

2. (a) Describe the two types of nuclear reactions.
   (b) For which nuclei does each type release energy?

3. (a) Compare the amounts of energy released by nuclear compared to exothermic chemical reactions.
   (b) What is the source of the energy in exothermic chemical reactions?
   (c) What is the source of the energy in nuclear reactions?
   (d) Account for the differing amount of energy released by these reactions.

4. (a) Explain the concept of mass defect.
   (b) What is the role of mass defect in nuclear reactions?
   (c) What is the role of mass defect in exothermic chemical reactions?
   (d) Compare the magnitude of the mass defect in nuclear and chemical reactions.
   (e) What evidence do we have to support your answer to (d)?
   (f) What name do we give to the energy equivalent of mass defect in a nucleus that has not decayed?

5. (a) What is meant by the 'equivalence of mass and energy'?
   (b) Recall the equation which connects mass and energy.
   (c) What is the relationship between mass defect and the size of a nucleus? Explain your answer.

6. A deuterium nucleus contains one proton and one neutron. Consider this statement about this nucleus. 'The mass of the nucleus is equal to the mass of the proton plus the mass of the neutron'.
   (a) Is this statement true or false?
   (b) If you judged it as false, what is the correct statement?
   (c) Explain your answer to (b).

7. Consider these two statements about mass defect as it applies to a nuclear reaction.
   Statement 1: The difference between the total mass of the products and the total mass of the reactants.
   Statement 2: The difference between the total mass of product atoms and reactant atoms.

   Which statement is correct? Justify your answer.

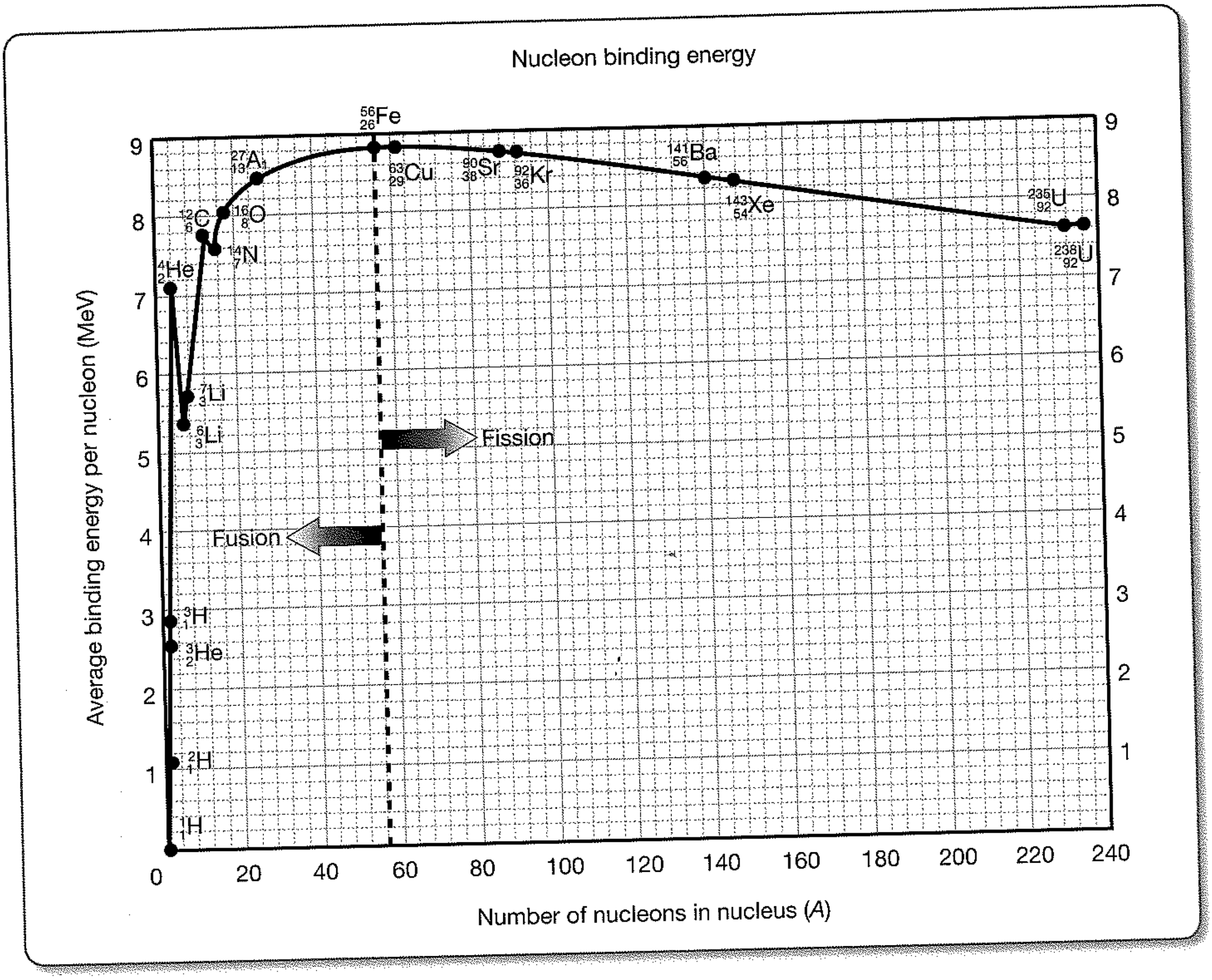
8. If a nuclear reactor converted 2.5 kg of uranium fuel pellets to energy every hour, how much energy would be produced by this reactor each hour?

9. Assuming 100% conversion of mass to energy, which nuclear fuel would release the most energy per kilogram, uranium or hydrogen? Explain your answer.

10. (a) Define binding energy.
    (b) What is mass deficit?
    (c) Explain the connection between mass defect and binding energy.
    (d) Explain the concept of binding energy per nucleon.
    (e) Explain why binding energy per nucleon is a more useful concept than binding energy.
    (f) Nucleus X has a higher binding energy per nucleon than nucleus Y. Explain what this means in terms of the stability of the two nuclei.

Use the information in the graph to answer the questions that follow.

The graph shows how the binding energy per nucleon is related to the total number of nucleons in a nucleus (the mass number of an atom).



11. Consider the two nuclei $^{7}_{3}$Li and $^{56}_{26}$Fe.

(a) Without making any calculations, which nucleus would have the greater total binding energy? Justify your answer.

(b) Which has the greater binding energy per nucleon?

(c) On this information alone, which of these two nuclei would be the most stable? Justify your answer.

12. The binding energy per nucleon of uranium-235 is 7.59 MeV. What is its total binding energy?

13. Calculate the binding energy of a tritium atom ($^{3}_{1}$H).

14. (a) Use the graph to explain why elements with mass numbers less than 56 are more likely to undergo fusion reactions rather than fission reactions.

(b) Use the graph to explain why elements with mass numbers greater than 56 are more likely to undergo fission reactions than fusion reactions.

SET 26 Mass Defect and Nuclear Energy

The table provides you with information needed to answer some of the questions. (Note that different resources may give slightly different values for the masses of some of the nuclides.)

Particle	Mass (amu)
${}^{27}_{13}Al$	26.99008
${}^{11}_{5}B$	11.012795
${}^{141}_{56}Ba$	140.9139
${}^{8}_{4}Be$	8.00785
${}^{12}_{6}C$	12.00000
${}^{0}_{-1}e$	0.000549
${}^{1}_{1}H$	1.0078825
${}^{2}_{1}H$	2.014102
${}^{3}_{2}He$	3.016029
${}^{4}_{2}He$	4.00260
${}^{19}_{9}F$	19.004448
${}^{92}_{36}Kr$	91.8973
${}^{139}_{57}La$	138.8061
${}^{7}_{3}Li$	7.016003
${}^{95}_{42}Mo$	94.9057
${}^{1}_{0}n$	1.008665
${}^{14}_{7}N$	14.003074
${}^{15}_{7}N$	15.000108
${}^{23}_{11}Na$	22.99705
${}^{16}_{8}O$	16.000000
${}^{17}_{8}O$	16.999131
${}^{226}_{88}Ra$	226.09600
${}^{222}_{86}Rn$	222.08690
${}^{88}_{38}Sr$	87.9056
${}^{235}_{92}U$	235.043923
${}^{136}_{54}Xe$	135.9072

1. (a) What is meant by the 'mass defect' of a reaction?

(b) How does the mass defect occur?

(c) How does mass defect relate to the binding energy of a nucleus?

2. Calculate the energy involved in each of the nuclear transformations shown. Give your answer in MeV and joules.

Note: 1 amu = 1.661×10^{-27} kg and 1 MeV = 1.6×10^{-13} J

(a) ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{95}_{42}Mo + {}^{139}_{57}La + 2({}^{1}_{0}n) + 7({}^{0}_{-1}e)$

(b) ${}^{14}_{7}N + {}^{2}_{1}H \rightarrow {}^{15}_{7}N + {}^{1}_{1}H$

(c) ${}^{14}_{7}N + {}^{4}_{2}He \rightarrow {}^{17}_{8}O + {}^{1}_{1}H$

(d) ${}^{7}Li_{3} + {}^{1}_{1}H \rightarrow {}^{4}_{2}He + {}^{4}_{2}He$

(e) $4{}^{1}_{1}H \rightarrow {}^{4}_{2}He + 2{}^{0}_{-1}e$

(f) ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3{}^{1}_{0}n$

(g) ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{136}_{54}Xe + {}^{88}_{38}Sr + 12{}^{1}_{0}n$

(h) ${}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + {}^{1}_{0}n$

(i) ${}^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$

(j) ${}^{11}_{5}B + {}^{1}_{1}H \rightarrow {}^{8}Be_{4} + {}^{4}_{2}He$

(k) ${}^{19}_{9}F + {}^{1}_{1}H \rightarrow {}^{16}_{8}O + {}^{4}_{2}He$

(l) ${}^{12}_{6}C + {}^{4}_{2}He \rightarrow {}^{15}_{7}N + {}^{1}_{1}H$

(m) ${}^{27}_{13}Al \rightarrow {}^{23}_{11}Na + {}^{4}_{2}He$

(n) Explain your answer to (c), (l) and (m).

3. (a) What is the mass defect for a lithium nucleus?

(b) The mass defect of a deuterium nucleus is 0.002388 u. What is its energy equivalent?

(c) What, in joules, is the energy equivalent of 1.0 gram of uranium?

(d) A nuclear transmutation released 2.50 MeV of energy. What is the mass defect for this reaction?

(e) A nuclear transmutation released 6.3×10^{-14} J of energy. What is the mass defect for this reaction?

4. Calculate the mass defect, in amu, for nuclear reactions which release the following energies.

(a) 2.36 MeV (b) 3.56 MeV

(c) 9.51 MeV (d) 10.1 MeV

(e) 13.6 MeV (f) 3.69×10^{-13} J

(g) 7.72×10^{-13} J (h) 7.84×10^{-13} J

(i) 1.04×10^{-12} J (j) 1.50×10^{-12} J

SET 27 Spontaneous and Artificial Transformations

1. (a) Explain the difference between a spontaneous and an artificial transmutation.
(b) What is the most common consequence of spontaneous nuclear transformations?

2. (a) The first artificial transmutation to be discovered was by Rutherford in 1919. He bombarded pure nitrogen gas with alpha particles to produce oxygen atoms and protons. Write the nuclear equation for this reaction.
(b) How did Rutherford know that a nuclear transformation had occurred in this experiment?

3. Describe the artificial transmutation represented by the following equation, and carried out by Irene Curie and Frédéric Joliot-Curie in 1934.

$$^{4}_{2}He + ^{27}_{13}Al \rightarrow ^{30}_{15}P + ^{1}_{0}n$$

4. Identify the missing species in each of the following artificial nuclear transmutation reactions.

(a) $^{4}_{2}He + ^{9}_{4}Be \rightarrow ^{12}_{6}C + \boxed{P}$

(b) $^{6}_{3}Li + \boxed{Q} \rightarrow ^{3}_{1}H + ^{4}_{2}He$

(c) $\boxed{R} + ^{1}_{0}n \rightarrow ^{1}_{1}H + ^{14}_{6}C$

(d) $^{6}_{3}Li + \boxed{S} \rightarrow ^{4}_{2}He + ^{4}_{2}He$

(e) $^{205}_{81}Tl + ^{2}_{1}H \rightarrow \boxed{T} + ^{1}_{0}n$

5. (a) What is the characteristic of a nucleus that makes it stable?
(b) What property of atoms makes them susceptible to spontaneous nuclear decay?
(c) Explain the reasoning behind both aspects of your answer to (b).

6. The graph of binding energy per nucleon suggests that nuclides with a mass larger than about 130 amu should spontaneously split apart to form lighter, more stable, nuclides. Experimentally, we find that spontaneous fission reactions occur for only the very heaviest nuclides — those with mass numbers of 230 or more.
(a) On the basis of your current knowledge, discuss the higher than expected stability of nuclei with masses above 130 but below 230.
(b) Research the ideas of 'magic numbers' and proton and neutron energy levels and briefly record how these ideas could account for this higher stability.
(c) Even when they do occur, the nuclear decay of heavier elements is very slow. The half-life for the spontaneous fission of ^{238}U, for example, is 10^{16} years, or about two million times longer than the age of our planet! How do scientists account for the very large half-life of these nuclides?

7. (a) What are the two types of artificial nuclear reactions?
(b) Describe briefly what happens in each of these.
(c) Apart from the mechanism of their reaction, what is the other major difference between fission and fusion?

8. The table shows the atomic symbol of the starting atom of each step in a natural decay sequence as well as its mass number.

(a) Identify the type of nuclear decay each nuclide undergoes to form the next nuclide in the sequence.

(b) Given that the decay sequence ends with ^{206}Pb, what can be said about this nuclide?

(c) Given that the atomic numberof the ^{218}Po in this series is 84 determine by considering the decay process of each element in the series, the atomic numbers of all the other elements in the series.

(d) Write the nuclear equation for each reaction.

Element	Symbol	Type of decay	Atomic number	Transmutation equation
Uranium	^{238}U			
Thorium	^{234}Th			
Protactinium	^{234}Pa			
Uranium	^{234}U			
Thorium	^{230}Th			
Radium	^{226}Ra			
Radon	^{222}Rn			
Polonium	^{218}Po		84	
Lead	^{214}Pb			
Bismuth	^{214}Bi			
Thallium	^{210}Tl			
Lead	^{210}Pb			
Bismuth	^{210}Bi			
Polonium	^{210}Po			
Lead	^{206}Pb			

SET 28 Neutron Induced Fission

1. (a) Why were the first particles used to bombard atomic nuclei positively charged protons (hydrogen nuclei) and alpha particles?

(b) What was the disadvantage of using these particles?

(c) Who first discovered neutron induced artificial nuclear transformations?

(d) Why are neutrons very useful in causing artificial nuclear transformations?

(e) What was a difficulty or limitation in using neutrons to induce nuclear reactions?

2. (a) The first man-made nuclear reaction was performed by Rutherford in 1919 when he bombarded nitrogen-14 with alpha particles. The equation summarising the reaction he studied is:

$$^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H$$

In your own words, describe what happens in this reaction and how the proton is formed.

(b) What was the main problem physicists had with inducing nuclear reactions around this time?

(c) English physicist John Douglas Cockcroft (1897-1967) and his co-worker, the Irish physicist Ernest Thomas Sinton Walton (1903-1995), were the first to design an accelerator capable of producing particles energetic enough to produce nuclear reactions. In 1932 they bombarded lithium atoms with accelerated protons and produced alpha particles. The nuclear reaction was:

$$^{1}_{1}H + ^{7}_{3}Li \rightarrow ^{4}_{2}He + ^{4}_{2}He$$

In what main way did this reaction differ from those observed before it?

3. The first to study neutron bombardment in detail was Italian physicist Enrico Fermi (1901-1954).

(a) Fermi found that a beam of neutrons was particularly effective in initiating nuclear reactions if it passed through water or paraffin first. Explain why these neutrons were more effective at initiating a nuclear reaction.

(b) What term was introduced to describe these slower neutrons?

4. (a) When a neutron is absorbed into an atomic nucleus, that nucleus does not necessarily become a new element. It may simply become a heavier isotope. Clarify this statement using as your example an O-16 atom being bombarded with a neutron.

(b) However, in gaining an extra neutron an element might become a radioactive isotope. In that case, it would then break down by emitting a beta particle. Clarify this statement considering O-18 gaining a neutron to form radioactive nuclide X which then undergoes beta decay to form nuclide Y. Identify X and Y.

(c) What did Fermi find interesting about this aspect of neutron bombardment?

(d) What were the two major results of the experiments done by Fermi and other scientists with neutron bombardment of uranium over the next 10 years or so?

(e) Following the discovery of the nuclear fission of uranium, a possibility considered disturbing by many scientists emerged. What was this possibility?

(f) What followed the realisation that this possibility existed?

SET 29 Controlled and Uncontrolled Chain Reactions

1. (a) Clarify the idea of a chain reaction.

(b) What are the high energy particles released during a nuclear fission reaction that are responsible for nuclear chain reactions?

2. (a) Describe, in terms of energy, a controlled nuclear reaction.

(b) How is a controlled nuclear chain reaction achieved in a nuclear reactor?

(c) How might more energy be produced in a controlled nuclear reaction?

(d) What conditions are essential requirements for a controlled nuclear reaction?

3. (a) In terms of energy, describe an uncontrolled nuclear reaction.

(b) How might an uncontrolled reaction in a reactor be prevented?

(c) Where have uncontrolled nuclear reactions been produced on Earth?

(d) What is the minimum requirement for an uncontrolled nuclear reaction?

(e) Predict possible consequences of an uncontrolled nuclear reaction.

4. (a) In his famous experiment with mouse traps and ping pong balls, Fermi's concluded that an average of 2.5 neutrons needed to be produced per fission reaction in order to produce a sustained, controlled, chain reaction. Why wouldn't these produce an uncontrolled nuclear chain reaction?

(b) Which of these reactions would be most likely to sustain a chain reaction? Justify your answer.

(A) ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3{}^{1}_{0}n$

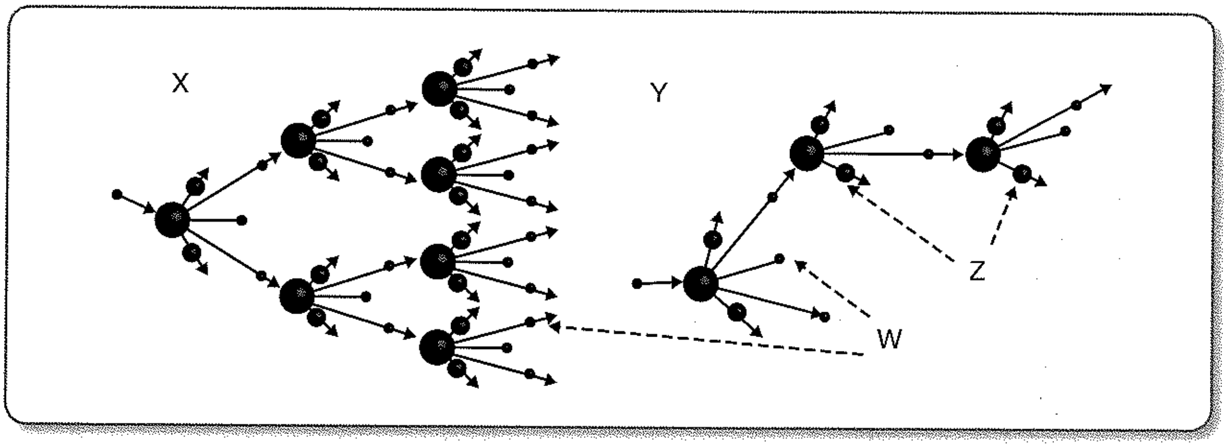
(B) ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{139}_{57}La + {}^{95}_{42}Mo + 2{}^{1}_{0}n + 7{}^{0}_{-1}e$

(C) ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{88}_{38}Sr + {}^{136}_{54}Xe + 12{}^{1}_{0}n$

(D) ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{147}_{57}La + {}^{87}_{35}Br + 2{}^{1}_{0}n$

(c) A nuclear reaction produces 2.5 neutrons per fission, but only 0.75 of them (on average) have sufficient energy to produce further fission reactions. What will happen to the energy production in this reactor? Justify your answer.

5. Consider the diagrams X and Y below.



(a) What do these diagrams show?

(b) What do particles Z represent?

(c) What are particles W?

6. (a) Predict what would happen to the reaction if, out of the average 2.5 neutrons produced by each fission, only 0.8, on average, caused additional fissions.

(b) Predict what would happen to the reaction if, out of the average 2.5 neutrons produced by each fission, exactly 1.0, on average, caused additional fissions.

(c) Predict what would happen to the reaction if, out of the average 2.5 neutrons produced by each fission, more than 1.0, on average, caused additional fissions.

7. The equations show three possible nuclear fissions for U-235. Use them and the information in the table to answer this question.

A: $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3(^{1}_{0}n)$

B: $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{139}_{57}La + ^{95}_{42}Mo + 2(^{1}_{0}n) + 7(^{0}_{-1}e)$

C: $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{136}_{54}Xe + ^{88}_{38}Sr + 12(^{1}_{0}n)$

Note: 1 amu = 1.661×10^{-27} kg and 1 MeV = 1.6×10^{-13} J

Particle	Mass (amu)
$^{141}_{56}Ba$	140.9139
$^{92}_{36}Kr$	91.8973
$^{139}_{57}La$	138.8061
$^{95}_{42}Mo$	94.9057
$^{136}_{54}Xe$	135.9072
$^{88}_{38}Sr$	87.9056
$^{235}_{92}U$	235.1170
$^{0}_{-1}e$	0.000549
$^{1}_{0}n$	1.008665

(a) Predict which of these might best sustain a chain reaction. Justify your choice.

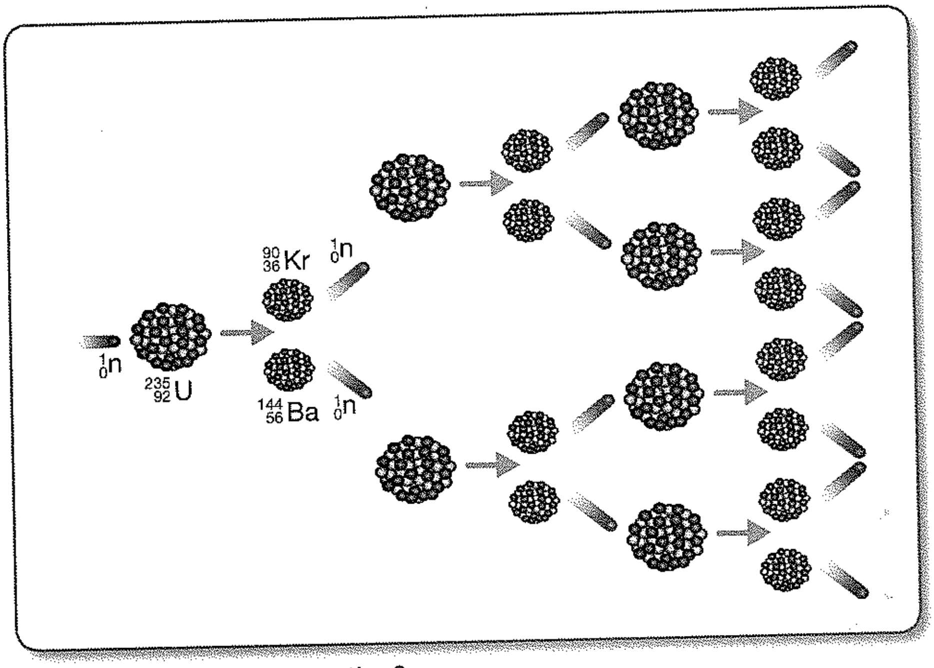
(b) Identify the additional data needed to confirm your prediction.

(c) Calculate the mass defect for each reaction.

(d) Identify from this which reaction will release the most energy per fission.

(e) From this, calculate the amount of energy which would be released by the fission of 1 kg of U-235 by the reaction in your answer to (d).

8. The diagram represents a chain reaction.



(a) Is the reaction a controlled or uncontrolled chain reaction?

(b) Does the diagram represent a fission or a fusion reaction?

(c) What are the daughter products of this reaction?

(d) What is the worrying characteristic about the daughter products of chain reactions?

(e) How is this problem solved?

(f) Why is it such a large problem?

(g) Technically, the diagram is incorrect. What is it failing to show?

SET 30 Nuclear Fission Reactions

1. In a typical fission reaction a neutron collides with a U-235 nucleus producing barium-141 and krypton-92 nuclei as well as a number of neutrons.

Given:

- Mass U-235 = 235.1170
- Mass Ba-141 = 140.9139
- Mass Kr-92 = 91.8973
- Mass neutron = 1.008665
- 1 amu = 931.5 MeV

(a) Write a nuclear equation for the reaction.

(b) Calculate the mass defect for this reaction.

(c) Calculate the energy released per fission.

2. What is the source of energy in a nuclear fission reaction?

3. Find the missing words in the sentences below.

(a) Heavy atoms such as uranium or plutonium can be split by bombarding them with ....

(b) The resultant fragments, called .... products, are of intermediate atomic weight, and have a combined mass that is slightly .... than the original nucleus.

(c) This difference in mass appears as ....

(d) The mass difference arises from the .... characteristics of heavy elements compared to elements of intermediate atomic weight.

(e) Since the binding energy of the fission products per nucleon is .... , their total nucleonic mass is ....

(f) The net result is that fission converts some of the .... of the heavy nucleus into ....

(g) The energy appears in various forms: the kinetic energy of the neutrons, the vibrational energy of the fission fragments, and .... radiation.

(h) All of these forms of energy are converted to heat by absorption in with the surrounding media in a .... , mainly by the .... and the moderator.

4. The mass of a helium nucleus, $^{4}_{2}He$, is 4.0015 u. Given the mass of a neutron as 1.008665 amu and that of a proton as 1.0078825 amu calculate the following quantities.

(a) The mass deficit for the helium nucleus.

(b) The binding energy of the nuclide in MeV.

(c) The binding energy per nucleon in MeV.

5. A particular fission reaction releases 200 MeV for each uranium nucleus that splits. If this uranium is used in a nuclear power station which produces 650 MW of energy, calculate the number of fissions occurring each second.

SET 31 Nuclear Fusion

1. What is the source of energy in a nuclear fusion reaction?

2. Find the missing words in the sentences below.

(a) Nuclear fusion involves the joining of .... nuclei to form a .... nucleus, releasing enormous amounts of energy and no radioactivity.

(b) It is the binding energy .... rather than the .... binding energy that determines the stability of a nucleus.

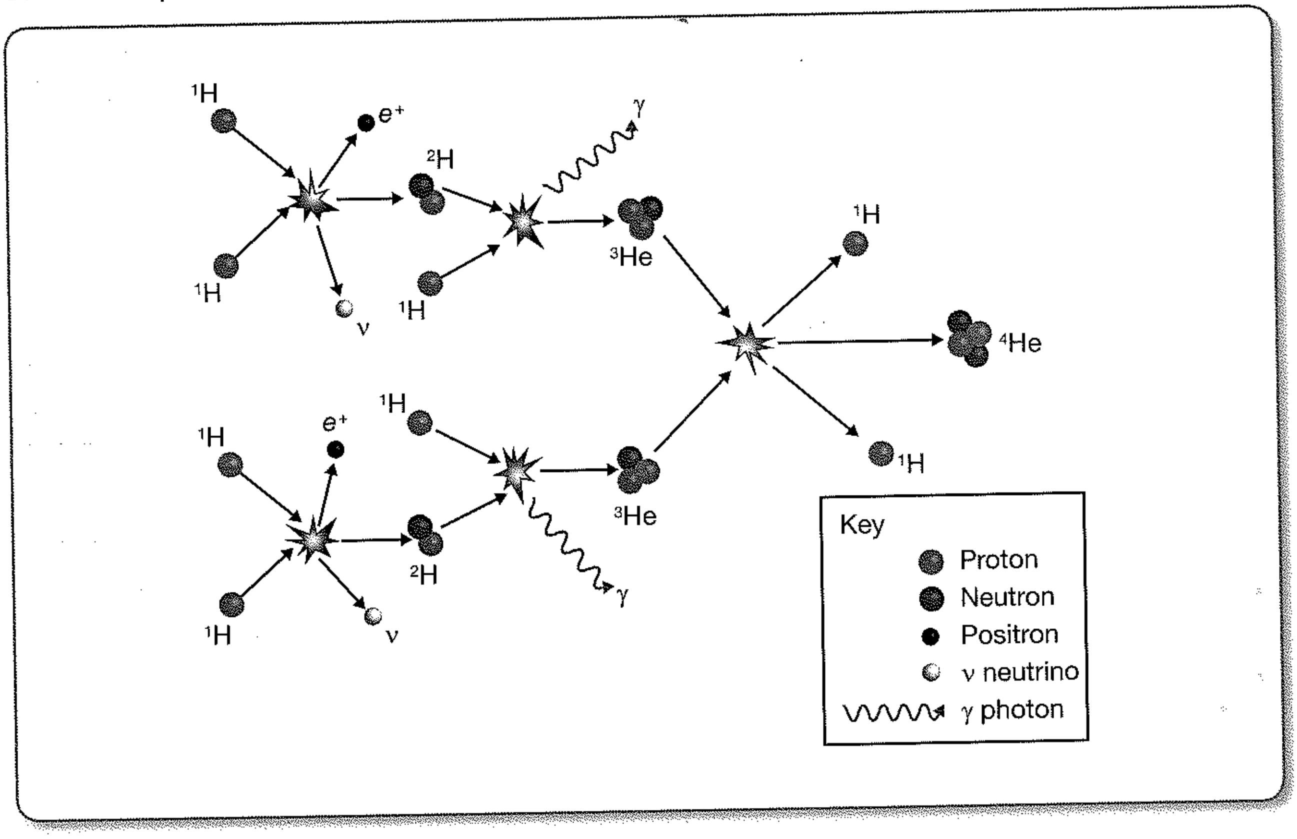
(c) Binding energy represents the energy required to .... an atom into its component parts.

(d) A nucleus with a .... binding energy per nucleon is more .... than a nucleus with a .... binding energy per nucleon.

(e) Nuclear fission will occur spontaneously only if the binding energy per nucleon of the products is .... than the binding energy per nucleon of the original nucleus.

(f) In other words, the product nuclei of the process are more .... than the original nucleus.

3. The diagram shows the sequence of reactions that occur in the fusion of hydrogen nuclei into helium in the Sun. This sequence of reactions is commonly referred to as the proton-proton (pp) chain.



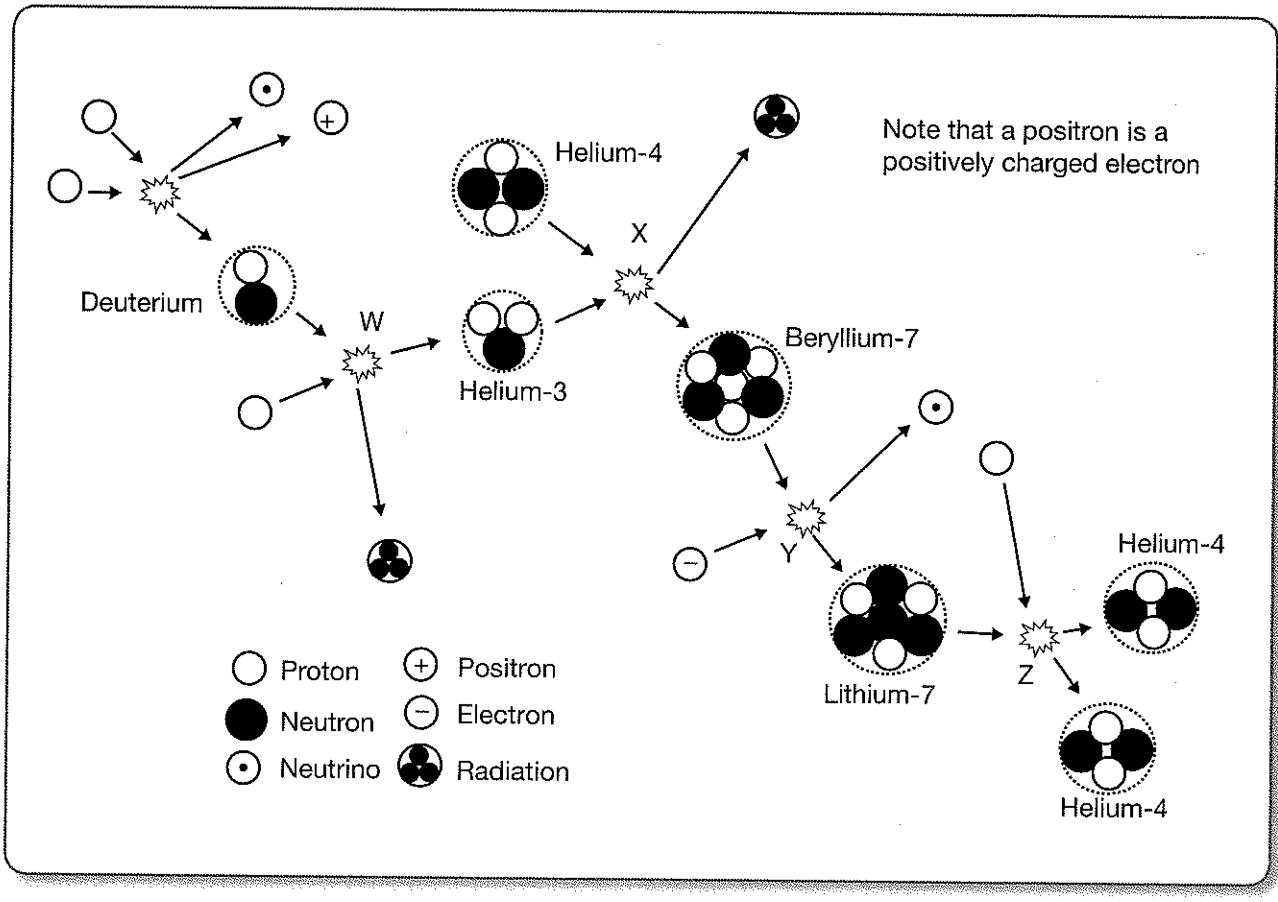
(a) Summarise, in general terms, what the proton-proton chain of reactions does.

(b) What happens in each successive step in the proton-proton chain?

(c) Why do fusion reactions never occur in our normal environment?

(d) What extraordinary condition must occur before fusion reactions can occur?

4. The diagram shows the five steps in the chain of reactions that produces helium-4 particles and solar energy in the core of the Sun.



(a) What nucleons does an atom of helium-4 contain?

(b) Which of these four steps in the process includes nuclear fission?

(c) Energy from the Sun results from the fusion of hydrogen nuclei to form helium. Which symbol represents a hydrogen nucleus?

(d) Write nuclear equations for each of the five reactions that occur in the energy production process in the Sun as shown by the diagram. Do not include radiation or neutrinos in your equations.

(e) Use the information in the table to calculate the mass defect in each of the five reactions.

(f) Calculate the total mass defect for the five reaction process.

(g) Calculate the total energy released during the five reaction process.

Particle	Mass (u)
$^{1}_{1}H$	1.008142
$^{2}_{1}H$	2.014735
$^{3}_{2}He$	3.016977
$^{4}_{2}He$	4.003873
$^{7}_{4}Be$	7.01915
$^{7}_{3}Li$	7.01822
$^{0}_{-1}e$	0.0000549
$^{0}_{+1}e$	0.0000549

SET 32 Comparing Fusion and Fission

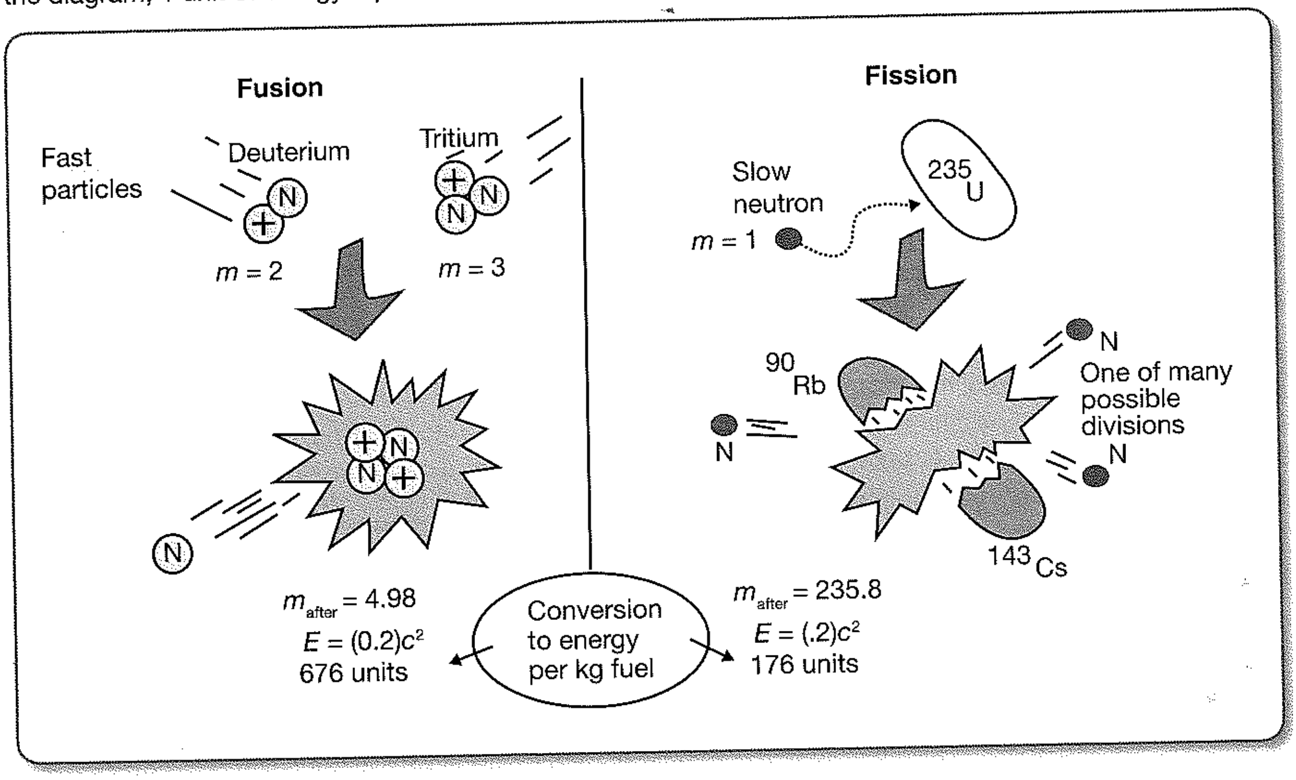
1. (a) Describe the differences between nuclear fission and nuclear fusion.
   (b) Compare advantages and disadvantages of nuclear fission and fusion. Put your answer in a table.

2. Why is fission used to produce energy on Earth but not the fusion which produces energy in stars? In other words, why don't we use the safe, more energetic fusion to produce energy on Earth?

3. Nuclear fission can occur naturally, but nuclear fusion will not occur without an enormous input of energy. Explain these two observations.

4. Consider the following four theoretical nuclear transformations.
   A: Breaking a nucleus of mass number 120 into two nuclei of about equal mass number.
   B: Fusing two nuclei of mass number 60 into one larger nucleus of mass number 120.
   C: Breaking a nucleus of mass number 20 into two smaller nuclei of mass number 10 each.
   D: Fusing two nuclei of mass number 10 into one larger nucleus of mass number 20.
   (a) Which of these transformations would release energy?
   (b) Justify your answer.

5. The diagram shows a typical fusion and fission reaction and the energy released by 1 kg of fuel in each. In the diagram, 1 unit of energy represents the amount of energy used by a person during one year.



   (a) According to this information, which reaction produces the greater mass defect? Justify your answer.
   (b) If these are typical examples of fusion and fission reactions, which would be the better to use as a source of energy? Justify your answer.
   (c) Account for the fusion reaction being the better to use to produce nuclear energy in spite of the fact that the mass defect is 10 times the size in the fission reaction.

6. The fusion reaction occurring in the Sun can be summarised by the equation:

$$4\,^1_1H \rightarrow \,^4_2He + 2\,^0_1e + 2\nu + 2\gamma + 27\text{ MeV}$$

This output seems small when compared to the energy released by the fission of one atom of uranium in a nuclear reaction according to this equation:

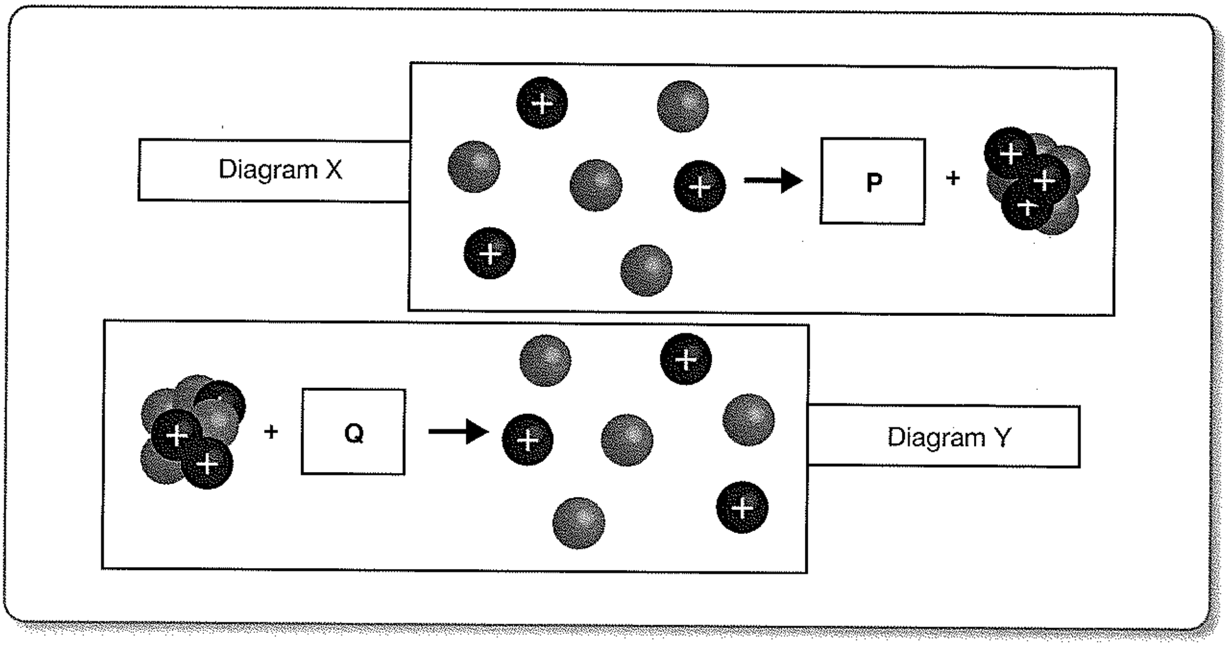
$$^{235}_{92}U + \,^1_0n \rightarrow \,^{92}_{36}Kr + \,^{141}_{56}Ba + 3\,^1_0n + 200\text{ MeV}$$

(a) Calculate the ratio of the energy emitted by one fusion reaction in the Sun to that of the energy emitted by one fission reaction in the reactor.

(b) Calculate the ratio of the energy emitted by 1 kg of hydrogen undergoing fusion in the Sun to that of the energy emitted when 1 kg of uranium undergoes fission reaction in a reactor.

(c) Comment on your answers.

7. (a) What do diagrams X and Y below show?



(b) What belongs in box P?

(c) What belongs in box Q?

(d) Clarify the idea of binding energy.

(e) What is the relationship between the energy involved in a nuclear process and binding energy?

(f) How can both spontaneous fission and fusion reactions release energy?

8. (a) What are the binding energy conditions that must apply for a nucleus to decay by spontaneous fission?

(b) What are the binding energy conditions that must apply for a nucleus to decay by spontaneous fusion?

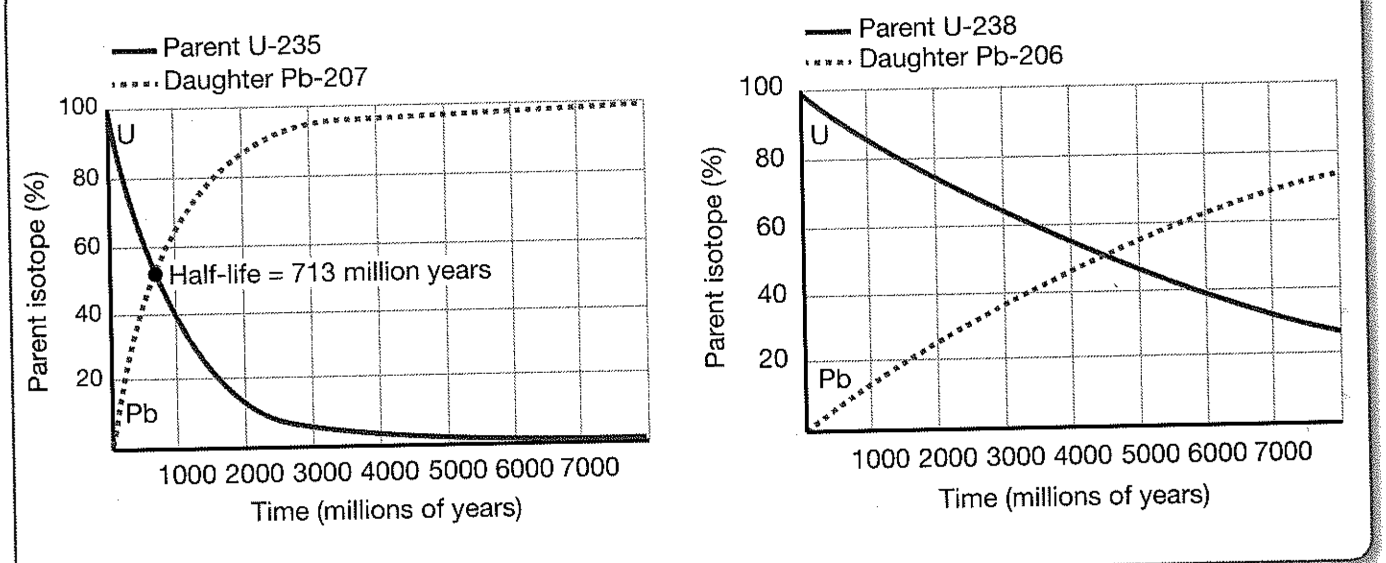
SET 33 Radioisotopes and Radiometric Dating

1. (a) What is radiometric dating?
(b) What is radiometric dating used for?
(c) Who developed the technique of radiometric dating and when?
(d) What did this scientist try to do with radiometric dating?

2. (a) Describe the principle by which radiometric dating works.
(b) Several different radioisotopes are used to date different things. What is the reason for this rather than for using one accurately known isotope?
(c) What is the practical limit for using a radioisotope?
(d) Why does this limit apply?
(e) Show, using any example you choose, how this limit is worked out.

3. (a) Explain how and why carbon-14 can be used to date remains of living organisms or any artefact made from products derived from living organisms.
(b) Explain why carbon-14 dating cannot be use to date inanimate objects.
(c) List an environmental factor which can lead to errors in carbon-14 dating and explain the effect it has.
(d) List two different examples of human activity on Earth which has caused correction factors to be introduced into carbon-14 dating methods.

4. (a) Explain the assumptions behind and the principle used in the radiometric dating of rocks.
(b) Uranium-lead radiometric dating has been refined to the point that the error in dates of rocks can be as low as less than two million years in 2.5 billion years. This is because uranium-lead dating provides two clocks, based on uranium-235's decay to lead-207 and on uranium-238's decay to lead-206. The graphs show the decay of uranium-235 and uranium-238 over time into lead daughter isotopes.



(i) According to the data in the graphs, what is the half-life of U-238?
(ii) Explain why this 'two clocks' dating provides a more reliable estimate of the age of rocks than other methods.

SET 34 The Manhattan Project

You may have to do research to find the answers to some of these questions.

1. What was the Manhattan Project?
   (A) The first experiments to produce a controlled nuclear reaction.
   (B) A project initiated in the USA to build atomic bombs.
   (C) A project to study the transmutation of uranium.
   (D) The first experiments to build a nuclear power station.

2. Who led the group of scientists in the Manhattan Project?
   (A) Bohr.
   (B) Oppenheimer.
   (C) Heisenberg.
   (D) Rutherford.

3. What was the major impact on society in general, of the Manhattan Project?
   (A) It caused serious debate as to the advantages and disadvantages of nuclear power.
   (B) It was to lead to the production of nuclear power stations.
   (C) It initiated the start of the nuclear arms race.
   (D) It was to be the cause of death of thousands of people in Japan.

4. Scientists working on the Manhattan Project were split as to their support of the use of their findings to develop nuclear weapons. What was the deciding factor in this decision?
   (A) The possibility of ending World War II.
   (B) The possibility of huge supplies of energy in the future.
   (C) The excitement of breaking new scientific frontiers.
   (D) Political pressure.

5. Recall the essential requirements for a chain reaction.

6. Define the purpose of the graphite blocks in Fermi's reactor.

7. Outline the function of the control rods in a reactor.

8. Suggest how Fermi would have 'shut the reactor down'.

9. Explain the rationale behind shutting a reactor down.

10. Outline the political pressure that caused the first practical application of nuclear fission to be an uncontrolled reaction.

11. Discuss the nuclear bombing of the Japanese cities of Hiroshima and Nagasaki.

12. Compare the two atomic bombs dropped on Hiroshima and Nagasaki.

13. 'Little Boy', the atomic bomb dropped on Hiroshima, contained more than a critical mass of enriched uranium. Explain why it did not explode spontaneously.

14. Einstein wrote, 'I made one great mistake in my life – when I signed that letter to President Roosevelt recommending that atom bombs can be made.' Suggest why he might have written these words.

15. One commentator wrote: 'The atomic bomb is the supreme example of the way in which the academic research of Einstein and his generation of physicists became, within a few decades, applicable in ways they could not have foreseen. In fact, the range of applications of their work has led to World War Two being called the physicists' war.'
   (a) Clarify this statement.
   (b) Recount events that might have led to this statement.

16. (a) Discuss the impact of the Manhattan Project on society during the 1940s.
   (b) Discuss the impact over the subsequent 30 years.
   (c) Discuss the impact at the present time.

17. Discuss the impact of nuclear technology on the environment.

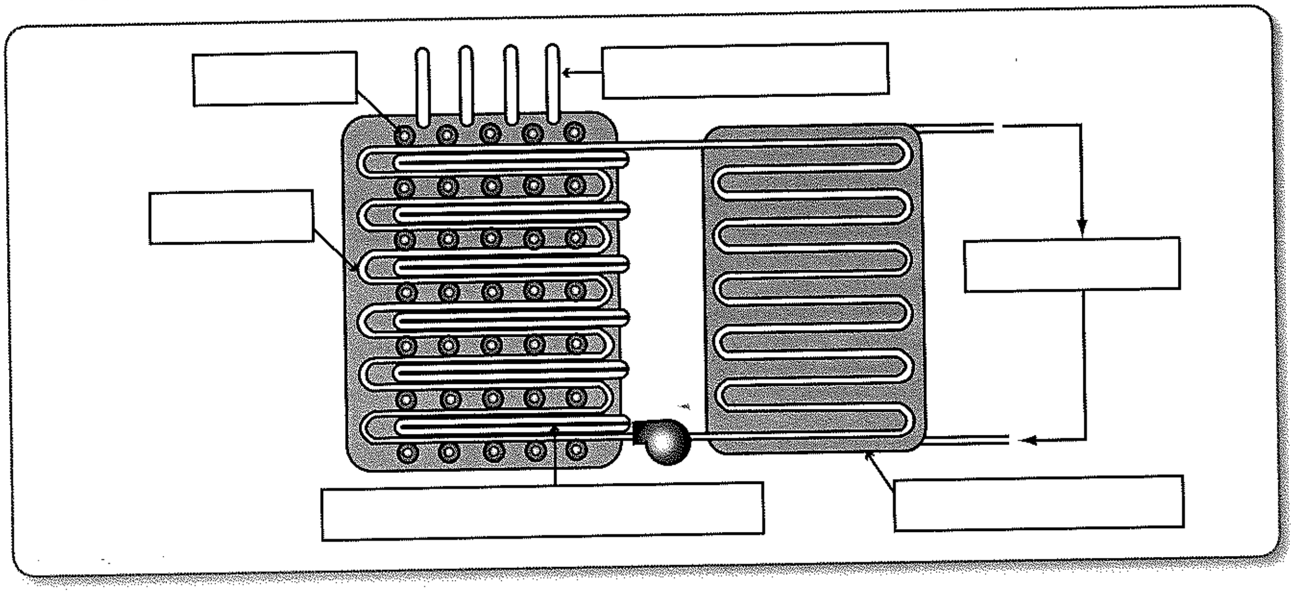
SET 35 Nuclear Reactors

1. List the five essential features of a nuclear reactor.

2. Outline the function of each component of a nuclear reactor.

3. The diagram shows a simplified nuclear reactor. Place the following six labels on the diagram.

- Heat exchanger
- Fuel rods surrounded by moderator
- To steam turbine
- Emergency control rods
- Control rods
- Coolant



4. Assess the use of water, heavy water and graphite as a moderator.

5. Contrast 'chain reaction' and 'fission reaction'.

6. Recall the criteria which must be met for a self-sustaining chain reaction.

7. If a critical mass of fissile fuel could be flattened into a sheet before it exploded, we would find that it was no longer a critical mass. Account for this.

8. Compare uranium and enriched uranium.

9. Account for the use of enriched uranium rather than uranium in a nuclear reactor.

10. Distinguish between a controlled and an uncontrolled nuclear reaction.

11. Identify where an uncontrolled nuclear reaction is useful.

12. Identify the requirements for a controlled nuclear reaction.

13. Identify the requirements for an uncontrolled nuclear reaction.

14. Clarify the importance of a critical mass for a chain reaction.

15. Predict what would happen to a chain reaction if the fuel mass were less than the critical mass.

16. Predict what would happen to a chain reaction if the fuel mass were more than the critical mass.

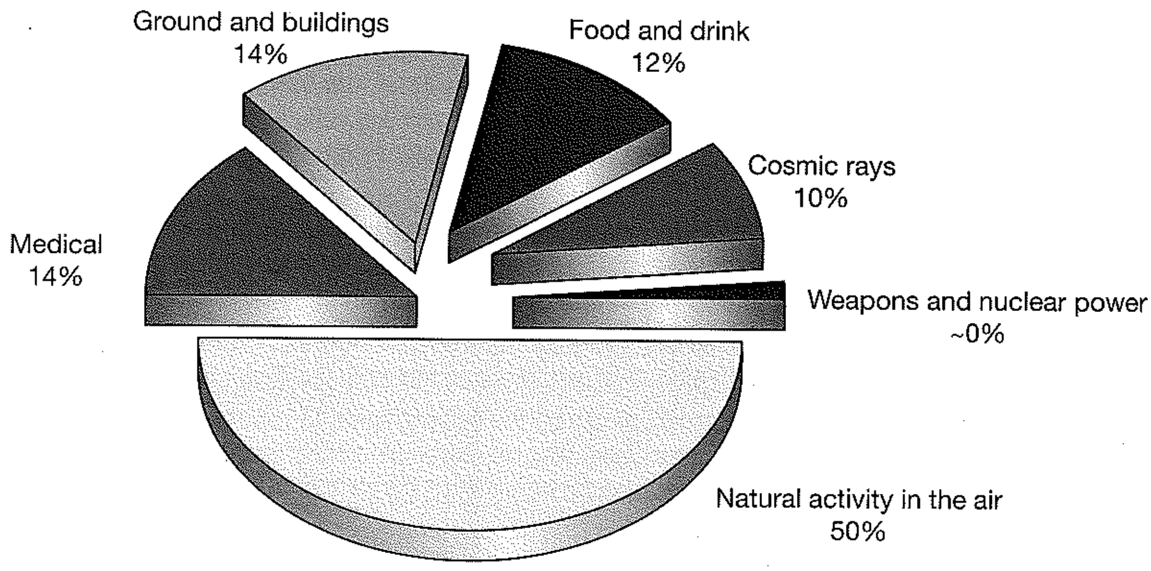
17. The total fuel mass in a reactor is many, many times larger than the critical mass. Explain why a reactor doesn't explode.

18. Explain why a chain reaction does not occur in naturally occurring uranium.

19. The first reactor, built by Fermi in 1942, used 50 tonnes of natural uranium dispersed amongst 400 tonnes of graphite. Propose why so much graphite was used.

SET 36 Nuclear Waste

1. The pie chart shows the various contributors to background radiation.



(a) How can buildings contribute to the background radiation?

(b) On the basis of this information, comment on the danger imposed by nuclear waste.

(c) If the contribution to background radiation from nuclear power and weapons is so little, why are people so concerned about it?

2. Complete the table to classify and give some information about nuclear wastes.

Nuclear waste type	What constitutes this waste type?	How is it disposed of?
Exempt or very low level		
Low level		
Intermediate level		
High level		
Transuranic waste		

3. Read the following material which has been adapted from a statement made in March 2013 by a member of the Australian Nuclear Forum. It presents another side to the nuclear waste argument. This member believes there are great opportunities – economic and environmental – for Australia if we were to become world leaders in the removal and safe burial of nuclear waste.

While acknowledging that the strongest opposition to having nuclear power in Australia comes from the great many people who assert that the problem of nuclear waste disposal has never been solved. The member maintains that this claim is false and always has been, ever since nuclear power was first generated in the late 1950s. He maintains that nuclear waste has been handled since then by hundreds of workers around the world on a daily basis, safely and securely, with never any adverse health effects on anyone.

His hypothesis is that there is an enormous environmental and economic opportunity awaiting Australia were we to take responsibility for the burial and removal from the environment forever of some, perhaps all, of the world's high level nuclear waste, and gives the following arguments in favour of the proposal.

(a) The volume of HLW compared with the volumes of other toxic waste we handle is small. Currently worldwide there are about 250 000 tonnes of waste stored in facilities attached to power stations.

(b) HLW is still extremely energy rich, as during the nuclear fuel's 18 months in a reactor only 0.7% of the contained energy has been used. With the developing integrated fast reactors which will be on line within 10 to 20 years, most of the remaining 99.3 per cent of the contained energy will be recovered.

(c) Integrated fast reactors enable an almost complete burn of the nuclear fuel, thereby reducing the real waste to very small volumes.

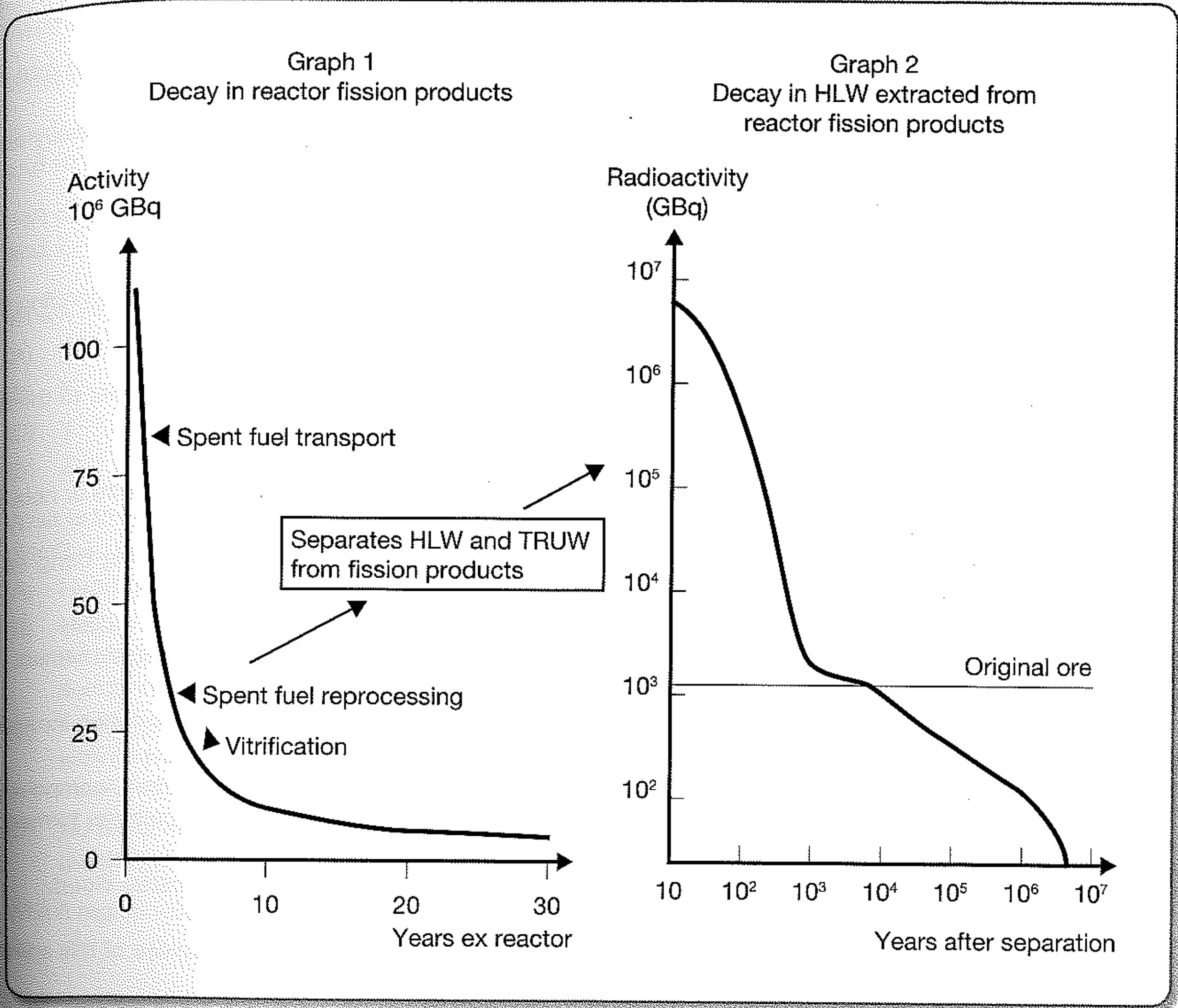
(d) The Officer Basin (a desert region straddling the South Australian and Western Australian border) has been identified as one of the few sites in the world suitable for such a scheme. The area is described as being as remote a place as can be and as a prime site for nuclear waste.

(e) The burial site would need an area of only about 1 km square for surface infrastructure to receive and take the waste underground.

(f) Australia would operate a vital world asset for which the world will pay us handsomely. The economics of the facility, carried out by Access Economics in 1998, suggested a $200 billion industry over 40 years or so with 20 000 infrastructure development jobs, 2500 operational jobs, and with $2.3 billion per year in taxes and royalties paid by user countries.

Make notes that comment on this proposal and support your comments with reasoned arguments. Perhaps, together with some classmates you could argue the rights and wrongs of it – a really good way to learn and develop better arguments, or maybe have a formal class debate on the topic.

4. Graph 1 show the radiation count for nuclear reactor fission products over time. Note that after about four years, the fission products are reprocessed to remove high level and transuranic wastes (HLW and TRUW). The second graph shows how the radioactivity of this HLW decreases with time.



(a) Suggest three reasons why the HLW is separated from the nuclear fission product wastes.

(b) Suggest why four years are allowed to pass before this separation occurs.

(c) Graph 1 shows the level of radioactivity of the fuel waste remaining after the HLW and TRUW have been removed as decreasing to about 1% of its initial level after 30 or so years. Does this mean that the material is now safe to dispose of by normal means? Explain your answer.

(d) A question being asked recently is whether wastes should be emplaced so that they are readily retrievable from repositories.

  (i) Suggest a reason in favour of this strategy.

  (ii) Suggest a reason against this concept.

(e) (i) Graph 2 has a horizontal line on it labelled 'Original ore'. What information is this line telling us?

  (ii) Does this imply that the HLW and TRUW waste material will be safe to handle after 1000 years? Explain your answer.

SET 37 The Birth of Stars

Match the following sentence halves to summarise the birth of stars.

(a) The Universe started at intense heat and has

(b) The Universe was initially compressed

(c) The temperature of the Big Bang is estimated at

(d) Only pure energy existed initially. As the Universe

(e) The first particles formed would have been the fundamental

(f) As the temperature fell further, the quarks started

(g) The next phase, 10^{-6} s, is thought to have been a time during

(h) However, due to an excess of matter

(i) The energy produced by the annihilation of the matter-antimatter combinations was enough to allow fusion

(j) Gravity collected (accreted) the newly forming particles

(k) This resulted in

(l) Small, but growing clumps of denser matter started

(m) As more matter started to be drawn closer

(n) This spinning motion caused the cloud to flatten

(o) Most of the galaxies we observe in the Universe are flattened spiral

(p) As their density increased and more matter accumulated at each point, the 'lumps' of

(q) Eventually a core of matter hot enough to sustain nuclear

(A) cooled, the energy started changing into matter.

(B) combining to form the hadrons, initially as isolated particles.

(C) a 'lumpy Universe'.

(D) into zero volume and has been expanding since the 'Big Bang'.

(E) out and form a disc perpendicular to the axis of the spin.

(F) together to form huge gas clouds or nebulae.

(G) been cooling down since the Big Bang as expansion occurs.

(H) over antimatter, some hadrons remained.

(I) into the cloud, its speed of rotation increased.

(J) fusion reactions formed – stars, composed of hydrogen were born, and galaxies formed.

(K) to form within the larger matter cloud.

(L) galaxies – so formed because of this spinning motion.

(M) 10^{32} K. Matter as we know cannot exist at this temperature.

(N) matter collapsed further, becoming compressed and hotter.

(O) which hadrons and antihadrons combined, releasing leptons and energy in the form of gamma rays.

(P) of some of the remaining hadrons into heavier nuclei, mainly deuterium, helium and lithium.

(Q) particles – the leptons, neutrinos and quarks – and mass less particles like gluons and photons.

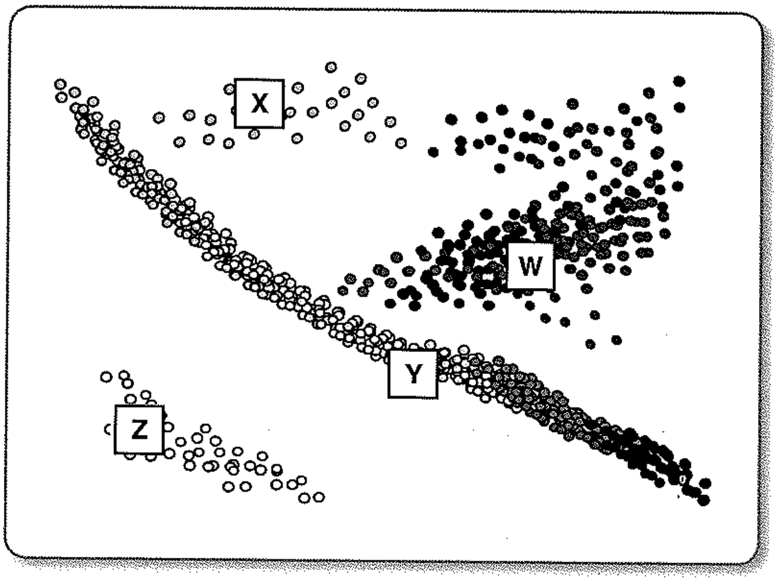
SET 38 The Hertzsprung-Russell Diagram

1. What is an HR diagram?

2. What new information did the first HR diagram show astronomers?

3. The *x*-axis on HR diagrams can show, either individually, or at the same time, the colours, spectral classes and temperatures of stars. Explain why.

Use the HR diagram below to answer some of the next 8 questions. Four regions of the HR diagram are labelled W, X, Y and Z.



4. Which region would contain red giants?
   (A) W
   (B) X
   (C) Y
   (D) Z

5. What is the energy source of a red giant?
   (A) Hydrogen fusion to form helium.
   (B) Helium fusion in the core, hydrogen and larger element fusion in shells surrounding the core.
   (C) Hydrogen fusion in the outer shell with heavier element fusion in inner shells up to iron in the core.
   (D) No fusion reactions occur in red giants.

6. Which region would contain the hottest stars?
   (A) W (B) X (C) Y (D) Z

7. Which region star would have yellow stars?
   (A) W (B) X (C) Y (D) Z

8. In which region would the stars have the shortest time to 'live'?
   (A) W (B) X (C) Y (D) Z

9. Which statement is correct?
   (A) Region X will contain the largest stars.
   (B) Stars in W can be yellow or blue.
   (C) Stars in Y will be hotter than stars in X.
   (D) Region Z will have the coolest stars.

10. Which star is most likely to be blue-white?
    (A) W (B) X (C) Y (D) Z

11. In which region are the stars at the end of their life cycle?
    (A) W (B) X (C) Y (D) Z

SET 39 Types of Stars

1. (a) List at least five different types of stars.
   (b) No black dwarf stars have been detected. Give two possible reasons for this.

2. (a) What are the characteristic properties of a main sequence star?
   (b) The HR diagram summarises trends in the properties of main sequence stars. Outline the trends it shows.

3. Complete the table.

Star type	Energy producing process(es)
Main sequence	
Red giants	
Supergiants	
White dwarfs	

4. (a) What are the oldest stars in the Universe?
   (b) What are the most abundant starts in the Universe?
   (c) What are the coldest stars in the Universe?
   (d) What are the least massive stars in the Universe?
   (e) Which stars burn their fuel least quickly?
   (f) Which stars have the longest predicted life span?

5. The fusion of hydrogen in the core of a main sequence star produces an enormous amount of energy.
   (a) Explain why the star does not expand and become larger and larger as time passes.
   (b) Explain what happens if the forces you referred to in (a) become unbalanced (two answers).
   (c) Provide an example of a situation where your two answers for (b) apply in our Universe.

6. (a) Explain the concept of shell burning.
   (b) What stars have you studied that undergo energy production by shell burning?
   (c) Explain why shell burning does not produce elements with higher atomic numbers than iron.
   (d) The spectrum of some stars shows the presence of elements higher than iron. Given your answer to (c), explain how this can happen.

SET 40 Life Cycles of Stars

1. (a) What is the initial stage in the life cycle of every star?

(b) From this initial stage, what is the next phase in the life cycle of every star?

(c) What is the major influencing factor in determining the particular pathway a star takes in its life cycle?

2. (a) Our Sun is at least a 'second generation' star. What is meant by this?

(b) What evidence do we have to make this statement?

(c) How would the 'first' generation of our Sun have been different to what it is now?

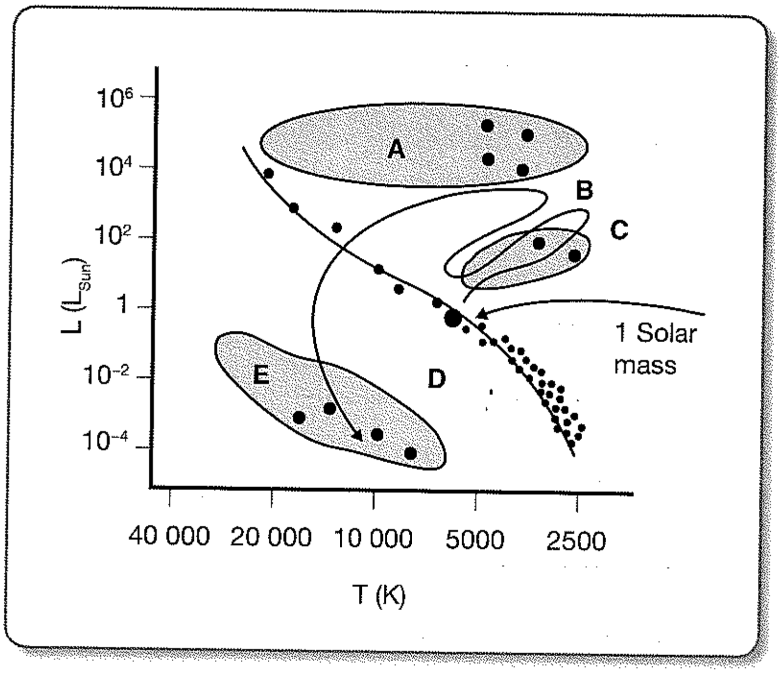
(d) Assuming that out Sun is a second generation star (rather than a third generation say), is it likely that it will form a third generation star in the future? Justify your answer.

(e) What will be the next stage in the life cycle of our Sun?

3. The diagram shows a partially completed HR diagram to which additional information has been added.

(a) Explain in detail what the added information is representing.

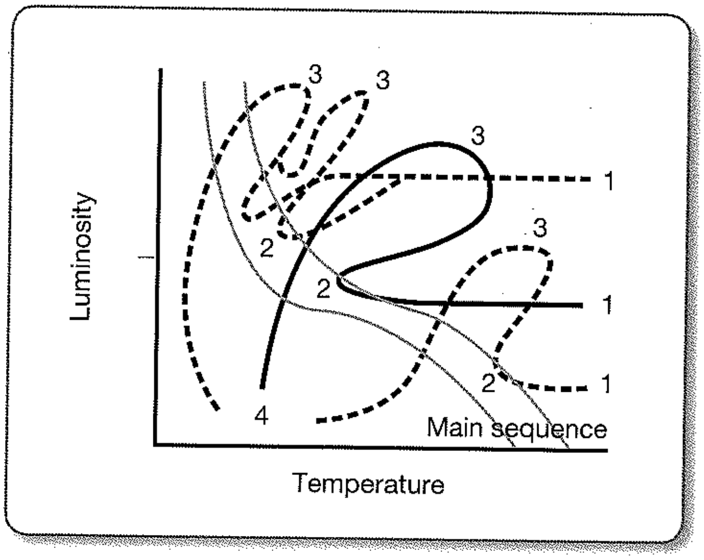
(b) Identify the labelled parts A to E.



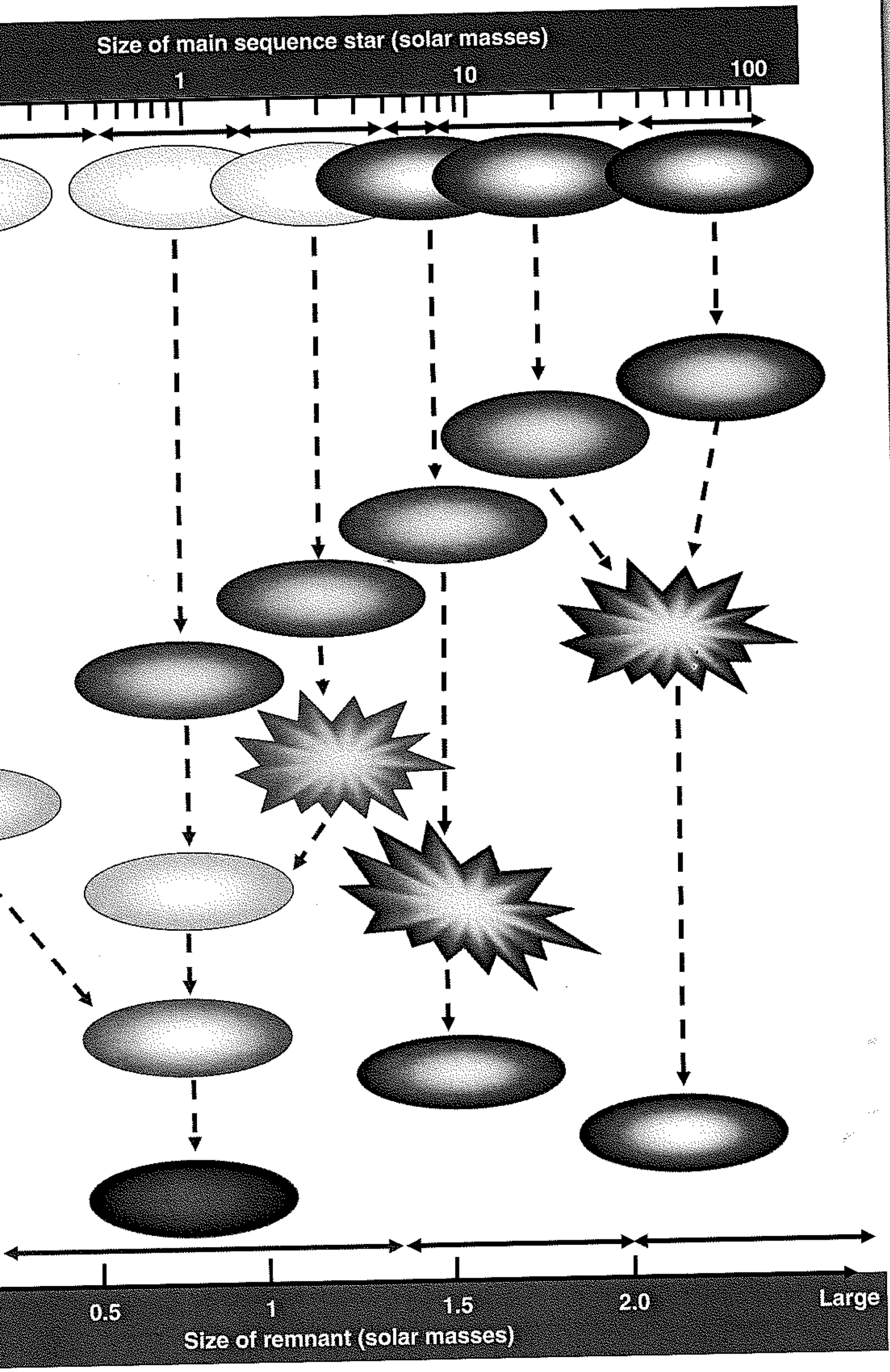
4. The diagram shows another HR diagram.

(a) Identify the types of stars represented by the numbers 1 to 4.

(b) Identify the initial mass of the stars represented by the evolutionary tracks (the full line, longer dashed line and shorter dashed line).



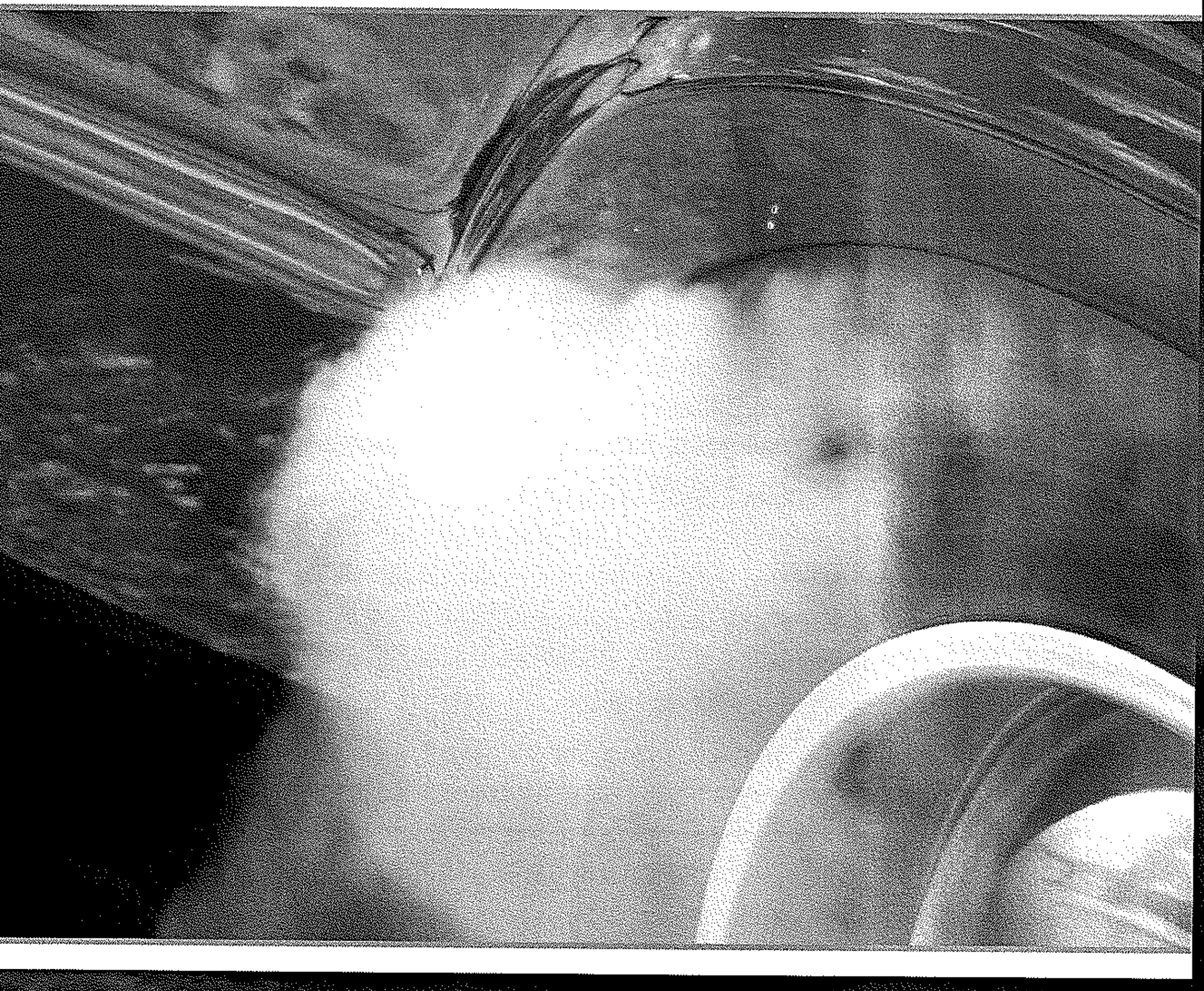
on about the evolutionary pathway taken by main sequence stars of different mass



Q+A

Questions and Answers

Electrical Circuits



SET 41 The Charge Model for Electric Current

1. (a) What are charged objects?
   (b) How does an object become negatively charged?
   (c) How does an object become positively charged?
   (d) What is the most common force involved in charge formation?
   (e) Name two other processes by which charge separation can be obtained.
   (f) What charge is on an object which has a deficiency of electrons?
   (g) What charge is on an object which has an excess of electrons?
   (h) Why don't we define positive and negative charges in terms of excesses or deficiencies of protons?

2. (a) What is the unit we use for electric charge, and what is its symbol?
   (b) Define this unit.

3. What has occurred (in terms of transfers of electrons) to produce the following charged objects.
   (b) Object A with a charge of +1.0 mC.
   (b) Object B with a charge of −2.5 μC.
   (c) Object C with charge $+8 \times 10^{-8}$ C.
   (d) Object D with charge −4.5 nC.

4. What charge does each of the following objects have?
   (b) Object A which has a deficiency of 3×10^{9} electrons.
   (b) Object B which has an excess of 6×10^{8} electrons.
   (c) Object C which has a deficiency of 1.5×10^{12} electrons.
   (d) Object D which has an excess of 9×10^{6} electrons.

5. (a) Define electric current in terms of moving charge.
   (b) Define 1 ampere in terms of charge flow.
   (c) Write down the equation connecting current, time and charge flow.
   (d) Distinguish between conventional current and electron flow through an electric circuit.

6. (a) 4.8×10^{17} electrons flow past a point in a circuit each second. What is the current in the circuit?
   (b) 2.4×10^{16} electrons flow past a point in a circuit each second. What is the current in the circuit?
   (c) 6.0×10^{17} electrons flow past a point in a circuit each minute. What is the current in the circuit?
   (d) 3.2×10^{19} electrons flow past a point in a circuit each minute. What is the current in the circuit?
   (e) 6.4×10^{17} electrons flow past a point in a circuit each 0.1 s. What is the current in the circuit?

7. (a) How many electrons flow past a point in a circuit if the current in the circuit is 0.25 A?
   (b) How many electrons flow past a point in a circuit if the current in the circuit is 1.5 A?
   (c) How many electrons flow past a point in a circuit if the current in the circuit is 6 A?
   (d) How many electrons flow past a point in a circuit if the current in the circuit is 2×10^{-6} A?
   (e) How many electrons flow past a point in a circuit if the current in the circuit is 4×10^{-9} A?

8. A current of 6.5 A flows through a conductor for 12 s. How many electrons pass each point in this time?

9. If 50 mA of current flows in a conductor, how long would it take for one mole of electrons (6.023×10^{23} electrons) to pass a point in the wire?

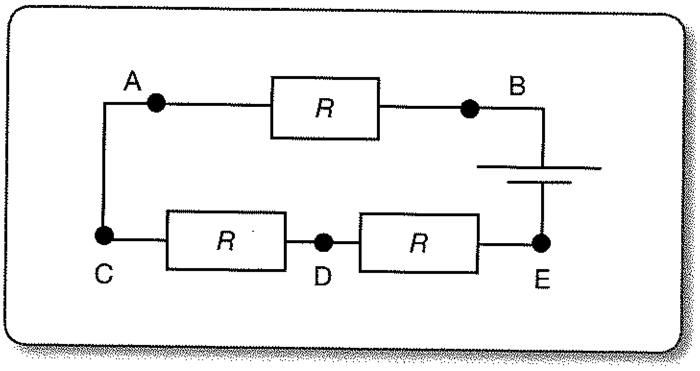
10. Consider the electric circuit diagram.

(a) Compare the current passing through A with that passing through B.

(b) Compare the current passing through A with that passing through C.

(c) Compare the current passing through A with that passing through D.

(d) Compare the current passing through D with that passing through E.

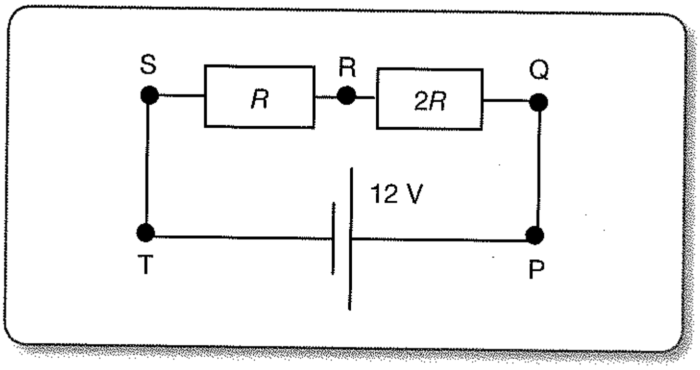


11. Consider the electric circuit diagram.

(a) Compare the number of electrons flowing through P with that flowing through Q.

(b) Compare the number of electrons flowing through P with that flowing through R.

(c) Compare the number of electrons flowing through P with that flowing through S.



(d) Compare the number of electrons flowing through P with that flowing through T.

(e) Compare the number of electrons flowing through Q with that flowing through S.

12. (a) Consider the circuit in Question 11. If the potential of the power supply was doubled, how would that affect the current flowing through each of the points?

(b) Compare the current through B with that through A when the potential of the power supply is tripled.

(c) Consider the circuit in Question 11. If the potential of the power supply was doubled, how would that affect the number of electrons flowing through each of the points?

(d) Compare the number of electrons through B with that through A when the potential of the power supply is tripled.

13. In a particular cathode ray tube computer monitor the current is 3.0 mA.

(a) What electron flow does this represent?

(b) What charge is transferred between the cathode and the anode each second?

14. When starting a particular car, 200 C of charge passed through the starter motor in 4.5 s. What current flow does this represent?

15. If 3×10^{20} electrons flow through a conductor every 5 s, what current is flowing?

SET 42 Electrical Potential Difference 1

1. (a) Define the electrical potential difference between two points in a circuit in terms of work done.
   (b) Write down the equations we get for potential difference from this definition.
   (c) What unit could we use for potential difference based on this definition?
   (d) What is the relationship between this unit and the volt?

2. 2.5×10^{-3} J of work is done moving a charge of 15 μC from A to B. What is the potential difference between A and B?

3. A 6.0 μC charge gains 4×10^{-4} J of energy when it is accelerated between two points in an electric field. Calculate the potential difference between the two points.

4. An electric charge of 8.0 μC is placed in a uniform electric field of strength 750 V m^{-1}.
   (a) How much work is needed to move the charge from X to Y, 10 cm apart parallel to the field?
   (b) What is the electrical potential difference between X and Y?

5. The work done by an external force in moving a 4.5×10^{-6} C charge from P to Q is 9×10^{-5} J. If the charge initially had 3×10^{-3} J of kinetic energy at point P, find the electrical potential difference between P and Q.

6. An electron in a cathode ray tube TV gains about 2.5×10^{-15} J of energy as it is accelerated by the electric field in the electron gun before moving through the tube to hit the screen. What is the potential difference producing the electric field in the electron gun?

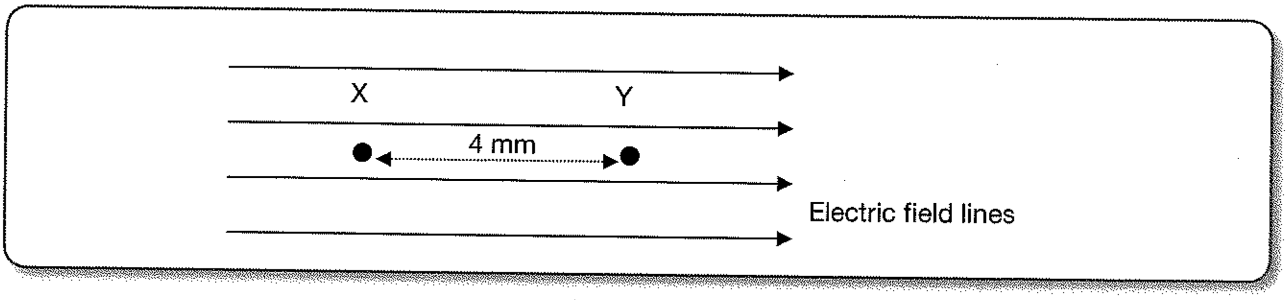
7. How much work is done by an electric field which moves a total charge of 7.5 C from one end of the heating element in an electric hot water jug to the other if,the potential difference across the element is 240 V?

8. On the positive terminal of a small battery, 3 nC of charge has 20 nJ of potential energy. When it reaches the negative terminal it has 2 nJ of potential energy. What is the potential difference between the two terminals of the battery?

9. You charge a plastic ruler positively by rubbing the bottom side of it on your sleeve. In doing this you set up a potential difference of 180 V between the two sides.
   (a) On which side of the ruler would a small negative charge have most potential energy? Explain your choice.
   (b) How much work would have to be done to move a charge of -4.0 μC, from one side of the ruler to the other?

10. In the electron gun of an old cathode ray TV tube, the potential difference between the cathode and the anode is 20 000 V. Ignoring relativistic effects, and assuming electrons leave the cathode with negligible speed, calculate:
    (a) The kinetic energy of each electron at the anode. The charge on the electron is 1.6×10^{-18} C.
    (b) The speed of each electron as it reaches the anode (mass of the electron = 9.11×10^{-31} kg).
    (c) If it travelled constantly at this speed, how long would it take an electron to reach the Moon about 400 000 km away.

11. X and Y are two points 4 mm apart in an electric field. When a charge of $+6.0\ \mu C$ is moved from X to Y, the field does 9×10^{-5} J of work.



(a) What is the potential difference between X and Y?

(b) If it took 3.0 ms for the charge to move from X to Y, what was the equivalent flow of current?

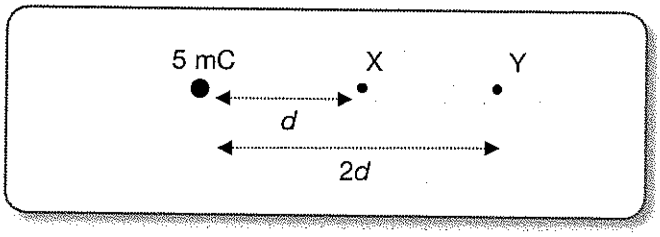
12. What is the potential difference between two points X and Y if:

(a) 1.6 J of work is done in moving $4.5\ \mu C$ of charge from one point to the other?

(b) An alpha particle (He^{2+}) gains 3.2×10^{-15} J of energy in moving freely from X to Y?

(c) Which point, X or Y is at the higher potential? Justify your answer.

13. Two points X and Y are distances d and $2d$ from a positive point charge of 5 mC as shown in the diagram. If it takes 2.5×10^{-5} J to move a charge of 6×10^{-8} C from X to Y, what is the potential difference between X and Y?

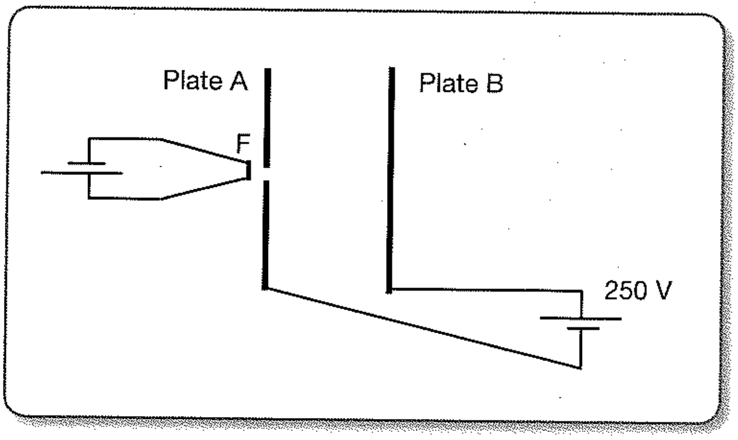


14. Electrons emitted from a hot filament, F, are accelerated through a hole across the gap between two parallel plates A and B as shown in the diagram. The potential difference between the plates is 250 V.

(a) What work is done by the field between the plates in accelerating the electron across the gap?

(b) What will be the speed of the electrons when they reach plate B?

(c) Suppose the distance between the plates was doubled, but the potential difference between them was unchanged. How would this affect your answers to (a) and (b)? Justify your answer.



15. Calculate the voltage of:

(a) A dry cell (battery) that supplies 12 J of energy for every 1.5 C of charge passing through it.

(b) A calculator battery which provides each electron passing through it with 1.5×10^{-18} J of electrical potential energy.

16. A typical car battery supplies 12 V of electrical potential energy to the car's electrical circuits.

(a) How much energy does it supply to each coulomb of charge passing through it?

(b) How much energy does it give to each electron passing through it?

17. How much work is done in moving 3.5 C of charge through the element of a kettle if the kettle is plugged into a 110 V power source?

SET 43 Electrical Potential Difference 2

1. (a) Define potential difference between two points in a circuit in terms of Ohm's law.
(b) Write down the equations we get for potential difference from this definition.
(c) What unit could we use for potential difference based on this definition?
(d) What is the relationship between this unit and the volt?

2. A current of 4 A flows through a conductor which has a resistance of 9 Ω. What is the electrical potential difference across the ends of the conductor?

3. 3 A flows through a length of conductor wire which has a resistance of 15 Ω. Calculate the potential difference applied across its ends.

4. A current of 7.5 A flows through a conductor which has a resistance of 24 Ω. What is the potential difference across the ends of the conductor?

5. A conductor with resistance 9 Ω has a current of 2.5 A flowing through it. What is the electrical potential difference across the ends of the conductor?

6. 6 A flows through a length of conductor wire which has a resistance of 45 Ω. What is the potential difference applied across its ends?

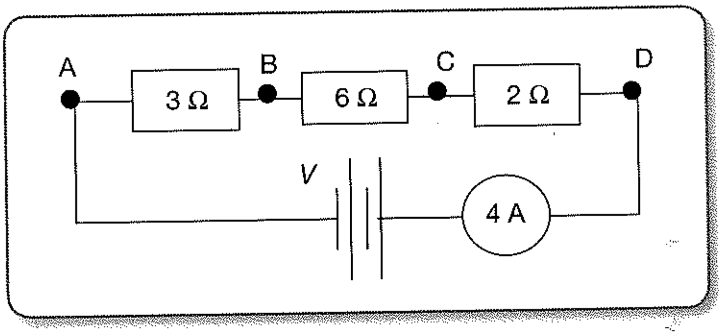
7. A conductor has a resistance of 2.5 Ω m^{-1}. What potential difference will cause a current of 8.0 A to flow through a 50 m length of the conductor?

8. 14 A flows through a length of conductor wire which has a resistance of 3.5 Ω. What is the potential difference applied across its ends?

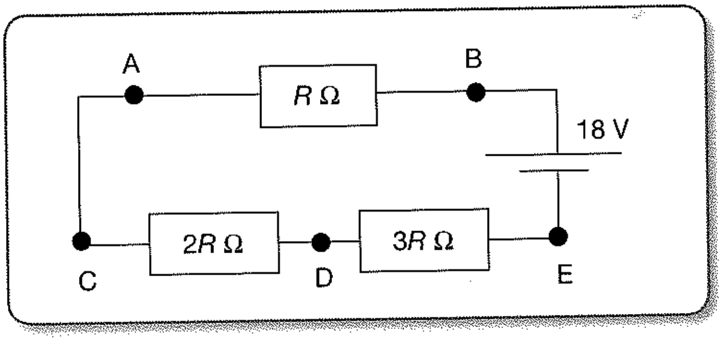
9. A conductor has a resistance of 4.5 Ω m^{-1}. What potential difference will cause a current of 6.0 A through a 2.0 km length of the conductor?

10. A conductor with resistance 6 Ω has a current of 32 A flowing through it. What is the electrical potential difference across the ends of the conductor?

11. Consider the electrical circuit diagram.
Using the definition of potential difference, find the potential difference between points:
(a) A and B. (b) B and C.
(c) C and D. (d) A and C.
(e) A and D. (f) B and D.
(g) What will be the potential difference across the the power supply, V?



12. Consider the electrical circuit diagram.
Find the potential difference between each of the following pairs of points in this circuit.
(a) A and B. (b) A and C.
(c) C and D. (d) D and E.
(e) A and D. (f) B and D.
(g) A and E. (h) C and B.



SET 44 The Nature of Electrical Resistance

1. (a) Define electrical resistance.
(b) What does electrical resistance do?
(c) What causes electrical resistance?
(d) State the main unit we use to measure electrical resistance.
(e) Define this unit, and give the symbol we use for it.
(f) Give the equation we use to calculate electrical resistance.
(g) Rearrange this equation to make current the subject.
(h) Rearrange the equation to make voltage the subject.

2. (a) Imagine a length of a constant resistance conductor at 20°C. Draw a graph to show the relationship between the potential difference across the ends of the conductor and the current flowing through it. Label this graph (a).
(b) Draw a similar graph for the relationship if the conductor was twice as long as the conductor you imagined in (a). Label this graph (b).
(c) Explain any differences in the graph you drew for (b) compared to the one you drew in (a).
(d) Draw a similar graph for the same conductor you imagined in (a) operating at 40°C.
(e) Explain any differences in the graph you drew for (d) compared to the one you drew for (a).

3. (a) List four factors that affect the resistance of conductors.
(b) Explain how and why each of these factors affects the resistance of a conductor.

4. In the junior school you may have talked about conductors, resistors and insulators.
(a) State the definition of a conductor as you learnt it in junior school.
(b) State the definition of a resistor as you learnt it in junior school.
(c) State the definition of an insulator as you learnt it in junior school.
(d) In the senior school we drop the classification 'resistor' and talk only about conductors and insulators. Explain why we do this.

5. A 36 Ω conductor has a potential difference of 240 V across it. Calculate the current flowing through it.

6. 24 V applied across the ends of conductor causes 6 A to flow through it. Calculate the resistance of the conductor.

7. 9 A flows through a length of conductor wire which has a resistance of 1.5 Ω. Calculate the potential difference applied across the ends of the conductor.

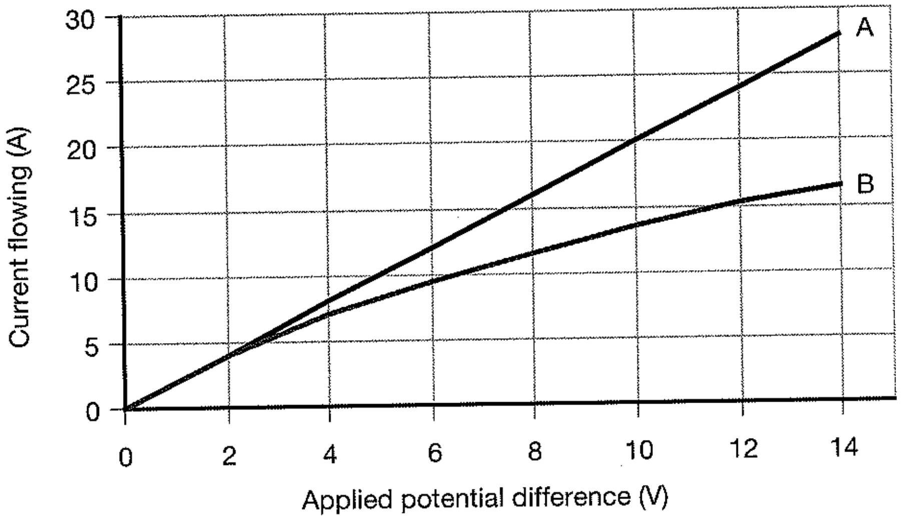
8. Identify the main, useful energy output from each of the following electrical devices.
(a) Soldering iron.
(b) Car hoist.
(c) Fire alarm.
(d) Dentists drill.
(e) Torch.

9. For each of the following energy changes, identify an electrical device that makes that energy change (do not use examples from Question 8).
(a) Electrical energy into light energy.
(b) Electrical energy into sound energy.
(c) Electrical energy into heat energy.
(d) Electrical energy into kinetic energy.
(e) Electrical energy into gravitational potential energy.

SET 45 Ohmic and Non-ohmic Conductors

1. (a) Describe the difference between an ohmic and a non-ohmic conductor.

(b) Are ohmic conductors always ohmic conductors? Explain your answer.



2. The graph shows the current-potential difference relationships for two conductors, A and B.

(a) Which of these conductors is ohmic. Justify your answer.

If A and B were connected in series, and the current flowing through the circuit was 10 A, what would be:

(b) The current through A?

(c) The current through B?

(d) The potential difference across A?

(e) The potential difference across B?

(f) The potential difference across the AB combination?

A and B are now connected in series into a circuit where the potential difference across B is 10 V. What is:

(g) The current through A?

(h) The current through B?

(i) The potential difference across A?

(j) The potential difference across the AB combination?

A and B are now connected in series into a circuit where the potential difference across A is 8 V and the potential difference across B is 12 V. What is:

(k) The current through A?

(l) The current through B?

(m) The total current flowing in the circuit?

(n) The resistance of the circuit?

SET 46 Electrical Potential Difference 3

1. (a) Define potential difference between two points in a circuit in terms of power dissipated.
   (b) Write down the equations we get for potential difference from this definition.
   (c) What unit could we use for potential difference based on this definition?
   (d) What is the relationship between this unit and the volt?

2. When a current of 8 A flows through a conductor, 120 W of power are dissipated. What is the potential difference across the ends of the conductor?

3. 400 W of power are dissipated when a current of 2.5 A flows through a conductor. What is the potential difference across the ends of the conductor?

4. What is the potential difference across the ends of the conductor if, when a current of 7.5 A flows through it, 750 W of power are dissipated?

5. A transformer power pack in a school laboratory with a voltage of 9.0 V is delivering 2.5 A to the circuit connected to it.
   (a) What is the power output of the power pack?
   (b) If it is used continuously for 3.0 minutes, how much electrical energy is used?

6. A button battery in a calculator is marked 0.7 mW, 1.5 V. What current does it deliver to the calculator?

7. An electric jug is marked '240 V, 1.5 kW'.
   (a) When used normally, what current flows through its heating coil?
   (b) How much electrical energy is used if it takes 1 minute, 35 seconds to boil the water in it?

8. The element of an electric toaster carries 5 A of current when used normally. It has a power rating of 600 W.
   (a) What charge moves through the heating element each second?
   (b) What potential difference should be used with this toaster?
   (c) How much energy is used by the toaster each second?
   (d) How much energy per coulomb does this toaster supply?

9. A current of 3.0 A flows through a heating element for 20 minutes. In this time it produces 864 kJ of heat energy. Assuming all electricity used was converted into heat energy, find:
   (a) The amount of electrical charge passing through the element.
   (b) The electrical potential difference across the element.
   (c) The power rating of the heating element.

10. Determine the work done in moving 15 μC of charge through a potential difference of 3.0×10^3 V.

11. An electron accelerated from the cathode to the anode of a discharge tube gains 4×10^{-16} J of kinetic energy. What is the electrical potential difference between the cathode and the anode?

12. The work done by an external force in moving a 3.0×10^{-5} C charge from X to Y is 8×10^{-3} J. If the charge had 3×10^{-3} J of kinetic energy at point Y, what is the electrical potential difference between X and Y?

SET 47 Electrical Power

1. (a) What is power?
   (b) What are the units for power?
   (c) What unit is used commercially for electrical power consumption?
   (d) Explain why this unit is used.

2. A battery causes 15 A to flow through a 5 Ω conductor. Calculate:
   (a) The power of the battery.
   (b) The total energy output from the battery in 15 hours.

3. A potential difference of 36 V is applied across the ends of a conductor of resistance 9 Ω. Calculate:
   (a) The power developed by the conductor in watts.
   (b) The energy dissipated (changed into heat and/or light energy) in 6 seconds.
   (c) The energy the conductor uses, in kWh, in 7 days.

4. A toaster is rated 240 V, 500 W. Calculate:
   (a) The current it will draw.
   (b) The resistance of its element.
   (c) How many hours of operation would use 25 kWh.

5. A heating coil has a resistance of 56 Ω. Calculate the voltage needed for it to produce 2000 W of power.

6. A potential difference of 16 V causes a current of 5 A to flow through a circuit. Calculate:
   (a) The power developed by the power source.
   (b) The total energy output in 30 minutes.

7. A heater has a resistance of 150 Ω. It operates for 6 hours on a 240 V supply. Calculate:
   (a) Its power rating.
   (b) Its energy consumption in the 13 hours.

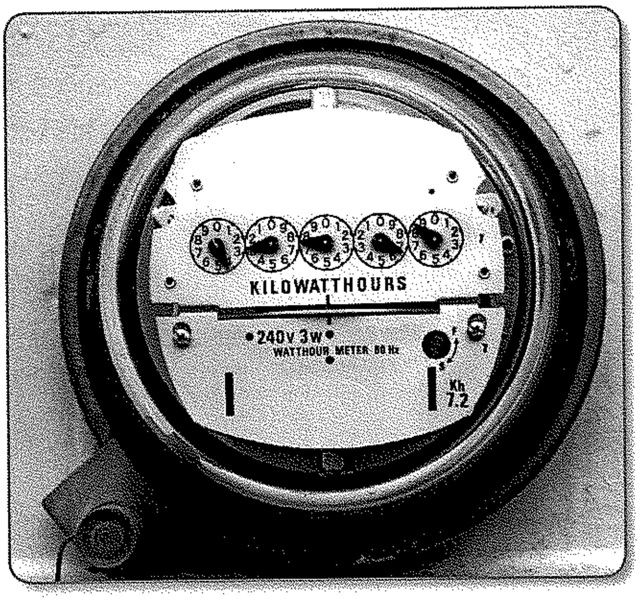
8. Find the energy dissipated in a coil of resistance 9 Ω when 4 A flows through it for 60 s.

9. Some globes we use in our homes are marked 240 V 25 W.
   (a) Calculate the current these globes draw.
   (b) Calculate the resistance of their filaments.
   (c) A different globe is marked 25 W but its voltage reading is blurred. Its resistance is measured to be 16 Ω. Calculate its operating voltage.
   (d) Predict what would happen to this globe if it was used in a 240 V circuit.

10. The heating coil of an electric jug consists of 8 m of a thin conductor. It develops 1200 W when connected to a 240 V supply.
    (a) Calculate the power it would develop if used overseas in a 110 V circuit.
    (b) Comment on the efficiency of the jug under these conditions.
    (c) Calculate the current the jug would draw in Australia.
    (d) Calculate the current it would draw overseas with a 110 V supply.

11. Some globes we use in our homes are marked 240 V 60 W.
    (a) Calculate the current these globes draw.
    (b) Calculate the resistance of their filaments.
    (c) A different globe is also marked 60 W but its voltage reading is blurred. Its resistance is measured to be 40 Ω. Calculate its operating voltage.
    (d) Predict what would happen to this globe if it was used in a 110 V circuit.

12. A 240 V heating coil uses 1200 W of power. What is its resistance?



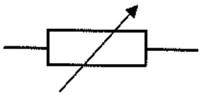
SET 48 Components in Simple Electric Circuits

1. (a) What is an electric circuit?

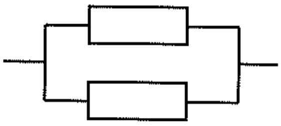
(b) Identify the two main functions of electric circuits.

2. Identify the electric component represented by each of the following circuit symbols, or groups of symbols, and state what each component is used for.

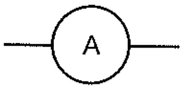
(a)

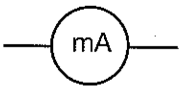

(b)


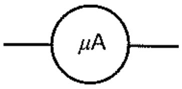
(c)

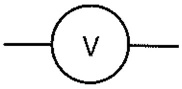

(d)


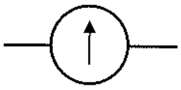
(e)


(f)


(g)


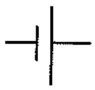
(h)


(i)


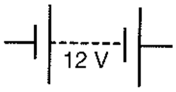
(j)


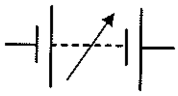
(k)


(l)


(m)


(n)


(o)


(p)


(q)

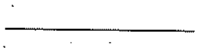

(r)

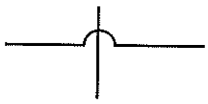

(s)


(t)

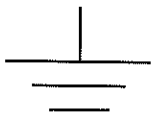

(u)


(v)


(w)


(x)


(y)


(z)


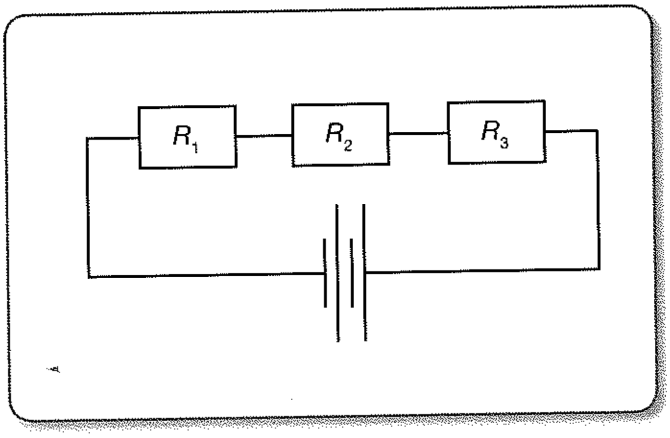
3. (a) Explain the difference between an open and a closed circuit.
(b) Explain what a 'short circuit' is.

4. Draw a diagram of a 9 V battery and label the positive and negative terminals.

5. (a) State how an ammeter is connected into an electrical circuit.
(b) Draw a diagram to show what you mean by this.
(c) Explain, in terms of the structure of the meter, why it is connected this way.

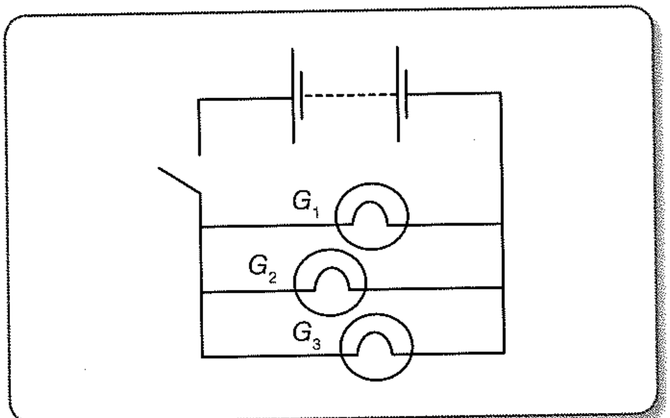
6. (a) State how a voltmeter is connected into an electrical circuit.
(b) Draw a diagram to show what you mean by this.
(c) Explain, in terms of the structure of the meter, why it is connected this way.

7. Copy the diagram into your book and use it to answer this question and Question 8.
Add ammeter(s) to the circuit to:
(a) Measure the current flowing through R_1.
(b) Measure the current flowing through R_2.
(c) Measure the current flowing through R_3.



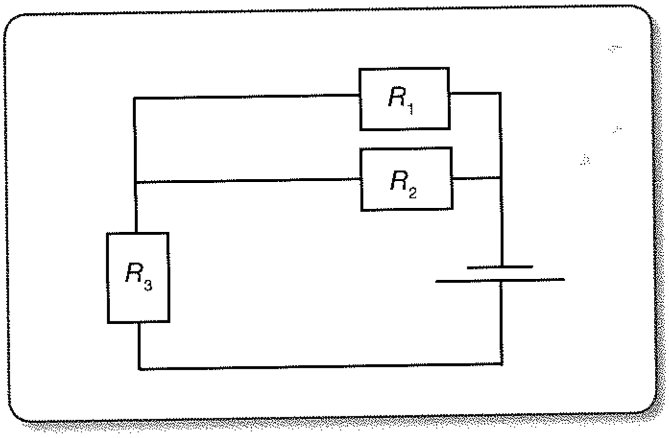
8. Add voltmeter(s) to the circuit to:
(a) Measure the potential difference across R_1.
(b) Measure the potential difference across R_2.
(c) Measure the potential difference across R_3.

9. Copy the diagram into your book and use it to answer this question and Question 10.
Add ammeter(s) to the circuit to:
(a) Measure the current flowing through G_1.
(b) Measure the current flowing through G_2.
(c) Measure the current flowing through G_3.



10. Add voltmeter(s) to the circuit to:
(a) Measure the potential difference across G_1.
(b) Measure the potential difference across G_2.
(c) Measure the potential difference across G_3.

11. Copy the diagram into your book and use it to answer this question and Question 12.
Add ammeter(s) into the circuit to:
(a) Measure the current flowing through R_1.
(b) Measure the current flowing through R_2.
(c) Measure the current flowing through R_3.



12. Add voltmeter(s) into the circuit to:
(a) Measure the potential difference across R_1.
(b) Measure the potential difference across R_2.
(c) Measure the potential difference across R_3.

SET 49 Using Ammeters and Voltmeters

Ammeters

1. (a) What is an ammeter?
(b) What is a milliammeter?
(c) What is a microammeter?

2. (a) How many milliamps are there in an amp?
(b) How many microamps are there in an amp?
(c) How many microamps are there in a milliamp?

3. (a) What is the symbol we used to represent amps?
(b) What is the symbol we used to represent milliamps?
(c) What is the symbol we used to represent microamps?

4. (a) Define one amp of electrical energy in terms of electric charge transfer.
(b) Define one milliamp of electrical energy in terms of electric charge transfer.
(c) Define one microamp of electrical energy in terms of electric charge transfer.

5. (a) Define one amp of electrical current in terms of the potential difference across a conductor, and the resistance of that conductor.
(b) What is the mathematical equation we get from this definition?

Voltmeters

Match the sentence halves to summarise the main information you need to know about voltmeters. There is no need to know this work beforehand, the syntax of each sentence should give you the matches.

1. A battery is	(a) potential difference across two points in a circuit.
2. A battery is often	(b) is measured in volts.
3. A battery is a source	(c) a circuit is called its voltage.
4. Electrons flow through a circuit from a	(d) across those two points.
5. The ability of a battery to 'pump' electrons through	(e) described as an electron 'pump'.
6. Voltage is a measure of how much	(f) for voltage is V.
7. The instrument used to measure voltage	(g) of electrons.
8. Voltmeters measure electrical	(h) battery because of forces of electrostatic repulsion.
9. To do this they must be connected	(i) is the voltmeter.
10. Voltage can also be	(j) a source of electrical energy.
11. Anything connected across two points in a circuit	(k) energy a battery can supply to a circuit.
12. Voltage	(l) is said to be connected in parallel.
13. The symbol	(m) per unit charge moving from one point to the other.
14. The electrical potential difference between two points is the change in energy	(n) expressed as joules per coulomb.

SET 50 Conductors in Series and in Parallel

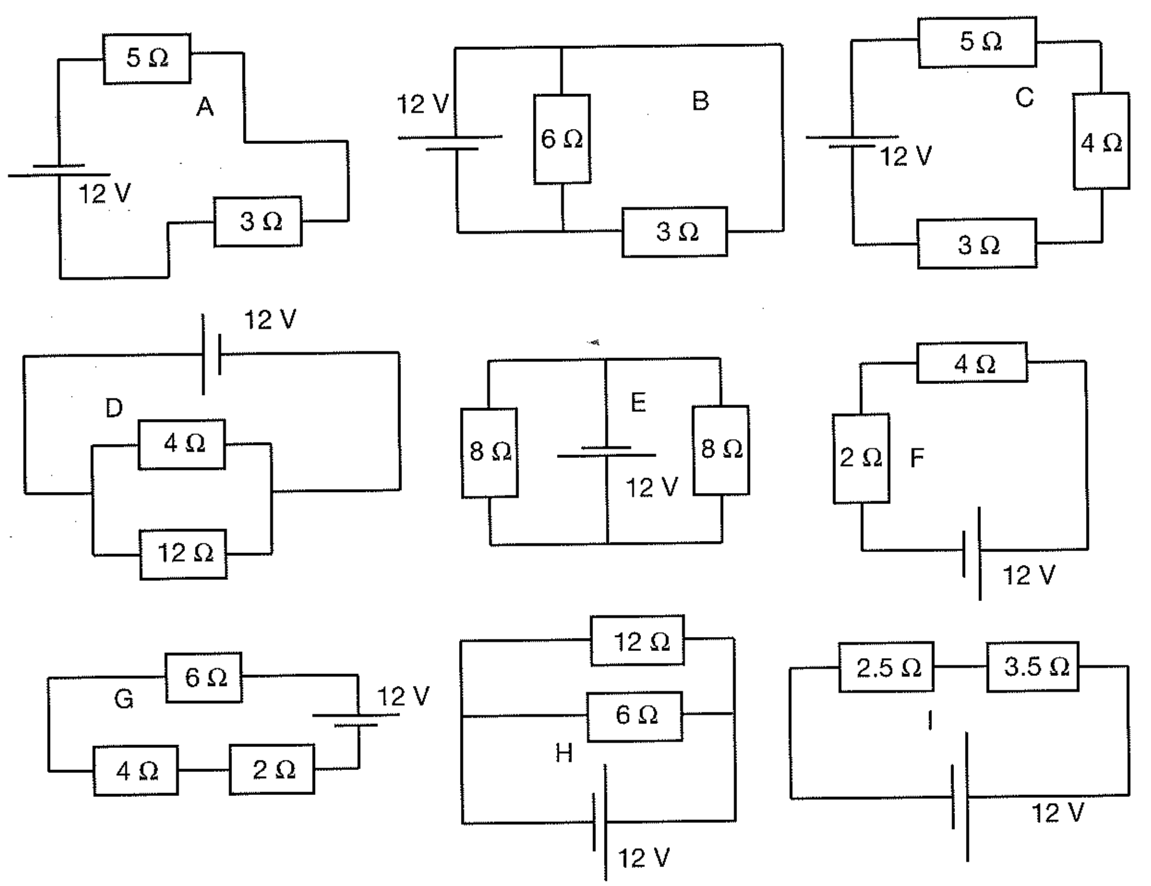
1. Explain the difference between conductors connected in series and those connected in parallel in terms of:

(a) Their physical connections. Give an analogy for each case.

(b) The current flowing though them.

(c) The potential difference across them.

2. Classify each of the following circuits as containing conductors connected in series or in parallel. Note that the potential of the power source for each circuit is 12 V.



3. (a) How do we determine the total resistance of a set of conductors connected to each other in series? Write an appropriate equation for this.

(b) How do we determine the total resistance of a set of conductors connected to each other in parallel? Write an appropriate equation for this.

4. (a) What is the relationship between the voltage of a power supply and the voltage across a set of conductors connected in series? Write an appropriate equation for this.

(b) What is the relationship between the voltage of a power supply and the voltage across a set of conductors connected in parallel? Write an appropriate equation for this.

5. (a) What is the relationship between the current drawn from the power supply and the current flowing in each of a set of conductors connected in series? Write an appropriate equation for this.

(b) What is the relationship between the current drawn from the power supply and the current flowing in each of a set of conductors connected in parallel? Write an appropriate equation for this.

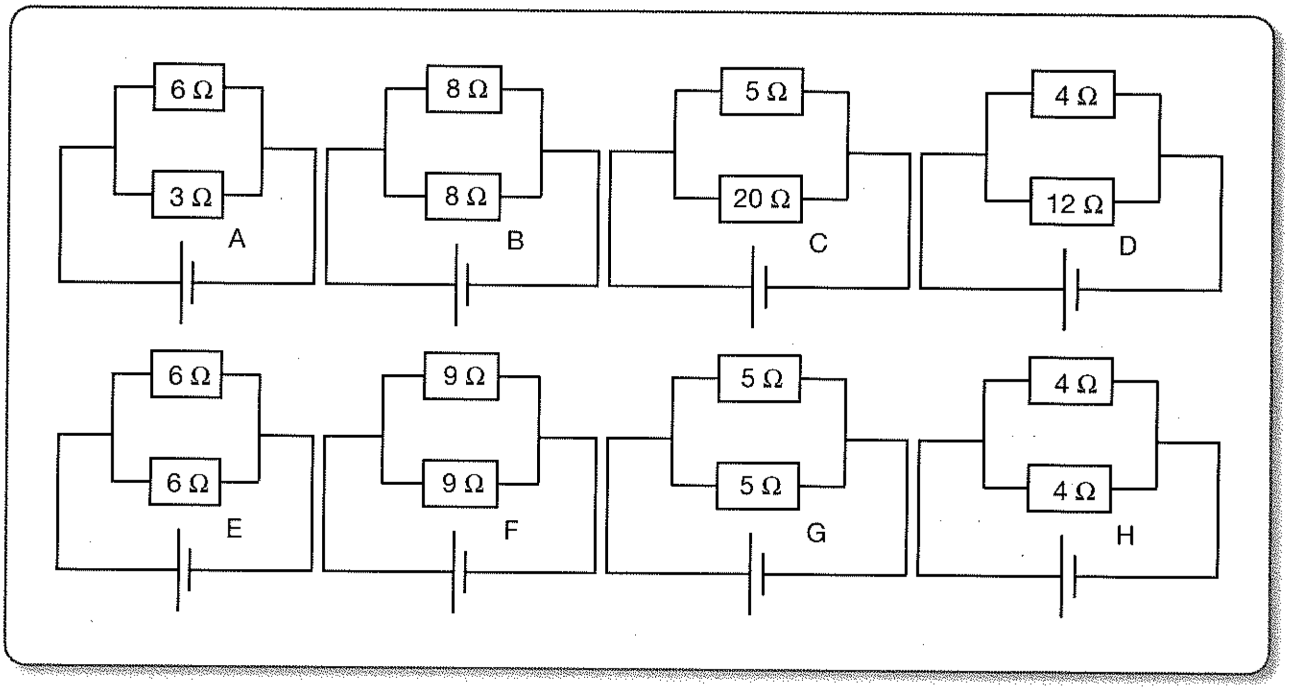
6. Calculate the total resistance of each circuit in Question 2.

7. In which of the circuits in Question 2 will each of the conductors have 12 V of potential difference across them?

8. (a) Identify the circuits in Question 2 in which every conductor has the same current flowing through it as all the other conductors in that circuit. Careful – one is tricky!

(b) Explain the 'tricky' one if you identified it correctly.

9. (a) Calculate the total resistance of each of the following circuits.



(b) Show that the total resistance of a circuit with two conductors in parallel can also be calculated using the expression:

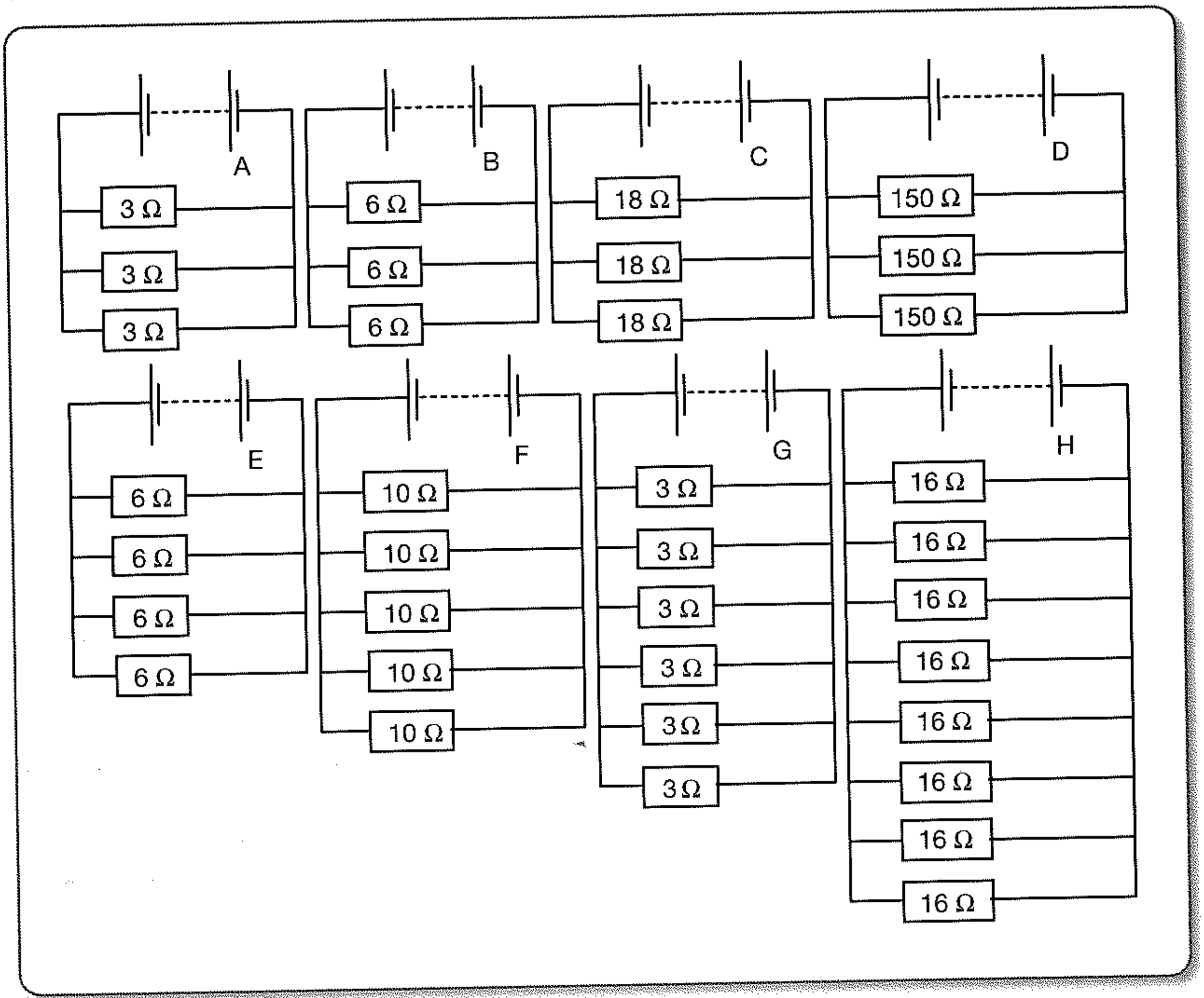
$$\text{Total resistance} = \frac{\text{product of the two resistances}}{\text{sum of the two resistors}} = \frac{R_1 \times R_2}{R_1 + R_2}$$

(c) Show that the total resistance of a circuit with two identical conductors in parallel can also be calculated using the expression:

$$\text{Total resistance} = \frac{\text{value of one resistance}}{2} = \frac{R}{2}$$

Science Press

10. (a) Calculate the total resistance of each of the following circuits using the inverse reciprocal formula.



(b) Show that the total resistance of a circuit with *n* identical conductors in parallel can also be calculated using the expression:

$$\text{Total resistance} = \frac{\text{value of one resistance}}{n} = \frac{R}{n}$$

11. (a) Draw a diagram of an electrical circuit which contains three light globes in parallel. Include switch(es) so that if one globe is on, then all will be on.

(b) Draw a another diagram of an electrical circuit which contains three light globes in parallel. Include switch(es) so that each of the globes can be turned on independently of the other two.

(c) Are these two options available if the three globes are connected in series with each other? Explain your answer.

12. (a) Explain, in terms of the function of the electric circuit, why conductors are connected in series.

(b) Is there any particular advantage or disadvantage in this type of circuit?

(c) Identify somewhere in your home where conductors are connected in series.

(d) Explain, in terms of the function of the electric circuit, why conductors are connected in parallel.

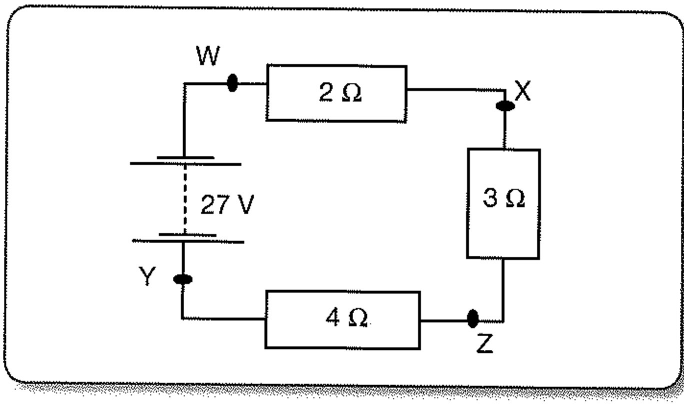
(e) Is there any particular advantage or disadvantage in this type of circuit?

(f) Identify somewhere in your home where conductors are connected in parallel.

SET 51 Potential Around a Series Circuit

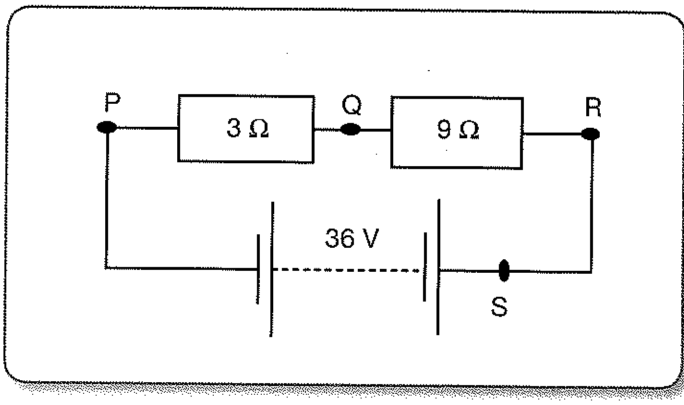
1. Identify the electrical potential of the labelled points on the circuit shown, and then use these to determine the potential difference between:

(a) X and Y.
(b) X and Z.
(c) W and Z.
(d) W and Y.



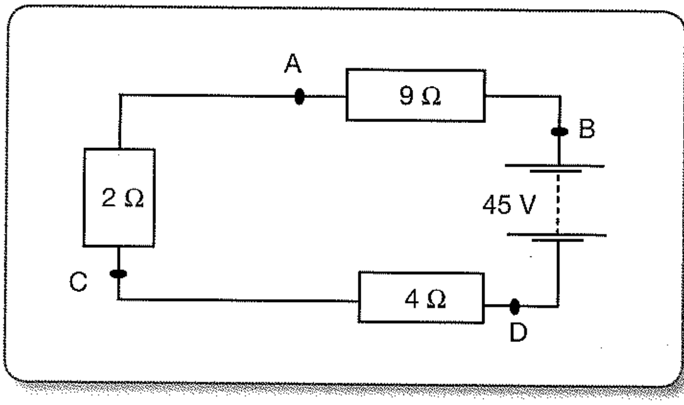
2. Identify the electrical potential of the labelled points on the circuit shown, and then use these to determine the potential difference between:

(a) P and Q.
(b) P and S.
(c) Q and S.
(d) R and S.



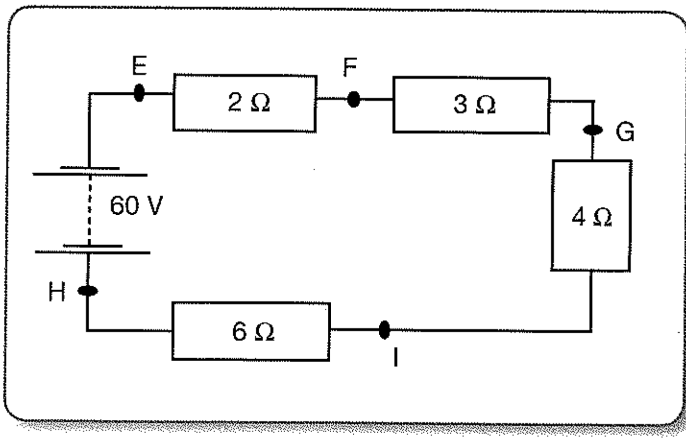
3. Identify the electrical potential of the labelled points on the circuit shown, and then use these to determine the potential difference between:

(a) A and B.
(b) C and D.
(c) A and D.
(d) C and B.



4. Identify the electrical potential of the labelled points on the circuit shown, and then use these to determine the potential difference between:

(a) E and F.
(b) F and G.
(c) G and I.
(d) H and G.
(e) F and I.



SET 52 Analysing Series Circuits

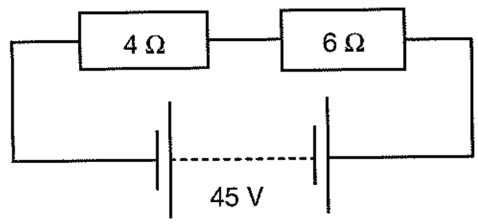
1. A circuit contains two conductors, with resistances of 4 ohms and 6 ohms, connected in series with each other as shown in the diagram. The power supply has a potential difference of 45 volts. Find:

(a) The total resistance of the circuit.

(b) The current delivered by the power supply.

(c) The current flowing in each conductor.

(d) The potential difference across each conductor.



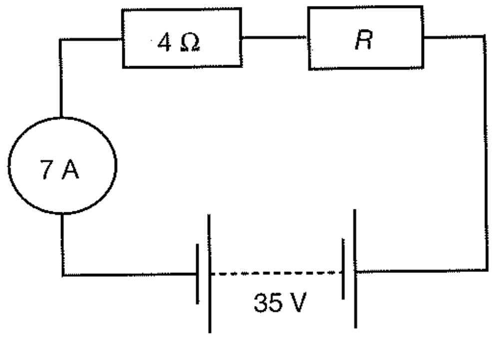
2. A circuit contains two conductors, one with resistance of 3 ohms and an unknown conductor *R*, connected in series with each other as shown in the diagram. The power supply has a potential difference of 35 volts. The current in the ammeter shown is 7 A. Find:

(a) The total resistance of the circuit.

(b) The value of *R*.

(c) The current flowing in each conductor.

(d) The potential difference across each conductor.



3. A circuit contains two conductors with resistances of 2.5 ohms and 5 ohms, connected in series with each other as shown in the diagram. The power source has an unknown potential difference, *V*. Find:

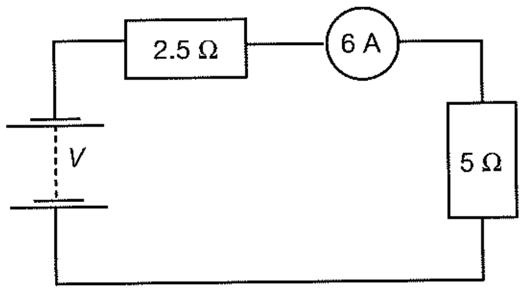
(a) The total resistance of the circuit.

(b) The current delivered by the power supply.

(c) The current flowing in each conductor.

(d) The potential of the power source.

(e) The potential difference across each conductor.



4. A circuit contains three conductors with resistances of 3 ohms, 6 ohms and 9 ohms, connected in series with each other as shown in the diagram. The power supply has an unknown potential difference, *V*. Find:

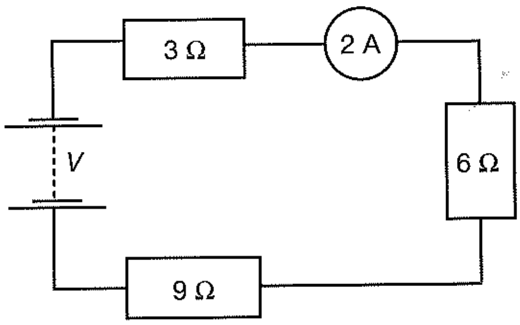
(a) The total resistance of the circuit.

(b) The current delivered by the power supply.

(c) The current flowing in each conductor.

(d) The potential of the power source.

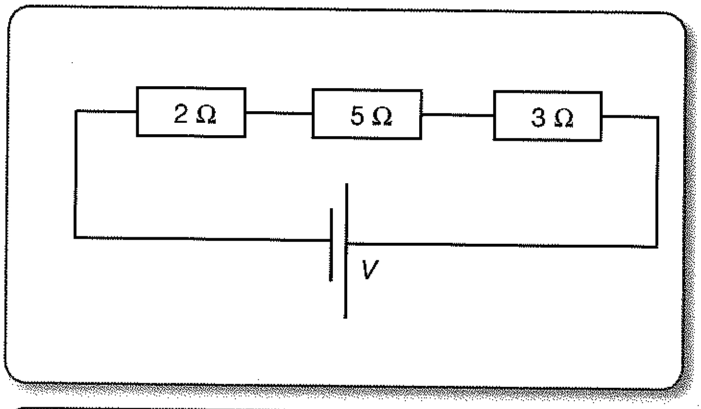
(e) The potential difference across each conductor.



5. A circuit contains three conductors with resistances of 2 ohms, 5 ohms and 3 ohms, connected in series with each other as shown in the diagram. The power supply has a potential difference of *V* volts.

(a) What is the ratio of the current flowing through the three conductors?

(b) What is the ratio of the electrical potential difference across each conductor?



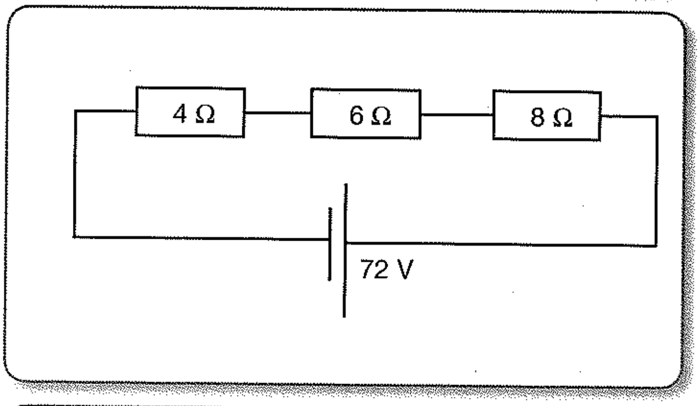
6. A circuit contains three conductors with resistances of 4 ohms, 6 ohms and 8 ohms, connected in series with each other as shown in the diagram. The power supply has a potential difference of 72 volts. Find:

(a) The total resistance of the circuit.

(b) The current delivered by the power supply.

(c) The current flowing in each conductor.

(d) The potential difference across each conductor.



7. A circuit contains three conductors with resistances of 2.5 ohms, 3.5 ohms and 4 ohms connected in series with each other as shown in the diagram. The current flowing through the ammeter shown is 6 A. Find:

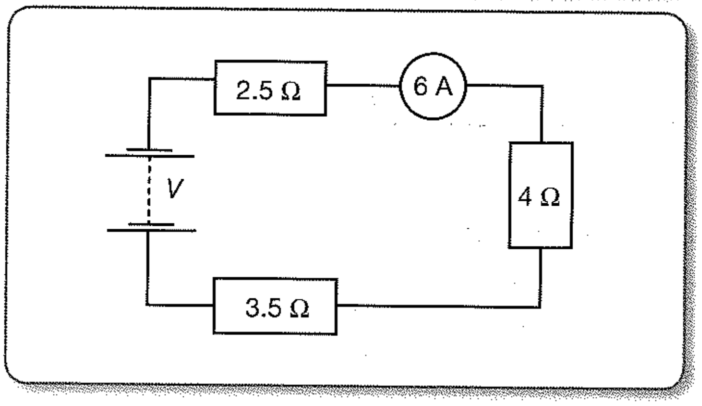
(a) The total resistance of the circuit.

(b) The current delivered by the power supply.

(c) The current flowing in each conductor.

(d) The potential of the power source.

(e) The potential difference across each conductor.



8. A circuit contains three conductors with resistances of 3 ohms, 5 ohms and unknown resistance *R*, connected in series with each other as shown in the diagram. The current flowing through the ammeter shown is 4 A, and the potential of the power source is 48 volts. Find:

(a) The current delivered by the power supply.

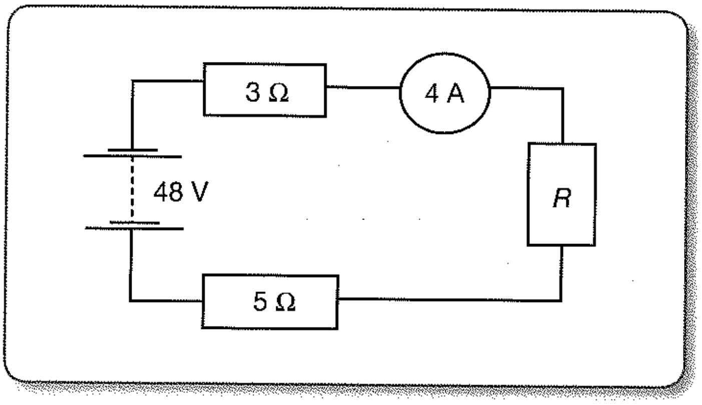
(b) The current flowing in each conductor.

(c) The total resistance of the circuit.

(d) The value of *R*.

(e) The potential of the power source.

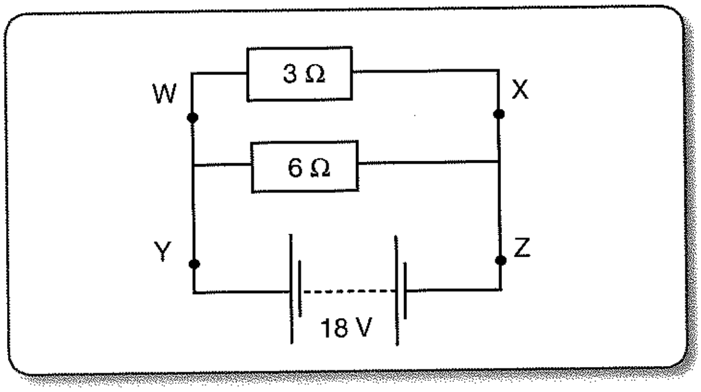
(f) The potential difference across each conductor.



SET 53 Potential Around a Parallel Circuit

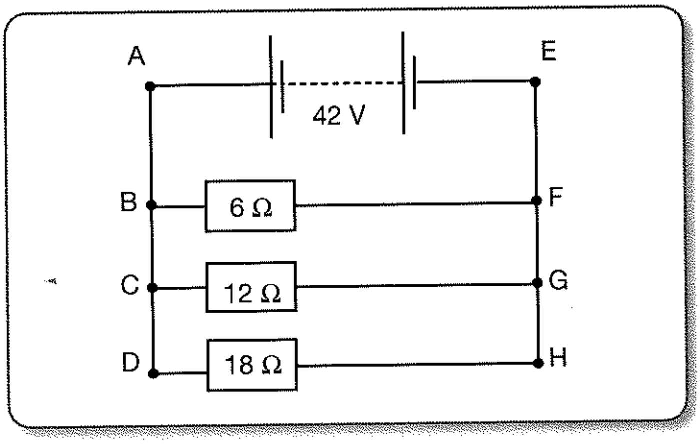
1. Identify the electrical potential of the labelled points on the circuit shown, and then use these to determine the potential difference between:

(a) W and X.
(b) W and Z.
(c) Y and X.
(d) Y and Z.



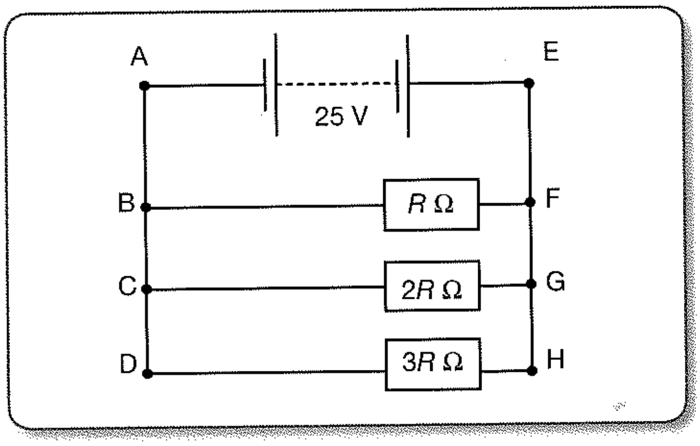
2. Identify the electrical potential of the labelled points on the circuit shown, and then use these to determine the potential difference between:

(a) A and E.
(b) B and F.
(c) C and G.
(d) D and H.
(e) A and H.



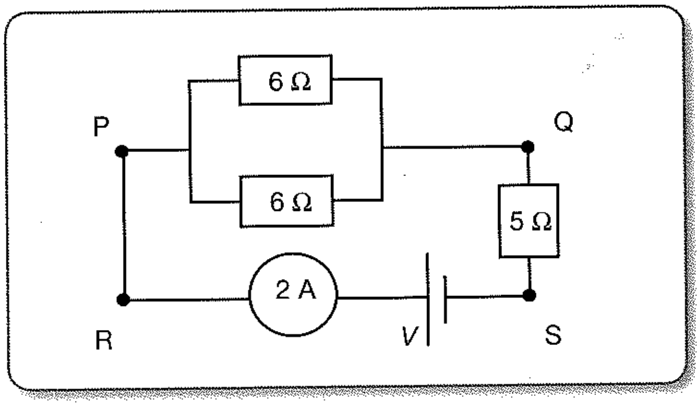
3. Identify the electrical potential of the labelled points on the circuit shown, and then use these to determine the potential difference between:

(a) A and E.
(b) B and F.
(c) C and G.
(d) D and H.
(e) A and H.



4. Identify the electrical potential of the labelled points on the circuit shown, and then use these to determine the potential difference between:

(a) P and Q.
(b) Q and S.
(c) R and S.
(d) R and Q.
(e) P and S.



SET 54 Analysing Parallel Circuits

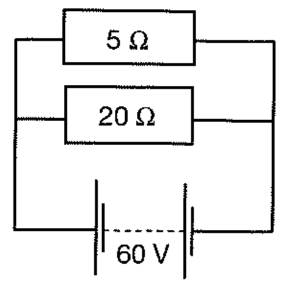
1. A circuit contains two conductors with resistances of 5 Ω and 20 Ω, connected in parallel with each other as shown in the diagram. The power supply has a potential difference of 60 volts. Find:

(a) The total resistance of the circuit.

(b) The current delivered by the power supply.

(c) The current flowing in each conductor.

(d) The potential difference across each conductor.



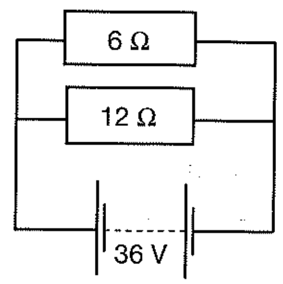
2. A circuit contains two conductors with resistances of 6 Ω and a 12 Ω, connected in parallel with each other as shown in the diagram. The power supply has a potential difference of 36 volts. Find:

(a) The total resistance of the circuit.

(b) The current delivered by the power supply.

(c) The current flowing in each conductor.

(d) The potential difference across each conductor.



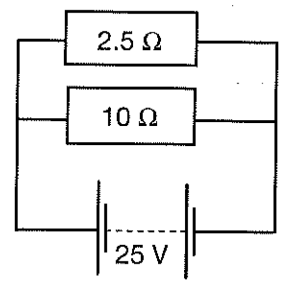
3. A circuit contains two conductors with resistances of 2.5 Ω and a 10 Ω, connected in parallel with each other as shown in the diagram. The power supply has a potential difference of 25 volts. Find:

(a) The total resistance of the circuit.

(b) The current delivered by the power supply.

(c) The current flowing in each conductor.

(d) The potential difference across each conductor.



4. A circuit contains two conductors with resistances of 2 Ω and a 6 Ω, connected in parallel with each other as shown in the diagram. The power supply has an unknown potential difference of V. Find:

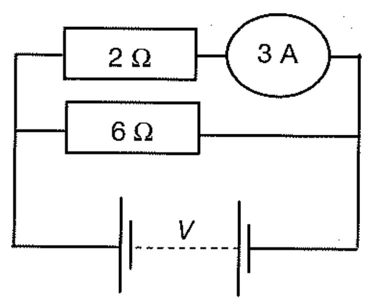
(a) The total resistance of the circuit.

(b) The current in the 6 Ω conductor.

(c) The current delivered by the power supply.

(d) The potential of the power supply.

(e) The potential difference across each conductor.



5. A circuit contains three conductors with resistances of 6 Ω, 3 Ω and 2 Ω connected in parallel with each other as shown in the diagram. 4 A flows through the 6 ohm conductor. The power supply has an unknown potential V. Find:

(a) The total resistance of the circuit.

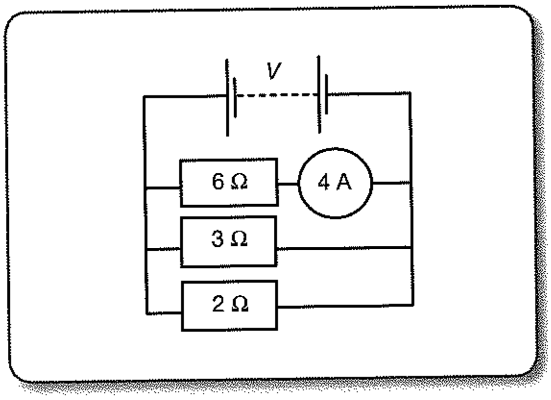
(b) The current in the 3 ohm conductor.

(c) The current in the 2 ohm conductor.

(d) The current delivered by the power supply.

(e) The potential of the power supply.

(f) The potential difference across each conductor.



6. A circuit contains three conductors with resistances of R Ω, 6 Ω and 12 Ω, connected in parallel with each other as shown in the diagram. 4 A flows through the ammeter shown. The power supply has a potential of 12 volts. Find:

(a) The current in the 6 Ω conductor.

(b) The current in the 12 Ω conductor.

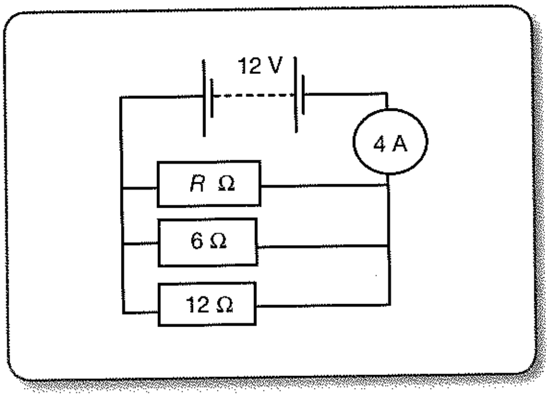
(c) The current in R.

(d) The current delivered by the power supply.

(e) The potential difference across each conductor.

(f) The value of R.

(g) The total resistance of the circuit.



7. A circuit contains three conductors with resistances of 6 Ω, 4 Ω and an unknown resistor R, connected in parallel with each other as shown in the diagram. 3 A flows through the unknown conductor. The power supply has a potential of 36 V. Find:

(a) The current in the 6 Ω conductor.

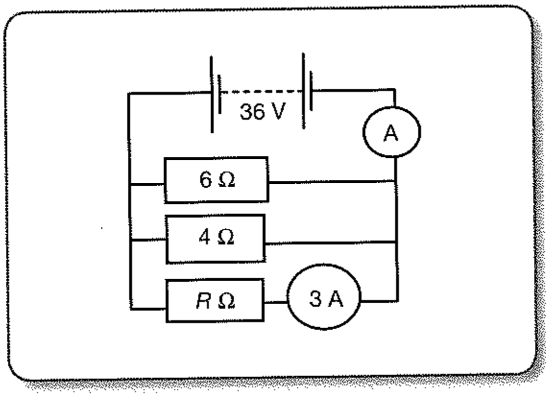
(b) The current in the 4 Ω conductor.

(c) The current reading on ammeter A.

(d) The value of R.

(e) The potential difference across each conductor.

(f) The total resistance of the circuit.



8. A circuit contains three conductors with resistances of 6 Ω, 3 Ω and another 6 Ω, connected in parallel with each other as shown in the diagram. 8 A flows through the ammeter shown. Find:

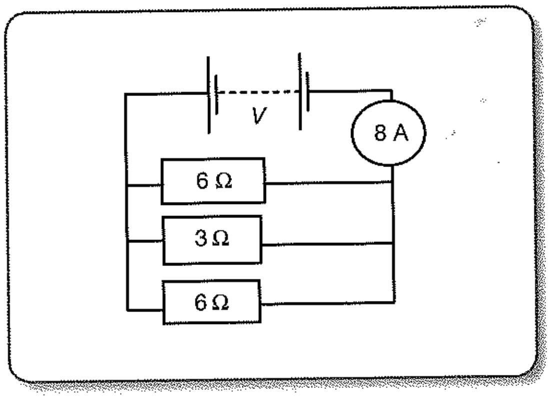
(a) The current in the 6 Ω conductors.

(b) The current in the 3 Ω conductor.

(c) The resistance of the circuit.

(d) The potential of the power supply.

(e) The potential difference across each conductor.



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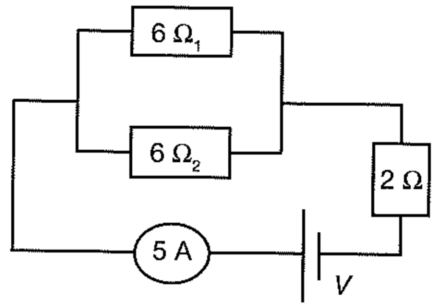
SET 55 Analysing Series and Parallel Circuits

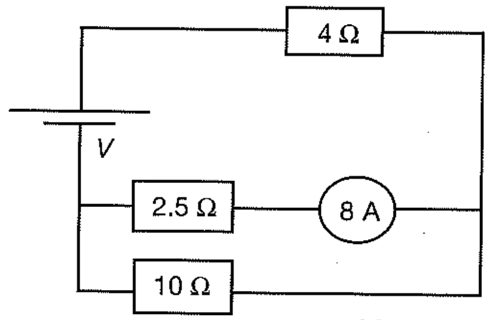
1. Consider the circuit shown in the diagram. Find:

(a) The total resistance of the circuit.
(b) The current in the 6 Ω conductors.
(c) The current in the 2 Ω conductor.
(d) The potential of the power supply.
(e) The potential difference across each resistor.



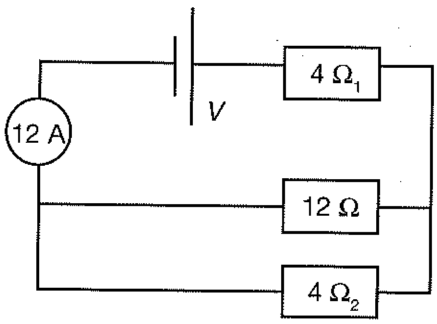
2. Consider the circuit shown in the diagram. Find:

(a) The total resistance of the circuit.
(b) The current in the 10 Ω conductor.
(c) The current in the 4 Ω conductor.
(d) The current delivered by the power source.
(e) The potential of the power supply.
(f) The potential difference across each conductor.



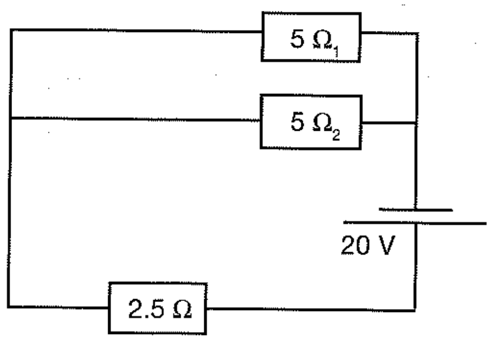
3. Consider the circuit shown in the diagram. Find:

(a) The total resistance of the circuit.
(b) The current in the 4 Ω conductors.
(c) The current in the 12 Ω conductor.
(d) The current delivered by the power source.
(e) The potential difference across each conductor.
(f) The potential of the power supply.



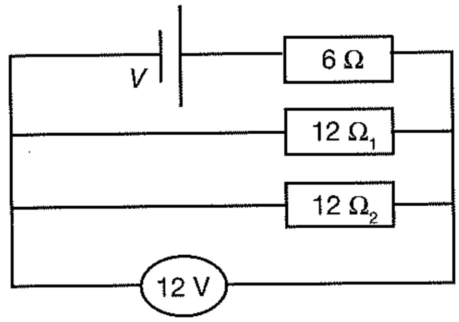
4. Consider the circuit shown in the diagram. Find:

(a) The total resistance of the circuit.
(b) The current delivered by the power source.
(c) The current in the 5 Ω conductors.
(d) The current in the 2.5 Ω conductor.
(e) The potential difference across each conductor.



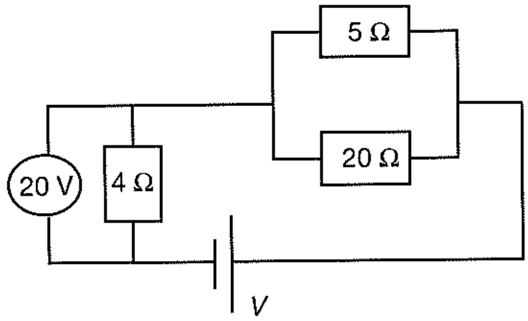
5. Consider the circuit shown in the diagram. Find:

(a) The total resistance of the circuit.
(b) The current in the 12 ohm conductors.
(c) The current in the 6 ohm conductor.
(d) The current delivered by the power source.
(e) The potential difference across each conductor.
(f) The potential of the power source.



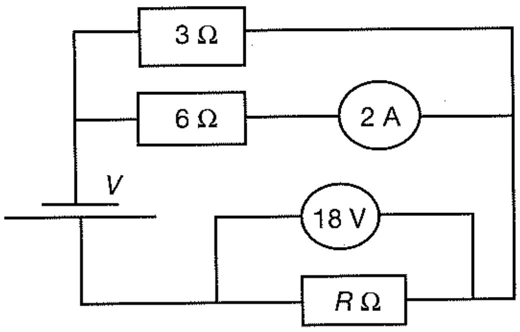
6. Consider the circuit shown in the diagram. Find:

(a) The total resistance of the circuit.
(b) The current in the 4 ohm conductor.
(c) The current in the 5 ohm conductor.
(d) The current in the 20 ohm conductor.
(e) The current delivered by the power source.
(f) The potential difference across each conductor.
(g) The potential of the power source.



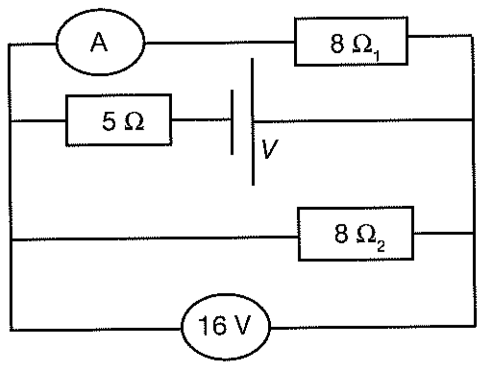
7. Consider the circuit shown in the diagram. Find:

(a) The current in the 3 ohm conductor.
(b) The current in *R*.
(c) The value of *R*.
(d) The total resistance of the circuit.
(e) The current delivered by the power source.
(f) The potential difference across each conductor.
(g) The potential of the power source.



8. Consider the circuit shown in the diagram. Find:

(a) The current in the 8 ohm conductors.
(b) The current in the 5 ohm conductor.
(c) The current delivered by the power source.
(d) The total resistance of the circuit.
(e) The potential difference across each conductor.
(f) The potential of the power source.



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SET 56 Transforming Electrical Energy

You may need to research the answers to some of these questions as they extend knowledge a little beyond that stipulated in the syllabus document.

1. List five devices that transform electrical energy into other useful forms of energy for use in our homes or industry. Alongside each, write the useful form of energy that device produces.

2. The production of heat energy in conductors can sometimes be a desired outcome and sometimes an undesired outcome.

(a) State three situations where it is the desired outcome.

(b) State three situations where it is an undesired outcome.

(c) What is the main form of undesired energy in electrical devices?

3. Electrical energy is also transformed so that it can be transmitted over long distances.

(a) What device does this transformation?

(b) What does the device actually do to the electricity input into it?

(c) Explain why this is done.

4. When transmitted electrical energy is received at the consumer's end it needs to be transformed again.

(a) Why does it need to be transformed again?

(b) What device does this transformation?

5. Explain the difference between a step-up and a step-down transformer in terms of:

(a) Their use.

(b) Their structure.

6. (a) The table shows data for electrical transmission lines from four 40 MW electrical generating stations. The electrical energy needs to be transmitted through 30 km of transmission lines which have a resistance of 4.0 Ω km^{-1}. Copy and complete the table by calculating the missing values.

	Station A	Station B	Station C	Station D
Power output (W)	40 000 000	40 000 000	40 000 000	40 000 000
Transmission voltage (V)	50 000	100 000	250 000	500 000
Current in transmission lines (A) **Use $I = P/V$**				
Power lost during transmission (W) **Use $P = I^2R$**				
Power reaching consumer (W)				
Power lost (%)				

(b) Which of the transmission voltages would be the best to use? Justify your answer with data from your completed table.

7. We actually use electricity as an energy source for other, more useful forms of energy. Electrical devices change electrical energy into the other forms we want. Unfortunately these devices are not always as efficient as we would like them to be, producing unwanted forms of energy as well as the useful forms. Regardless, we pay for the electricity to produce them all.

For each device listed in the table, indicate the output form of energy that we actually use directly, and at least one non-useful form of energy also produced. Complete your copy of the table.

Electrical device	Input form of energy	Useful output form of energy	Non-useful form of energy also produced
TV	Electricity		
Radio	Electricity		
Frying pan	Electricity		
Washing machine	Electricity		
Battery charger	Electricity		

8. Copy then complete the table. Do not use any devices used in the table in Question 7.

Electrical device	Input form of energy	Useful output form of energy	Non-useful form of energy also produced
	Electricity	Heat	
	Electricity	Light	
	Electricity	Sound	
	Electricity	Gravitational potential energy	
	Electricity	Kinetic energy	
	Electricity	Elastic potential energy	
	Electricity	Kinetic energy	

9. A diesel generator used on an isolated property generates 4.8 kW of electricity and transmits it to the homestead at 240 V. The homestead is 2.5 km away and the electricity is transmitted through wires which have a resistance of 3.0 W km^{-1}.

(a) Calculate the current in the transmission lines.

(b) Calculate the voltage drop between the generator and the homestead.

(c) From this deduce the voltage available at the homestead.

(d) Comment on the usefulness of this generating system to the people in the homestead. Justify your answer.

(e) How could the situation be improved?

SET 57 Energy Efficiency

1. (a) What is meant by the efficiency of a device?
   (b) How do we usually express efficiency?
   (c) Give the equation we use to find efficiency.

2. (a) What principle in physics holds when circuit components transform electrical energy into other forms?
   (b) Electric light globe filaments transform electrical energy into useful light energy. However, not all the electrical energy is transformed into light. Heat energy is also produced. Does this mean that the principle you mentioned in (a) does not hold in this situation? Explain your answer.

3. A 9 V electric motor is connected to a string which passes over a pulley and then to a 4.0 kg mass which is resting on the floor below. When the motor is switched on, 4 A of electricity flows and it winds in the string and raises the mass 0.75 m in 3.5 s. Calculate:
   (a) The power developed by the motor.
   (b) The total electrical energy used by the motor in lifting the mass.
   (c) The gravitational potential energy gained by the mass.
   (d) The efficiency of the motor.

4. An engine with a power output of 1.5 kW and an efficiency of 60% pulls an object of weight 800 N at a constant speed a distance of 15.0 m up a smooth 30° incline.
   (a) What force must the engine supply to move the block up the incline?
   (b) How much work must the engine do on the block?
   (c) Find the effective energy output of the engine.
   (d) How long will it take the block to move up the 15 m?

5. A motor applies 140 N to move a load of 14 kg up a vertical height of 6.0 m in 25 s.
   (a) How much work is done on the load?
   (b) The motor lifting the load is 86% efficient. How much work must it do to lift the load?
   (c) If the motor is a 110 V motor, what current flows in it?
   (d) If all non-useful energy is used against friction within the motor, how much heat is generated as it lifts this load?

6. A train of mass 5000 kg moves slowly up a hill on a steep incline gaining 2.5 MJ of gravitational potential energy and taking 300 s. If the efficiency of its engines is 20%:
   (a) How high is the hill?
   (b) How much energy was transformed into other forms of energy by the engine during the climb?
   (c) If a current of 15 A operates the motors in the train, what potential difference drives them?

7. An engine generates 40 kW of power. The litre of fuel it uses every 5 minutes provides 15 MJ.
   (a) How much energy does the engine produce each second?
   (b) How much energy does the fuel produce each second?
   (c) What is the efficiency of the engine in this situation?

8. A small petrol generator runs thirty 60 W globes in the backyard for a night time party for 6 hours. The petrol supplies 30 MJ L^{-1} of energy to the generator, and the generator runs at an efficiency of 80%.
   (a) How much energy do the globes use in the 6 hours?
   (b) How much energy does the engine supply in this time?
   (c) How much petrol is used?

SET 58 Other Problems with Transmitting

Unlike DC electricity, which can be stored (albeit in small amounts) in batteries, AC electricity cannot be stored. AC has to be produced as it is needed. AC thermal power stations are huge, highly polluting and therefore usually a fair distance from populated areas, although, in true population growth patterns, the population soon grows to be close to the stations.

Huge amounts of electricity are transferred from where it is produced to where we need to use it. However, this creates energy loss problems, mainly due to resistance in the transmission lines (about 6 ohms per 100 km of wire) which converts some of the electrical energy into heat.

1. Copy and complete the table to calculate possible energy losses during electricity transmission. Assume the power station is producing 4.0 MW of power, and needs to transmit it 50 km through 4 ohm km^{-1} lines.

Transmission voltage (V)	30 000	50 000	250 000	500 000
Power generated	4 MW	4 MW	4 MW	4 MW
Current in lines $I = P/V$				
Power loss in lines ($P = I^2R$)				
Power left after losses				
Power lost (%)				

2. What are the implications in your calculations above for the transmission of power over significant distances?

3. Copy and complete the table by briefly describing the function of each structure.

Structure	How this protects against lightning strikes
Shield conductors	
Earth cable	
Insulation chains	
Metal tower	
Distance between towers	

SET 59 Circuits in Homes

1. (a) Identify the three different types of circuits used in homes.
   (b) Why are three types of circuits needed?
   (c) Identify the purpose of each type of circuit.
   (d) Is it correct to assume that homes will only need one dedicated circuit? Explain your answer.
   (e) How might the electrical wiring for dedicated circuits be different to that used in lighting or power circuits? Explain the reason for the difference.

2. (a) Which of the three types of circuits in homes are series circuits? Explain why.
   (b) Which of the three types of circuits in homes are parallel circuits? Explain why.

3. Consider a lighting circuit in homes which can carry a maximum 10 A.
   (a) What is the maximum number of 60 W lights that can be on at the same time on this circuit?
   (b) How many 25 W globes could be used ?
   (c) If more than the maximum number of globes was on, what could happen?
   (d) Suppose a home required more than the maximum number of lights that could be safely accommodated on a lighting circuit? What would have to be done?

4. Calculate the maximum total wattage of the appliances that could be used at the same time on the same 15 A power circuit.

5. A bedroom has two lights, one either side of the bed. These lights can be switched on and off independently, so one person can lie awake reading while the other sleeps.
   (a) Explain how and why these lights have been wired into the lighting circuit.
   (b) Draw a diagram to show the section of the circuit that contains the lights and switches involved.

6. The power circuit in a home is designed to carry a maximum of 15 A. In the kitchen there are several appliances as listed.

Toaster	= 240 V, 800 W
Kettle	= 240 V, 1200 W
Coffee machine	= 240 V, 1260 W
LCD TV set	= 12 V, 45 W
Rice cooker	= 240 V, 400 W
Frypan	= 240 V, 1800 W

   (a) What is the maximum number of these appliances that could be used at the same time?
   (b) Identify the appliances that could be used.
   (c) What is the minimum number of appliances that could be used at the same time?
   (d) Identify these appliances.

7. The lights in a string of 300 fairy lights look beautiful, but can be a nuisance if one globe blows because if this happens, 19 other globes will go out. Finding the blown globe can be quite a problem.
   (a) Explain the circuit structure of the string of lights.
   (b) Suggest a reason why the string has been structured this way.
   (c) Imagine a much shorter string with only 45 lights in it. Draw a diagram to show the structure of the wiring in the circuit connecting them (you can abbreviate the number of lights in each section).

8. Older homes have fuses in the power box. Newer homes have circuit breakers.

(a) What is the purpose of a fuse?

(b) What is the purpose of a circuit breaker?

(c) Explain why circuit breakers have replaced fuses in electrical circuits.

9. (a) Identify the type of electrical connection used for the lights in a room if one switch turns them all on, but at the same time, if one blows, all the others stay on.

(b) Draw a sketch of this circuit to show what you mean. Include a DC power source in your circuit.

(c) If there are four lights in a room and each can be turned on separately, what is the minimum number of switches required?

(d) Draw a diagram of the circuit needed for (c).

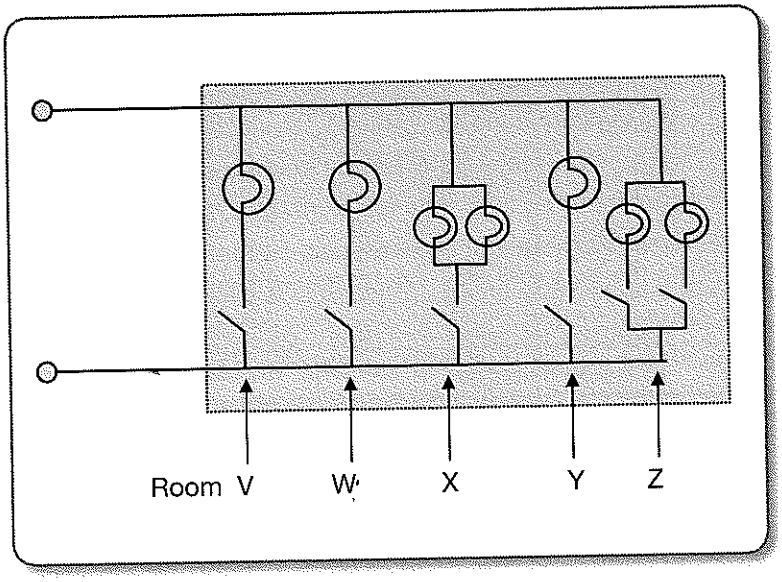
10. The circuit diagram shows a typical lighting circuit for a home. Use it to help you answer this question.

(a) Describe the difference in the switching of the lights in rooms X and Z.

(b) How are the lights in each room connected into this circuit?

(c) Explain why they are connected this way.

(d) If one of the lights in room X blows, does the other? Justify your answer.



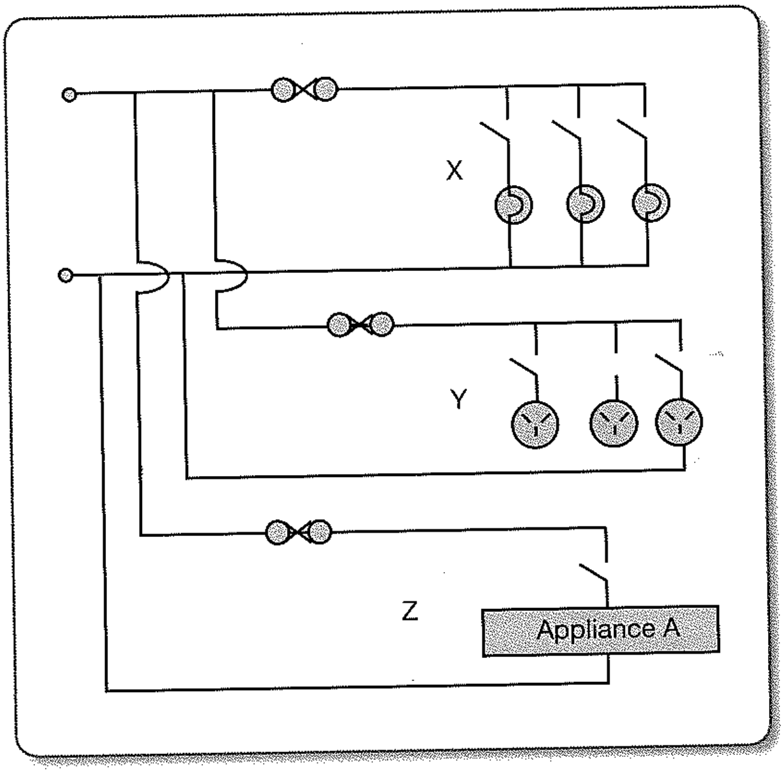
11. The diagram shows a simplified illustration of the three different types of electrical circuits used in homes.

(a) Identify the type of circuits labelled X, Y and Z.

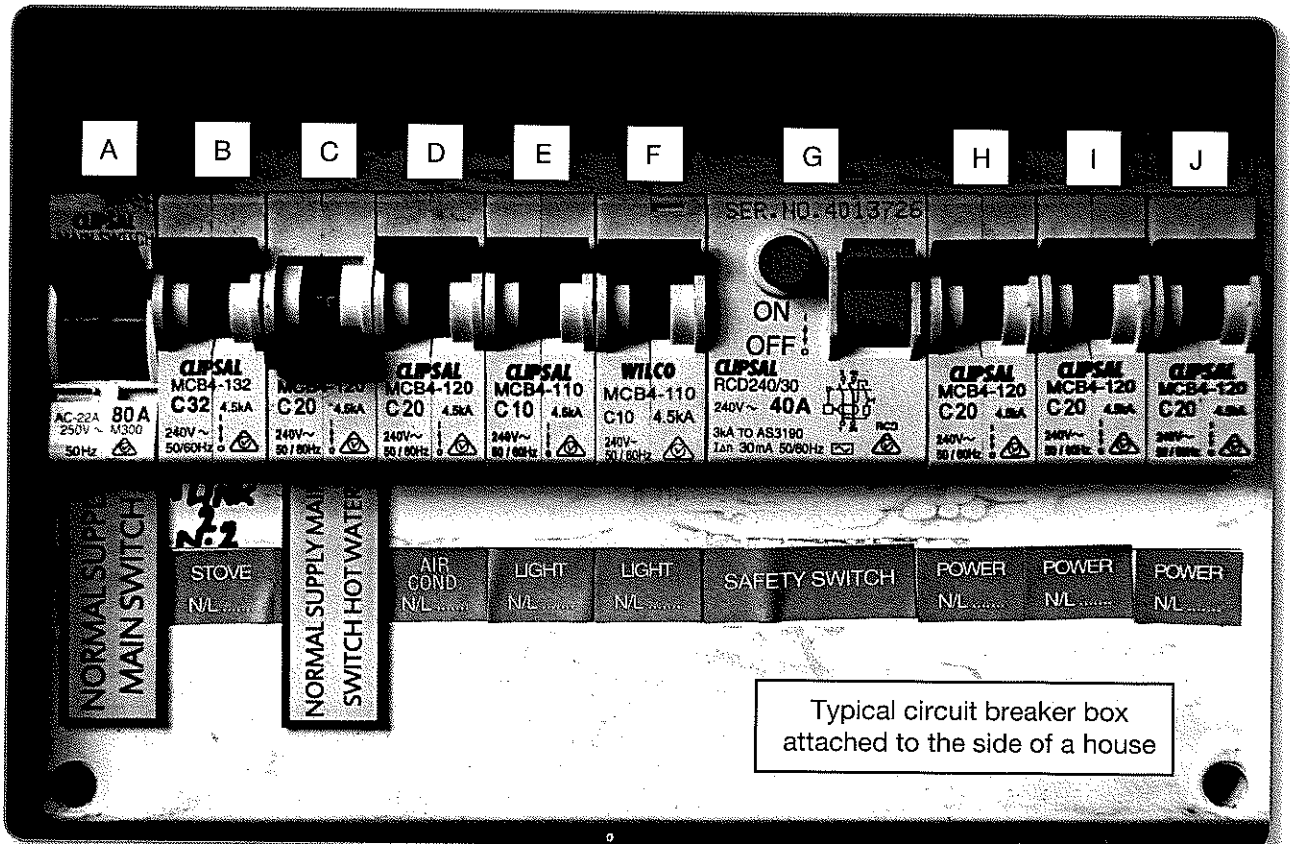
(b) Identify the way components in circuits X, Y and Z are connected.

(c) Suggest three different possibilities for appliance A.

(d) Why is it necessary to have these three different types of circuits in homes?



12. The photograph shows the circuit breaker safety switches for a typical household electrical supply. Use it to answer the questions which follow.



(a) Which of the individual circuits in the home (A, B, C, ... J) provide power for lights?

(b) Which of the individual circuits in the home (A, B, C, ... J) provide power for appliances?

(c) Which of the individual circuits in the home (A, B, C, ... J) provide power for dedicated appliances?

(d) Identify the purpose of the switch labelled A.

(e) The switch for circuit C is off. In fact it is usually left off. Explain why.

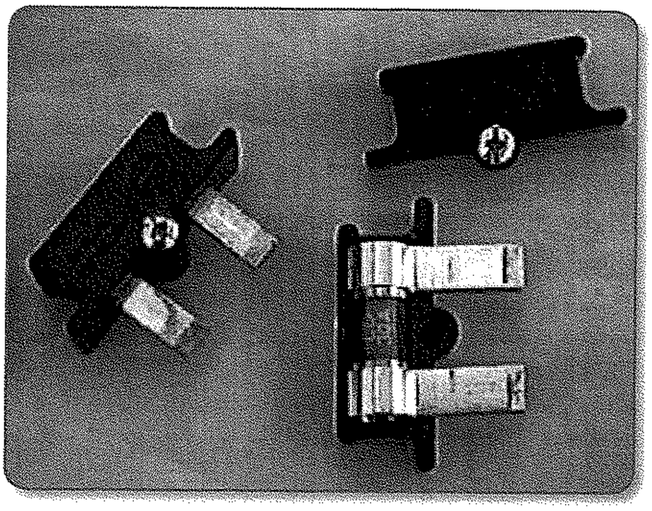
(f) When might switch C be turned on? Why?

(g) Propose the purpose of the switch labelled G.

(h) What would be the result if switch A was turned off?

(i) Many older homes have wire fuses like the one shown in the photo on the right instead of circuit breakers. These are not nearly as safe as circuit breakers. By explaining how they work, explain why they are not as safe.

(j) What differences might you expect in the fuse box on the side of a house if it contained fuses rather than circuit breakers?



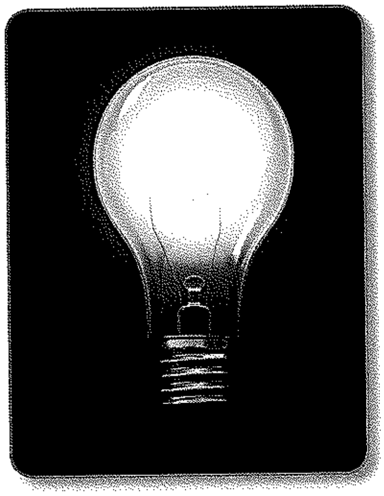
SET 60 Energy Efficiencies of Light Sources

1. Read the following information then answer the questions that follow.

A 'normal light bulb' is also known as an **incandescent light bulb**. These have a thin tungsten filament which has a relatively high resistance. Incandescent globes commonly range in energy output from 25 W to 100 W.

When electricity flows through the filament, resistance turns electrical energy into **heat** energy. The filament glows because of the heat and produces light – it **incandesces**.

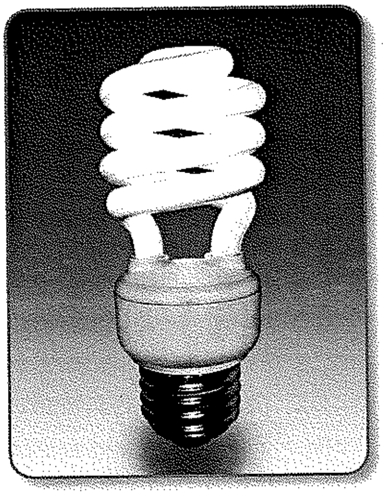
The problem with incandescent light bulbs is that the heat wastes a lot of electricity. Heat is not light, and the purpose of the light bulb is light, so all of the energy spent creating heat is a waste. Incandescent bulbs are therefore very inefficient, producing only about 15 lumens per watt of input power.



A **fluorescent or a compact fluorescent bulb** (CFL) uses a different principle to produce light. There are electrodes at both ends of a fluorescent tube, and a gas containing argon and mercury vapour is inside the tube.

Electrons flow through the gas from the cathode to the anode, bumping into the mercury atoms along the way and exciting them. As the mercury atoms move from the excited state back to the unexcited state, they emit high frequency **electromagnetic photons** (UVL). These photons hit and transfer energy to the phosphor coating inside the fluorescent tube producing visible light.

A fluorescent bulb produces little heat, so it is much more efficient. They can produce between 50 and 100 lumens of light per watt of electrical energy. This makes fluorescent bulbs four to six times more efficient than incandescent bulbs.



(a) What is the main source of inefficiency in light bulbs according to this data?

(b) What is the principle of operation of an incandescent light bulb?

(c) What is the principle of operation of a fluorescent light bulb?

(d) According to this data, approximately how many lumens of light will a 40 W incandescent globe produce?

(e) According to this data, approximately how many lumens of light will a 40 W compact fluorescent globe produce?

You may need to research the principle of the photoelectric effect to answer the next three questions.

(f) Explain what is meant by 'excited' mercury atoms. How do they emit electromagnetic photons?

(g) Why is it essential that in a fluorescent light bulb current electrons cause the emission of high frequency electromagnetic photons from excited mercury atoms?

(h) Explain how the high frequency electromagnetic radiation causes the emission of visible light from the phosphor coating on the inside of the fluorescent tube.

2. Consider the information in the table below.

Environmental impact	Incandescent light bulbs	CFLs	Halogen light bulbs	LEDs
Contains mercury?	No	Yes	No	No
Relative carbon emission	10	2	2	1
Lifetime hours	3000 to 6000	10 000	5000	Up to 50 000
Relative cost	1	10 to 20	10	5 to 20
Durability	Low – breaks easily	Low	Medium	High
Turns on instantly	Yes	No	Yes	Yes
Efficiency	See data in the table in Question 3			

(a) Which type of light bulb should be recommended for use in homes by government building standards? Explain the advantages and disadvantages of this choice.

(b) The Australian government has restricted sales of incandescent light and halogen bulbs as from November 2009, with a view to eliminating them altogether. Why do you think this action has been taken?

3. The table shows the light output and energy input for several types of lighting sources. Note that different sources of information may give slightly different values for these quantities.

Light output (lumens, lm)	Power input (watts, W)							
	Incandescent bulb	Efficiency ($lm\ W^{-1}$)	Compact fluorescent bulb (CFL)	Efficiency ($lm\ W^{-1}$)	240 V halogen bulb	Efficiency ($lm\ W^{-1}$)	Light emitting diode (LED)	Efficiency ($lm\ W^{-1}$)
220	25		5 to 7		18		2 to 3	
450	40		9 to 13		28		4 to 5	
800	60		13 to 15		42		6 to 8	
1100	75		18 to 25		52		9 to 13	
1600	100		23 to 30		70		16 to 20	
2600	200		30 to 55		140		25 to 28	

(a) Rank the four different types of light sources given in terms of most efficient to least efficient conversion of electrical energy input to light output.

(b) Copy and then complete the table above to list the efficiencies of each type of globe for each output power in lumens per watt ($lm\ W^{-1}$).

(c) Use information from the table above to complete your copy of the table below to compare the relative efficiencies of the light sources for an output of 25 W.

Complete for power output 25 W	Incandescent bulb compared to	CFL compared to	240 V halogen bulb compared to	LED compared to
Incandescent bulb				
CFL				
240 V halogen bulb				
LED				

(d) Use information from the table above to complete your copy of the table below to compare the relative efficiencies of the light sources for an output of 100 W.

Complete for power output 100 W	Incandescent bulb compared to	CFL compared to	240 V halogen bulb compared to	LED compared to
Incandescent bulb				
CFL				
240 V halogen bulb				
LED				

(e) Suggest the relationship between the relative efficiencies of the light types as their output power increases.

(f) Comment on the reliability of your prediction.

4. The table compares the equivalent wattage of the other three types of globes to a 60 W incandescent globe.

Assuming that the cost of electricity is 27 cents per kWh, calculate how much it would cost to run each light for 6 hours per day for a 365 day year. For the bulbs where a range of wattage is given, calculate the range of costs. Put your answers in a copy of the table in your workbook.

Type of bulb	Incandescent	Compact fluorescent (CFL)	240 V halogen	Light emitting diode (LED)
Equivalent wattage (W)	60	13 to 15	42	6 to 8
Cost				

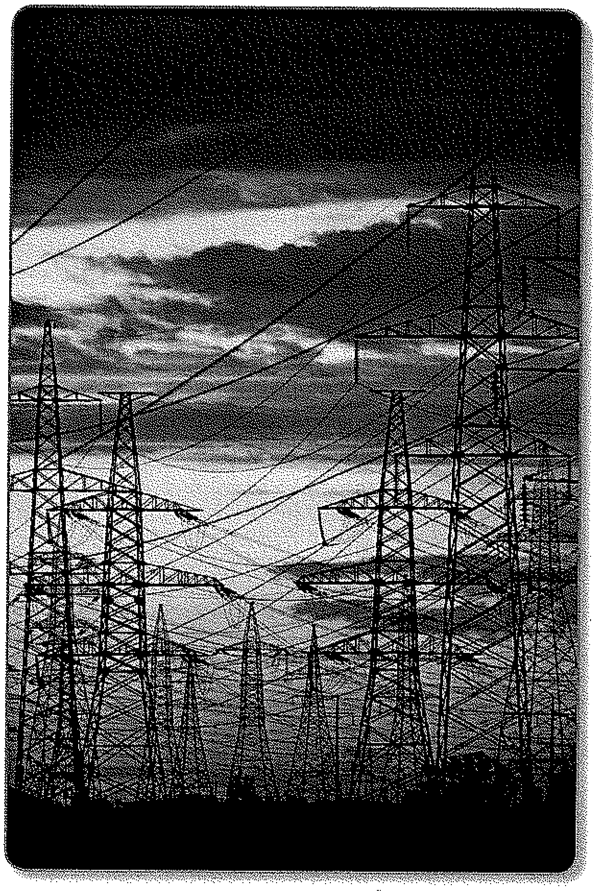
SET 61 Impacts of Electricity

1. Imagine your life using candles at night, cooking on a wood fired oven, chopping wood for cooking and heating, no radio or TV, no heavy machinery to make roads, no workshop tools. Outline how electricity impacts on you.

2. Research to find five reasons why AC electricity is preferred over DC electricity for household and most commercial uses.

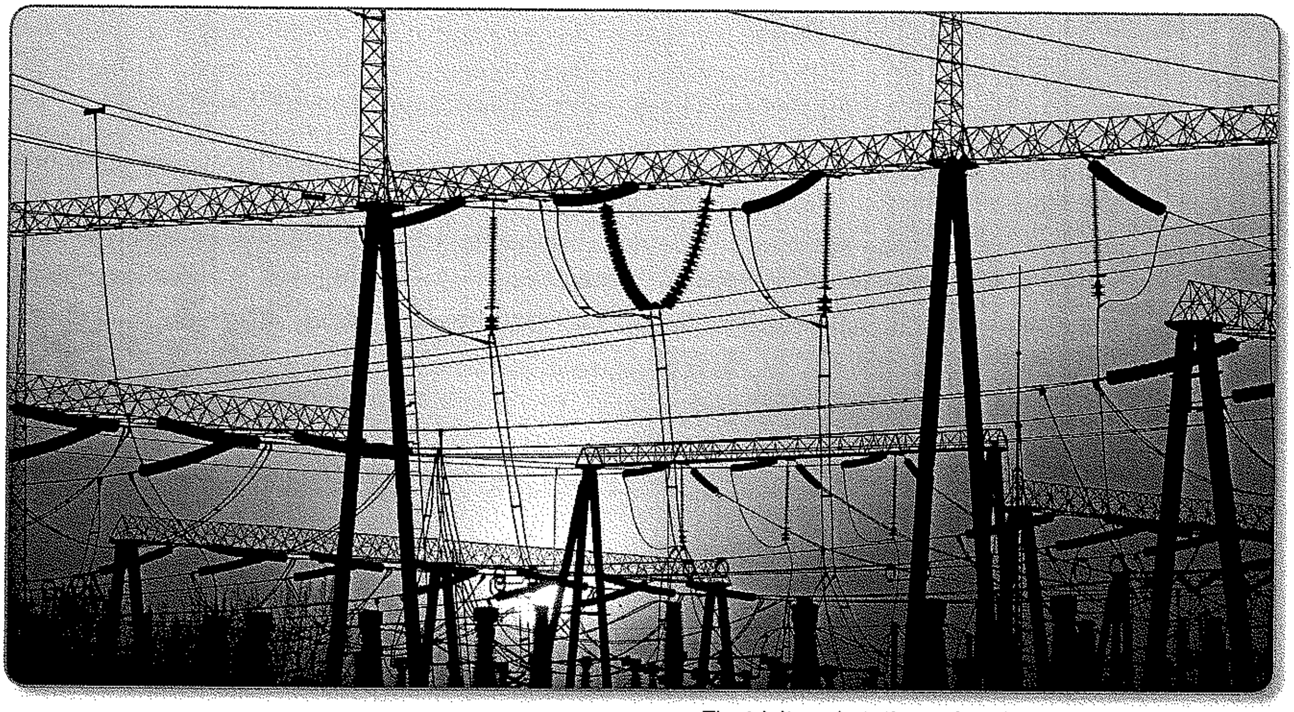
3. Summarise three major impacts of the production and use of electricity on people (society). Make sure your answer states generalities then goes deeper to analyse the 'chain reaction' impacts – the 'flow-on' effects of each generality.

4. Summarise three major impacts of the production and use of electricity on the environment. Make sure your answer states generalities then goes deeper to analyse the 'chain reaction' impacts – the 'flow-on' effects of each generality.



High voltage transmission towers visually pollute our environment.

5. Research the health risks associated with living near high voltage transmission lines.



Electricity substations visually pollute our suburbs.

SET 62 Scientists Building on Ideas

You may have to research the information for some of these questions as they may extend beyond the material your teacher has done with you.

1. (a) Outline the contribution JJ Thomson made to our understanding of the nature of electricity and the structure of matter following his cathode ray tube experiments.

(b) Outline the contribution Millikan made to our understanding of the nature of electricity and the structure of matter following his famous oil drop experiments.

(c) Outline the contribution Faraday made to our understanding of the nature of electricity and the structure of matter following his experiments in electrolysis.

JJ Thomsom (1856-1940)

2. Discuss how the work of JJ Thomson, Millikan and Faraday illustrate the idea that the development of models and theories can take several decades and the cumulative work of many scientists who build on the work of predecessors and share their own theories and data.

3. At the time JJ Thomson did his famous charge to mass ratio experiment with cathode rays, there was controversy in the scientific world about their nature.

(a) What was this controversy?

(b) Why did it exist?

(c) How did Thomson's experiment solve the problem which caused the controversy?

4. (a) What did Thomson do in this experiment that had not been done previously by any of the other scientists of his time?

(b) Outline how Thomson was able to determine the velocity of cathode rays in the first part of his experiment. Show relevant mathematical equations.

(c) Show, again using relevant equations, how Thomson was able to determine a value for the ratio of the charge on a cathode ray to its mass.

(d) How was Thomson able to conclude from his results that cathode rays were a new, previously undiscovered particle?

(e) Outline, with reference to the work of George Stoney, the assumptions and conclusions Thomson made after analysing the results of his experiment.

5. Outline, with the aid of a labelled diagram, the experiment done by Millikan to determine the magnitude of the charge on an electron.

6. In a Millikan oil drop experiment, the electric plates are 2.5 cm apart. The oil used has a density of 0.75 g cm^{-3}, and the atomiser that sprays the oil drops produces drops of diameter 1.5 mm.

(a) Calculate the volume of the oil drops.

(b) Use the density of the oil to calculate the mass of the oil drop.

(c) Consider a particular drop which carries four electronic charges. Calculate the potential difference needed between the plates to hold the drop stationary. (Assume the mass is the same as in (b).)

(d) Another drop (same mass) requires a potential difference of 2.04 V to hold it stationary. What charge does it carry?

7. A student obtained the following values for the charge (in coulombs) on five different drops in Millikan's oil drop experiment.

(i) 3.2×10^{-19}

(ii) 5.6×10^{-17}

(iii) 4.8×10^{-18}

(iv) 8.0×10^{-18}

(vi) 6.4×10^{-19}

(vii) 9.6×10^{-18}

(a) Based on your knowledge of electric charge, which result is an incorrect result? Explain your reasoning.

(b) Suppose Millikan got these results in his original experiment, what would his conclusion have been? Explain your reasoning.

Robert Millikan (1868-1953)

8. In an oil drop experiment similar to that done by Millikan, an oil drop carrying a charge Q is held stationary between the plates by applying a potential difference of 250 V. To keep another drop of half the radius stationary, the potential difference had to be increased to 375 V. Determine the charge on the second oil drop.

9. (a) Define the coulomb.

(b) What is 1 mol of a substance in terms of the mass of that substance?

(c) Define 1 mol of a substance in terms of number of particles.

(d) How many electrons are involved in making 1 mol of silver ions (valency 1) from silver atoms?

(e) How many coulombs of electric charge does this (answer (d)) represent?

(f) How many mol of electrons are involved in making 1 mol of copper atoms from 1 mol of copper ions (valency 2)?

(g) How many coulombs of electricity does this (answer (f)) represent?

10. (a) State Faraday's first law of electrolysis. Include any relevant equations.

(b) Define the electrochemical equivalent as derived from Faraday's first law.

(c) Determine the electrochemical equivalent for silver, valency 1. (Take the atomic mass of silver as 108.)

(d) Define the chemical equivalent of a substance.

(e) Determine the chemical equivalent for silver, valency 1.

(f) What would be the electrochemical equivalent for silver, valency 2?

(g) What would be the chemical equivalent for silver, valency 2?

(h) Explain why these values (answers to (f) and (g)) are different to silver, valency 1. Give any relevant equations.

(i) State Faraday's second law of electrolysis.

(j) What is the significance of the figure 96 368 coulombs (often rounded to 96 400, or in some texts, even to 96 500)?

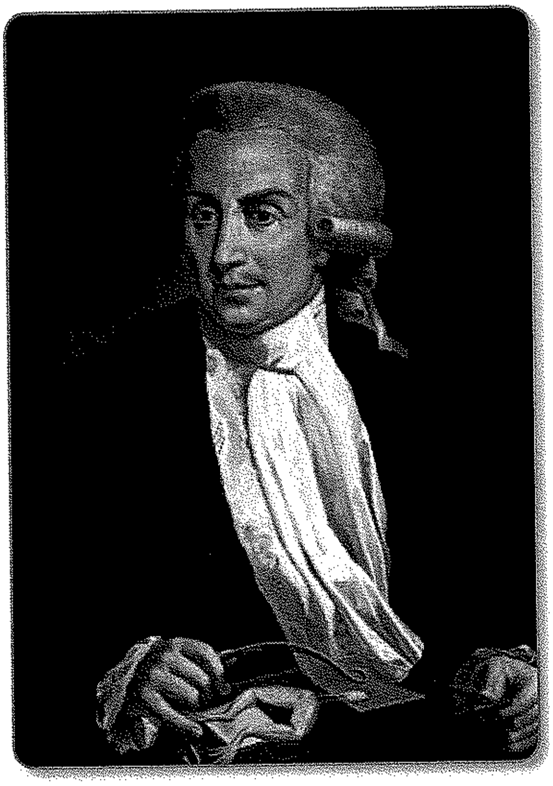
Michael Faraday (1791-1867)

11. Outline the nature of the experiments done by Galvani and how he interpreted his observations.

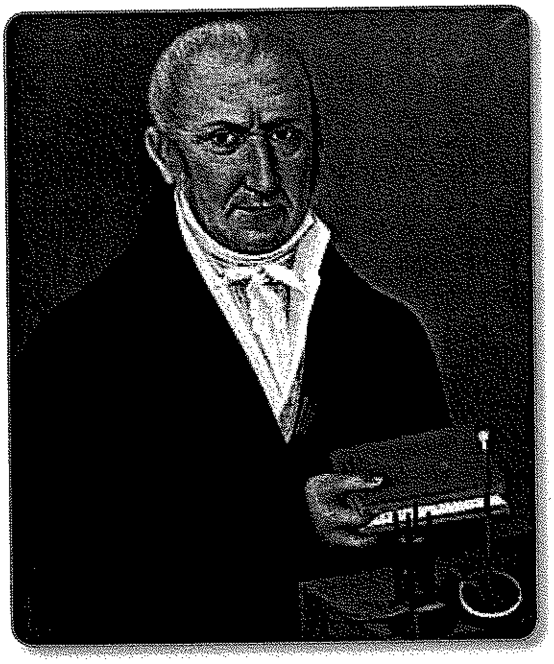
12. Outline the experiment done by Volta and how he interpreted his observations.

13. Clarify the different ideas Galvani and Volta held about the source of the electricity they were observing.

14. Discuss which scientist contributed more, if at all, to our understanding of electricity.



Luigi Galvani (1737-1798)



Alessandro Volta (1745-1827)

SET 63 Energy Efficiencies of Batteries

1. (a) List five different types of dry cells (commonly known incorrectly as 'batteries').
(b) Why is it scientifically incorrect to call dry cells 'batteries'?
(c) What is the difference between a wet cell and a dry cell?
(d) What is the difference between a primary cell and a secondary cell?

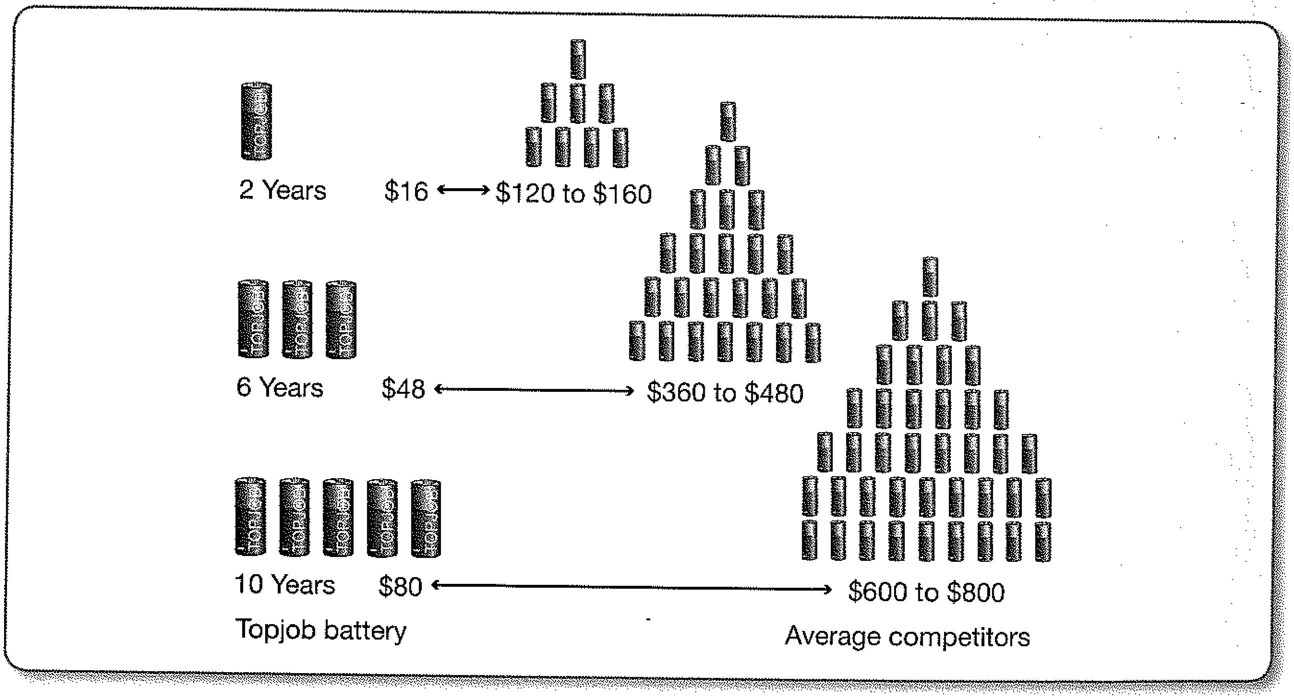
2. (a) Carbon-zinc cells are one of the oldest and most widely used types of dry cells. Briefly describe how they work.
(b) What are the two main advantages of carbon-zinc cells?
(c) What is their disadvantage compared to other types of cells?

3. (a) What makes alkaline cells different from normal dry cells?
(b) What makes alkaline cells 'better' than carbon-zinc cells?
(c) Suggest why the 'better' in (b) has been put in inverted commas.

4. (a) For many years nickel-cadmium (Ni-Cd or Nicad) cells were used, but these have been replaced by a better alternative for two main reasons. What are these two reasons?
(b) What type of cell has replaced them?
(c) What is meant by the 'memory effect' when referring to cells?

5. (a) What type of battery is currently used increasingly for laptops, mobile phones, iPads and the like?
(b) Give three reasons why these are the preferred cells now.

6. The diagram shows information about Topjob batteries and their competitors.



(a) What is the diagram attempting to communicate to readers?
(b) Comment and explain the effect of factors which might affect the validity of this information.
(c) As a reader, what tells you whether or not this information has been collected and compared through scientific means?

show the initial voltage produced
different batteries, and the change
ge over time as they are used to
l appliances for 10 and then
e after 10 hours and again after
se.

then complete the table to show
crease in voltage of each battery
0 hours.

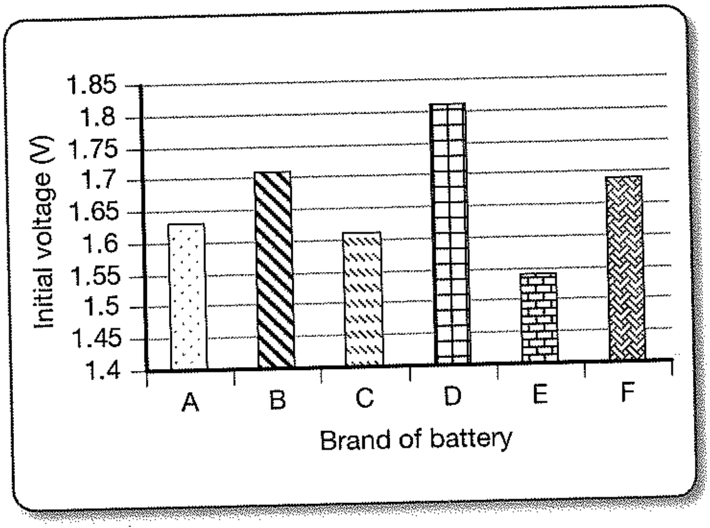
ery	Voltage loss after 10 hours	Voltage loss after 10 hours (%)

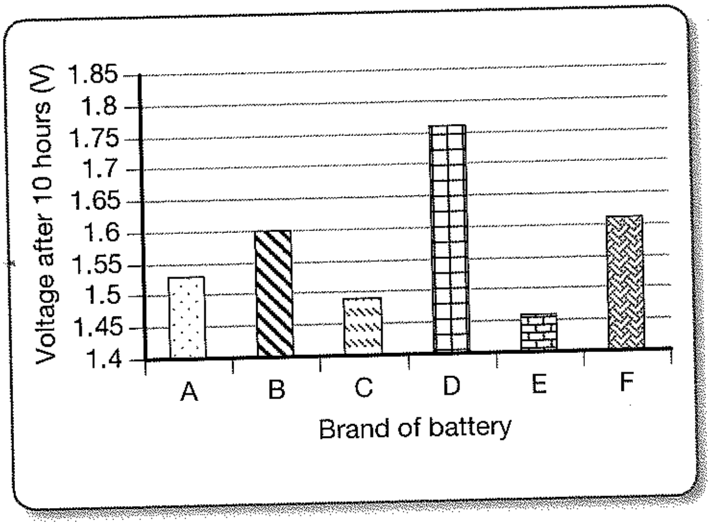
then complete the table to show
ecrease in voltage of each battery
20 hours.

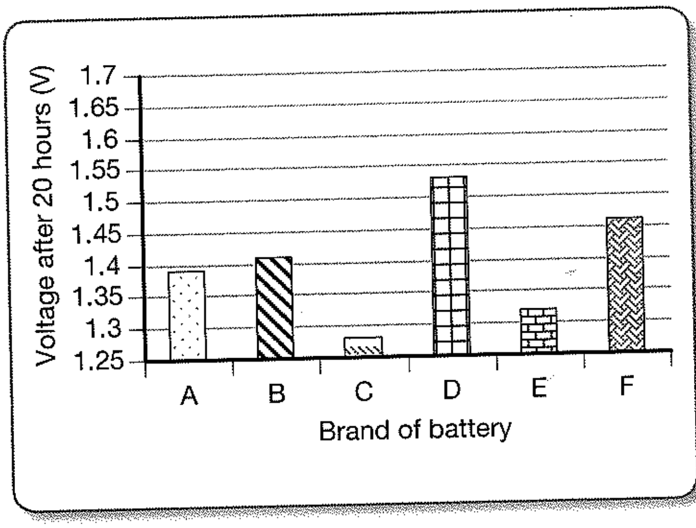
tery	Voltage loss after 20 hours	Voltage loss after 20 hours (%)
A		
B		
C		
D		
E		
F		

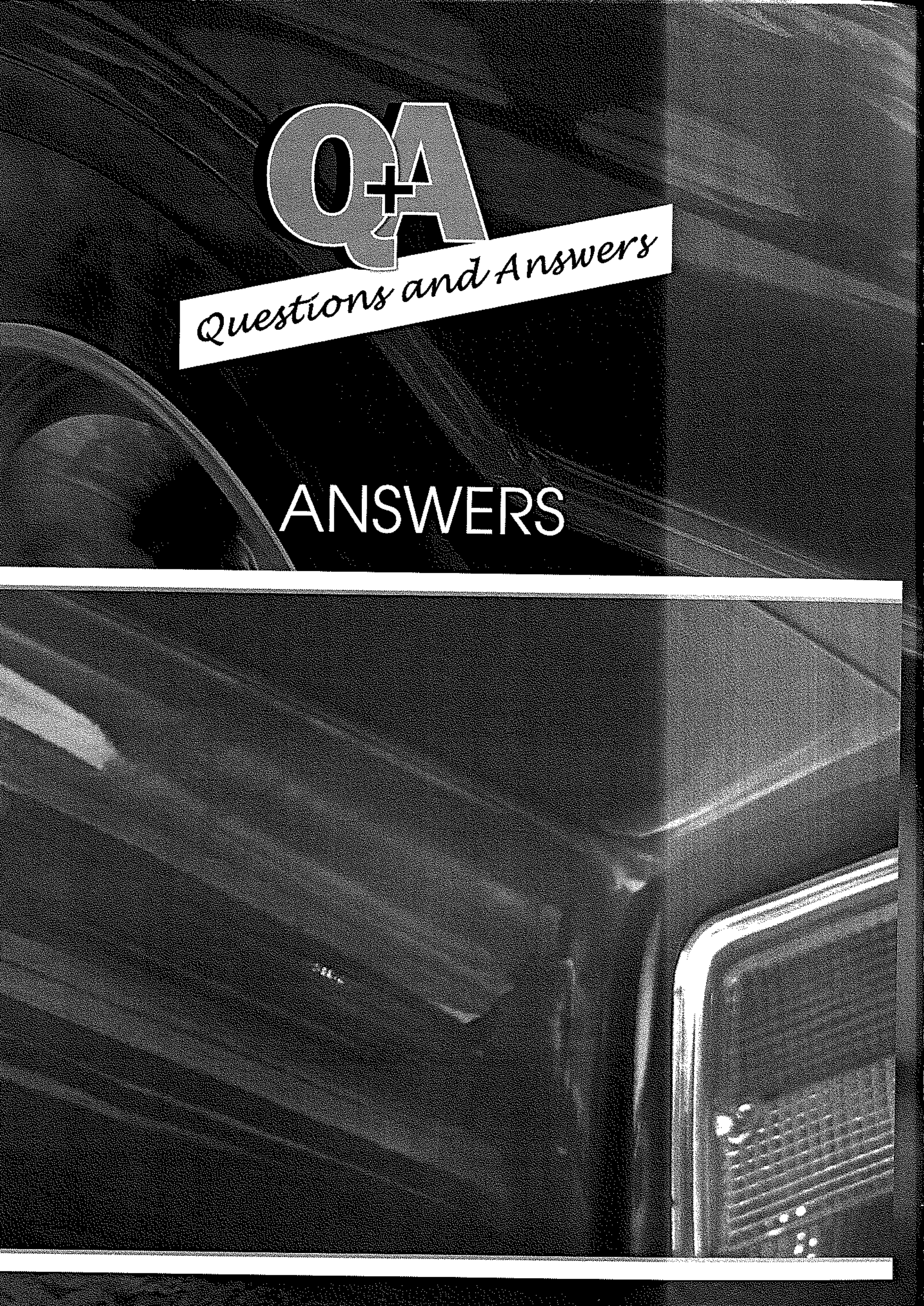
e batteries are unable to run the
liance when their voltage reduces
ow 1.00 V, predict which battery will
the longest. Justify your answer.

the basis of these figures which battery would appear to last the shortest time? Justify your
wer.









Q+A Questions and Answers

ANSWERS

Set 1 The Kinetic Theory of Matter

1.
   - All matter is made up of small particles.
   - These particles are always moving except at absolute zero which is defined as the temperature at which all particle motion ceases.
   - The particles are held together by forces which vary in strength.
2. Temperature is a measure of the average kinetic energy of the particles of matter.
3. The particles of matter are too small to be seen, so we are not describing what they do from observations of the particles themselves. We deduce their behaviour from the properties of matter.
4. (a) We use the kinetic theory to explain and predict the behaviour of matter.
   (b) Any model in science is only as good as its ability to explain and predict accurately, and so far, the kinetic theory model has worked extremely well.
   (c) Only if we discover properties of matter that we cannot explain using the kinetic theory, then we will need to rethink the theory, perhaps modifying it so that these new properties are also explained.
5. (a) A = solid
   B = gas
   (b) In A, particles are close packed and are not needing to be contained to stay together.
   In B, particles are relatively far apart and moving freely in random directions.
   (c) For a liquid, the particles will be taking the shape of their container, and will not completely fill it.
   (d) The particles will be close packed as in the solid.
   (e) In solids the particles vibrate in fixed positions. In liquids they roll over one another and in gases they are free to move in any direction.
6. (a) The amount of gas inside the balloon is constant (same balloon in each container) so the size difference is due to a difference in the pressure of the gas inside the container but outside the balloon ($Z > X > Y$).
   (b) The number of particles in the gas in the container is indicative of the amount of gas and therefore its pressure in a confined place.

Set 2 Kinetic Theory and Properties of Matter

1.

Solids	
Property	**Feature of diagram**
Solids cannot be compressed	Particles are drawn touching each other
Solids have a fixed shape	Particles are drawn in fixed lattice positions
Solids do not diffuse	Particles are drawn in fixed lattice positions
Solids expand least when heated	Particles are drawn in fixed lattice positions

Liquids	
Property	**Feature of diagram**
Liquids cannot be compressed	Particles are drawn touching each other
Liquids flow	Particles are shown rolling over one another
Liquids take the shape of their container	Particles are shown rolling over one another
Liquids expand when heated	Particles are shown rolling over one another

Gases	
Property	**Feature of diagram**
Gases are easily compressed	Particles are drawn far apart
Gases flow	Particles are drawn showing free movement
Gases fill their containers	Particles are drawn showing free movement
Gases expand quickly when heated	Particles are drawn showing free movement

2. (a) Because the particles in concrete (as in any solid) are as close together as they can be.
   (b) Because the particles in glass (as in any solid) are held together in fixed positions by strong forces.
   (c) The particles in the gaseous perfume vapour are not held together and are free to move so they spread out (diffuse) quickly.
   (d) Particles in liquids can roll over one another and are not held as tightly as in solids, so they can spread out into the holes in the paper towel.
   (e) Particles in the liquid dye roll over one another and are not held together strongly, so they can diffuse into the water.
   (f) The particles in the metal are help together by strong forces which can be partially overcome to bend the bar.
   (g) Wood is not as dense as metal (has air in it) so there are not as many forces to overcome so it is easier to break/bend than a metal bar.
   (h) Particles in liquids are free to roll over one another. Particles in solids are held together by forces which hold them in position and prevent them from diffusing.
   (i) Particles in gases are free to move so they spread out and fill their container and take whatever shape it is.

(j) Forces between the lipstick particles and your lips' particles are stronger than forces between lipstick particles.

(k) Compressed air is air in which the particles have been forced into a much smaller volume. They collide with each other and their container producing a high pressure. In a jumping castle as more air is pumped in, there are more and more particles in the castle which produce a pressure higher than the air pressure outside the castle and make it firmer.

(l) Compressed spray has particles which have been forced into a much smaller volume. They collide with each other and their container producing a high pressure. When the button is pushed down it provides an outlet to a region where the pressure is lower (due to fewer particles not as close together). Collisions between the particles from the compressed spray push them out of the can to equalise the pressures.

(m) Particles of water moisture in the warm air hit the colder glass of the window, slow down and change state to form water liquid.

(n) The tyre becomes excessively hot causing an increase in its internal pressure which may exceed the strength of the tyre sidewall.

Set 3 Temperature and the Kinetic Theory

1. (a) Temperature is a measure of how fast the particles of matter are moving.

(b) Temperature is a measure of the average kinetic energy of the particles of matter.

(c) The higher the temperature, the faster the particles are moving.

(d) When matter is heated its particles absorb energy and move faster.

(e) When matter is cooled its particles lose energy and slow down.

(f) Gas particles have more energy due to their state than liquid particles at the same temperature.

(g) Similarly, liquid particles have more energy than solid particles at the same temperature.

(h) In both cases (f) and (g), this is due to the extra energy they have because the particles move more freely.

2. (a) B It is the coldest, so according to the concept of temperature as a measure of average kinetic energy of particles, and therefore the speed of the water particles will be the slowest.

(b) If the steam is at 100°C, then the particles in A and C will have the highest temperature and therefore the highest kinetic energy. However, if the steam in either of them is hotter than 100°C, then its particles will have the most kinetic energy.

(c) B < D < A < (or perhaps equal to) C.

(d) Steam particles move more freely than water particles and are not held to other steam particles, so they can penetrate pores in our skin much more effectively and give a deeper burn.

3. (a) Givn that temperature is a measure of the average kinetic energy of particles of matter, then when the particles stop moving their kinetic energy, and therefore the temperature will be zero. This will be an absolute zero, because the particles cannot move slower than being stopped.

(b) –273.15°C

Set 4 Changes of State and the Kinetic Theory

1. (a) As a solid is heated, its particles move faster and vibrate more violently.

(b) As the particles absorb energy they start to overcome the forces holding them together.

(c) Eventually, the particles have enough energy to totally overcome the forces holding them together.

(d) They then break away from their fixed positions and roll over one another.

(e) At this stage the solid starts to melt and becomes a liquid.

(f) As more energy is added, the particles in the liquid roll around faster and faster.

(g) Eventually they have enough energy to overcome the forces holding them together.

(h) They then break away from each other and move freely.

(i) The liquid evaporates and becomes a gas.

2. (a) Change of state is gas to liquid (condensation).

(b) The average *KE* of the particles does not change because the question indicates that the process is occurring at a constant temperature.

(c) The forces between the particles increase as they change from the gaseous to the liquid state.

(d) In the liquid state (diagram C).

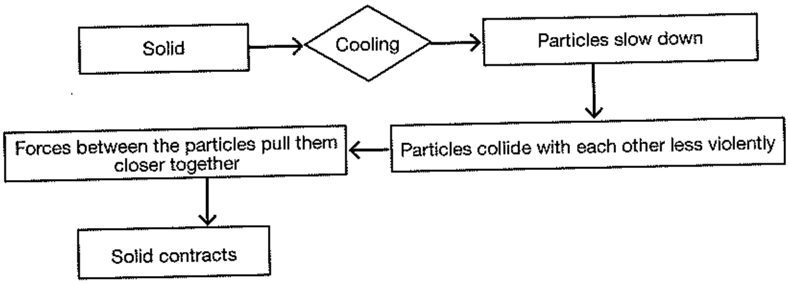
(e) Again, given that the temperature remains constant, the rate of movement of the particles will also remain constant. When molecules are closer the forces of attraction are greater so movement slows. However, the way in which they move obviously changes from freely in the gas to just sliding past each other in the liquid.

(f) A = gas

B = gas condensing to form liquid

C = liquid

3.

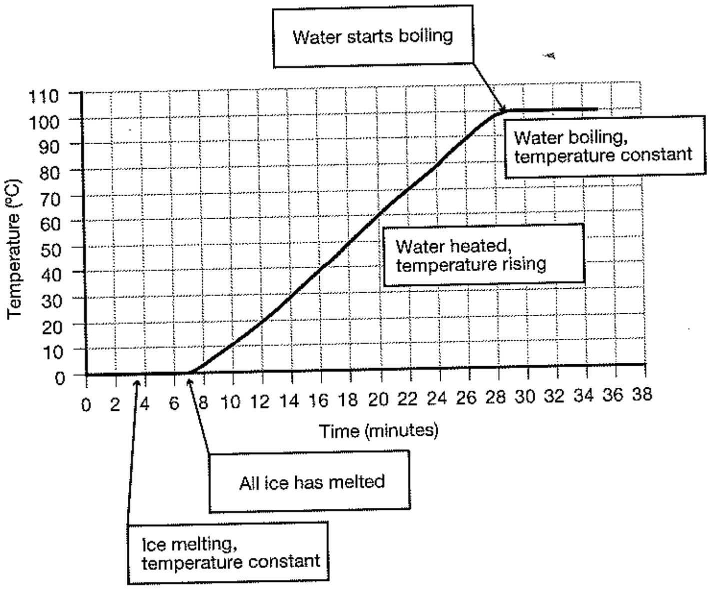


4.

State or process	Name of state or process
E	Sublimation
F	Sublimation
P	Melting or fusion
Q	Freezing or solidification
R	Condensing
S	Boiling or evaporating
V	Energy in or energy increasing
W	Energy out or energy decreasing
X	Solid
Y	Liquid
Z	Gas

Set 5 Changes of State and Latent Energy

1. (a)



(b) The energy is being absorbed by the ice to melt it.

(c) The energy is being absorbed to evaporate the water.

2. (a) Latent energy in fusion is used to overcome the forces holding the particles of the solid in their fixed, lattice positions, enabling them to roll over one another. Measured in kJ kg^{-1}.

(b) Latent heat of fusion, L_f is the energy required to change the state of a substance from solid to liquid. Also referred to as the specific heat of fusion.

(c) Latent energy in fusion is used to overcome the forces holding the particles of the solid in their fixed, lattice positions, enabling them to roll over one another. Measured in kJ kg^{-1}.

(d) Latent heat of vaporisation, L_v is the energy required to change the state of a substance from liquid to gas. Also referred to as the specific heat of vaporisation.

(e) Latent energy in evaporation is used to overcome the forces holding the particles of the liquid together enabling them to break away from each other and move independently. Measured in kJ kg^{-1}.

(f) Yes. In this case the energy is released as bonds between particles form rather than absorbed to break the bonds holding the particles together. The value is the same as the latent heat of fusion.

(g) Yes. In this case the energy is released as bonds between particles form rather than absorbed to break the bonds holding the particles together. The value is the same as the latent heat of vaporisation.

3. (a) $L_v = \Delta H/m = 12\,000/150 = 80$ J g^{-1} = 80 000 J kg^{-1} = 80 kJ kg^{-1}
(b) $m = \Delta H/L_v = 2.5/80 = 0.03125$ kg = 31.25 mL
(c) $\Delta H = m \times L_v = 1 \times 80 = 80$ kJ

4. (a) $\Delta H = m \times L_f = 0.2 \times 334 = 66.8$ kJ
(b) $m = \Delta H/L_f = 16.0/334 = 0.048$ kg = 48 g
(c) 334 kJ

5. (a) $\Delta H = m \times L_f = 0.15 \times 334 = 50.1$ kJ
(b) 8.35 kJ min^{-1}
(c) $\Delta H = (m \times c \times \Delta T) = 0.15 \times 4.18 \times 100 = 62.7$ kJ
(d) Time = energy/rate supplied = 62.7/8.35 = 7.51 minutes
(e) $\Delta H = m \times L_v = 0.15 \times 2260 = 339$ kJ
(f) Time = energy/rate supplied = 339/8.35 = 40.6 minutes

6. (a) Total energy removed = energy as the water cooled + energy as the water froze
$= (m \times c \times \Delta T) + m \times L_f$
$= (0.150 \times 4.18 \times 15) + (0.15 \times 334)$
$= 9.41 + 50.1 = 59.42$ kJ
(b) Rate = total energy/time = 59.42/1.25 = 47.54 kJ per hour

7. (a) Energy = $m \times L_v = 1.5 \times 2260 = 3390$ kJ
(b) Jug supplies 2400 J s^{-1}
So time needed = 3390 000 ÷ 2400 = 1412.3 s = 23.5 minutes
(c) The same amount = 3390 kJ

8. (a) To determine the relationship between temperature and time as a mass of solid is heated until the liquid formed and as it melts and evaporates.
(b) Dependent variable = temperature
Independent variable = time
(c) 40°C
(d) Total energy = energy supplied by heater per second × time in seconds
$= 1200 \times 27 \times 60 = 1\,944\,000$ J = 1944 kJ
(e) From $P = VI$
$1200 = 240 \times I$
Therefore $I = 5.0$ A
(f) Latent heat of vaporisation is larger because time to evaporate the liquid is longer than time to melt the solid.
(g) Solid takes 6 minutes to melt.
Therefore amount of energy to melt is = $1200 \times 6 \times 60 = 432\,000$ J = 432 kJ
Therefore L_f = energy/mass = 432/0.09 = 4800 kJ kg^{-1}
(h) Liquid takes 8.5 minutes to melt.
Therefore amount of energy to melt is = $1200 \times 8.5 \times 60 = 612\,000$ J = 612 kJ
Therefore L_f = energy/mass = 612/0.09 = 6800 kJ kg^{-1}
(i) Liquid takes 7.5 minutes to heat from 40°C to 85°C.
Therefore amount of energy to heat is = $1200 \times 7.5 \times 60 = 540\,000$ J = 540 kJ
Therefore specific heat = energy/(mass × ΔT) = 540/(009 × 45) = 133.3 kJ kg^{-1} °C^{-1}

9. (a) Energy given out by the oil = energy gained by water + energy to evaporate water + energy to heat steam
Let the mass of water involved = m
From energy = $m \times c \times \Delta T$
We get $2.8 \times 10^7 = (m \times 4.18 \times 80) + (m \times 2260) + (m \times 2.0 \times 200)$
From which $m = 9.35$ kg = 9.35 L of water per litre of oil.
(b) Crude oil is less dense than water, so it floats on top of the water, thereby exposing it to the oxygen in the air, which it uses to burn. Also, if the water is under the oil, it is less efficient in absorbing the heat generated by the oil.

10. Energy given out by the granite = energy gained by water + energy to evaporate water.
Let the mass of granite involved = m.
From energy = $m \times c \times \Delta T$
We get $m \times 0.79 \times (500 - 100) = (4 \times 4.18 \times 85) + (0.025 \times 2260)$
From which $m = 4.68$ kg.

Set 6 Transferring Heat Energy

1. In a closed system, energy transferred from A to B = energy received by B.

2. (a) The temperature rise in Y will be much greater (6 times) that of X because its specific heat is six times lower. In other words, only one sixth of the energy is needed to cause a one degree temperature rise compared to X.

   (b) Because Y requires much less energy to have the same temperature rise, the source of energy heating Y will be (6 times) less energetic.

   (c) Because of the lower specific heat of Y, the mass of Y must be 6 times that of X.

3. Energy transfer = $(m \times c \times \Delta T)$

   Therefore $2500 = 0.25 \times c \times 18$

   Therefore $c = 555.6$ J kg^{-1} °C^{-1}

4. Energy transfer = $(m \times c \times \Delta T)$

   Therefore $E = 0.25 \times 156 \times 125$

   Therefore $E = 4875$ J

5. Energy lost by hot water = energy gained by colder water,

   $(m \times c \times \Delta T)_{\text{hot water}} = (m \times c \times \Delta T)_{\text{cold water}}$

   Because we don't know the change in temperature, let the final temperature = T

   Therefore, temperature change for hot water = $80 - T$ (it gets cooler)

   And temperature change for cold water = $T - 60$ (it gets warmer)

   Substituting: $300 \times 4.18 \times (80 - T) = 250 \times 4.18 \times (T - 60)$ (conversion of mass to kg cancels)

   $100\,320 - 1254T = 11045T - 62\,700$

   $163\,020 = 2349.9T$

   Therefore final temperature, $T = 69.4$°C

6. Energy lost by hot water = energy gained by colder water

   $(m \times c \times \Delta T)_{\text{hot water}} = (m \times c \times \Delta T)_{\text{cold water}}$

   Because we don't know the change in temperature, let the final temperature = T

   Therefore, temperature change for hot water = $75 - T$ (it gets cooler)

   And temperature change for cold water = $T - 18$ (it gets warmer)

   Substituting: $200 \times 4.18 \times (75 - T) = 300 \times 4.18 \times (T - 18)$ (conversion of mass to kg cancels)

   $62\,700 - 836T = 1245T - 22\,572$

   $85272 = 2081T$

   Therefore final temperature, $T = 41$°C

7. (a) We must assume the density of the milk is the same as water, 1.0 g cm^{-3} (slightly incorrect)

   Energy lost by hot coffee = energy gained by milk

   $(m \times c \times \Delta T)_{\text{hot coffee}} = (m \times c \times \Delta T)_{\text{milk}}$

   Because we don't know the change in temperature, let the final temperature = T

   Therefore, temperature change for coffee = $100 - T$ (it gets cooler)

   And temperature change for milk = $T - 5$ (it gets warmer)

   Substituting: $200 \times 4.18 \times (100 - T) = 40 \times 4.18 \times (T - 5)$ (conversion of mass to kg cancels)

   $83\,600 - 836T = 167.2T - 836$

   $84\,436 = 1003.2T$

   So, final temperature, $T = 84.2$°C

   (b) Energy lost by coffee + energy lost by cup = energy gained by milk

   $(m \times c \times \Delta T)_{\text{hot coffee}} + (m \times c \times \Delta T)_{\text{cup}} = (m \times c \times \Delta T)_{\text{milk}}$

   Because we don't know the change in temperature, let the final temperature = T

   Therefore, temperature change for hot coffee and cup = $100 - T$ (it gets cooler)

   And temperature change for milk = $T - 5$ (it gets warmer)

   Substituting: $200 \times 4.18 \times (100 - T) + 250 \times 800 \times (100 - T) = 40 \times 4.18 \times (T - 5)$

   $83\,600 - 836T + 20\,000\,000 - 200\,000T = 167.2T - 836$

   $20\,084\,436 = 201\,003.2T$

   So, final temperature, $T = 99.9$°C

8. Energy lost by water = energy gained by iceblocks in melting + energy gained by ice water

$(m \times c \times \Delta T)_{water} = (m \times L_f)_{ice} + (m \times c \times \Delta T)_{ice\ water}$

Because we don't know the change in temperature, let the final temperature = T

Therefore, temperature change for water = $20 - T$ (it gets cooler)

And temperature change for ice water = $T - 0$ (it gets warmer)

Substituting: $400 \times 4.18 \times (20 - T) = 80 \times 4.18 \times (T - 0) + 80 \times 334$

$33440 - 836T = 334.4T + 26\,720$

$7620 = 1170.4T$

Therefore final temperature, $T = 6.5°C$

9. (a) Energy transfer = $(m \times c \times \Delta T)$

Therefore $E = 0.3 \times 236 \times 70$

Therefore $E = 4956$ J

(b) Energy lost by metal = energy gained by colder oil

$(m \times c \times \Delta T)_{metal} = (m \times c \times \Delta T)_{oil}$

We know that the final temperature is 55°C.

Therefore, temperature change for metal = 80 – 55 = 25

And temperature change for oil = 35 (given)

Substituting: $300 \times 236 \times 25 = 600 \times 1.5 \times c \times 35$ (conversion to kg cancels)

$1\,770\,000 = 31\,500c$

Therefore $c = 56.2$ J kg^{-1} °C^{-1}

Set 7 Heat Conduction

1. (a) When we are cooking and need to stir food, we usually use a wooden rather than a metal spoon.
(b) A metal spoon would get hot because heat energy from the food can transfer easily into it.
(c) This happens because metals are good conductors of heat.
(d) We use conductors when we want heat to travel quickly through something.
(e) Because of this we use metals to make saucepans, barbecue plates, kettles, radiators in cars.
(f) Non-metals, like wood, are non-conductors of heat.
(g) Non-conductors of heat are also called heat insulators.
(h) Heat energy does not pass through insulators.
(i) Air is one of the best insulators.
(j) Many substances that contain a lot of air, such as cork, polystyrene foam, fibreglass and wool, are therefore good insulators.
(k) We use insulators when we don't want heat travelling through something.
(l) So we use wood or plastic handles on saucepans, fibreglass lagging on hot water pipes, air cavities in the walls, and polystyrene in picnic baskets.

2. (a) To study the conduction of heat energy through a metal rod.
(b) Results show that the further the metal is from the source of the heat, the less energy has transferred.
(c) The rod must be a metal rod because it is conducting heat energy.
(d) It is an indirect relationship – the further the distance from the Bunsen, the lower the temperature is.
(e) Heat energy is absorbed by the metal particles causing them to oscillate more rapidly in their fixed positions and to collide more violently with neighbouring particles thus transferring kinetic energy to them. These particles, in turn, transfer energy to their neighbouring particles in the same way. The energy gradually transfers through the rod.
(f) The first thermometer may show a rise in temperature depending how far along the glass it is from the heat source. The other two thermometers would not show heat transfer as glass is a non-conductor of heat energy.

3. (a) If the outer saucepan is heated by running hot water over it, it will absorb heat energy from the water by conduction and expand. The inner, wedged saucepan will become loose and can be removed.
(b) Your finger is warmer then either the air or the water, but because water is a better conductor than air, heat from your finger transfers more quickly to the water making your finger feel cooler.
(c) Heat transfers more quickly from your hand into the metal because it is a better conductor than the wood of the bench, so the metal will feel cooler.

4. The glass in the sun will have more moisture on its outside. Heat energy is conducted from the air to the glass and through the glass to the orange juice. Air near the outer side of the glass cools and condensation of water vapour occurs forming the moisture on the outside of the glass. The glass in the sun has a greater temperature difference between the air and the orange juice so more energy transfers through to the orange juice, cooling more air (convection currents are also involved here) and so condensing more water vapour.

5. In metals the valence electrons are delocalised and are free to move. When heated these electrons gain kinetic energy (as do the atoms as a whole within the metal) and, being free to move, transfer this energy with them along the metal. This is much faster than ordinary conduction via collisions between atoms within the metals.

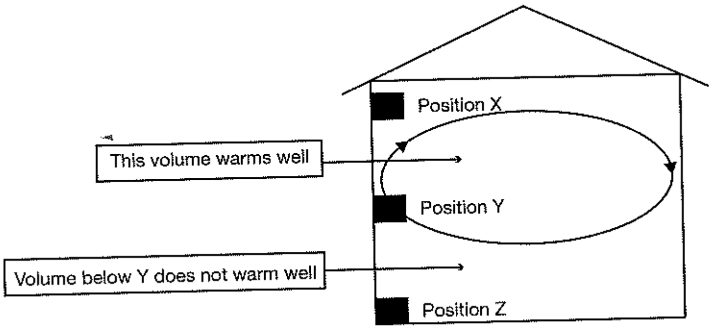
6. Convection currents will set up in the top half of the water in the tube, but not the bottom half and because water is a poor conductor of heat energy, the heat does not transfer to the bottom of the test tube to melt the ice.

Set 8 Heat Convection

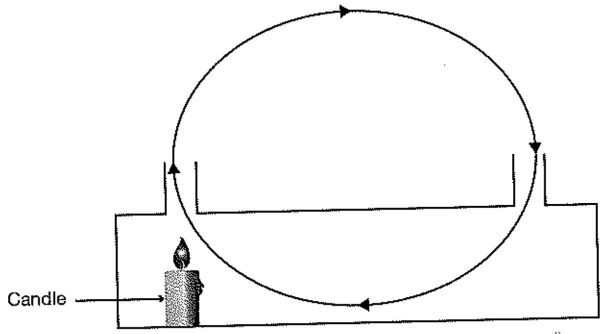
1. (c) If water is heated, it moves with a circular motion called a convection current.
   (i) Convection currents start because the water at the bottom of a container being heated expands.
   (a) As the water expands it becomes less dense.
   (g) The less dense water then rises to the top of the container.
   (f) At the top of the container this water cools down.
   (h) More rising hot water from the bottom pushes the cooling water to the side.
   (b) As the water cools down, it becomes denser.
   (d) The cooler, denser water sinks to the bottom of the container to take the place of the rising hot water.
   (e) These processes repeat over and over setting up the convection current.

2. (a) The transfer of heat energy by convection occurs in gases and liquids, collectively known as fluids, because their particles can move more freely than the particles in solids. They can both flow.
   (b) Particles in gases are free to move and can therefore move about much more than particles in liquids. Gases can therefore transfer heat energy by convection faster and more efficiently than particles in liquids.

3. (a) Position Z would be the most efficient as the convection currents formed will fill and therefore warm the whole room.
   (b) If the heater was placed at position Y, the convection currents formed would not heat the volume of the room below position Y as well because the convection currents formed by Y will not move air as efficiently below Y as those produced by heating at Z.



4. Hot air from the candle keeps rising up and will be pulled sideways into right side vent by the convection current which sets up.



Set 9 Heat Radiation

1. (a) Heat radiation refers to the transfer of heat energy outwards from a hot source via electromagnetic radiation (infra-red rays).
   (b) Heat radiation occurs as a hot object releases energy by emitting infra-red electromagnetic waves.
   (c) At the side, you only receive heat energy by radiation. Above the fire heat energy reaches you via radiation and convection currents. Because air is a good insulator little heat is conducted in any direction.

2. (a) Dark coloured objects absorb radiated heat energy better than lighter coloured objects.
   (b) Dark coloured objects emit radiated heat energy better than lighter coloured objects.
   (c) Dull objects absorb radiated heat energy better than shiny objects.
   (d) Dull objects emit radiated heat energy better than shiny objects.

3. (a) Infra-red radiation.

(b) Wavelength between about 1 μm (one micrometre or one millionth of a metre) and 0.1 mm.

(c) It is these wavelengths of electromagnetic energy (which carry amounts of energy) which are absorbed by our bodies and cause molecules in the skin to vibrate/oscillate faster and this is what our senses interpret as warmth.

4. The beaker glass is heated by radiant heat directly from the flame and by convection currents. Conduction from the red hot gauze adds to these. Heat is then conducted through the glass to heat the bottom of the water in the beaker. Convection currents set up in the water to transfer the heat throughout the water in the beaker.

5. (a) The hottest will be B > A > D > C which will be the coolest.

(b) The hottest will be C > D > A > B which will be the coolest.

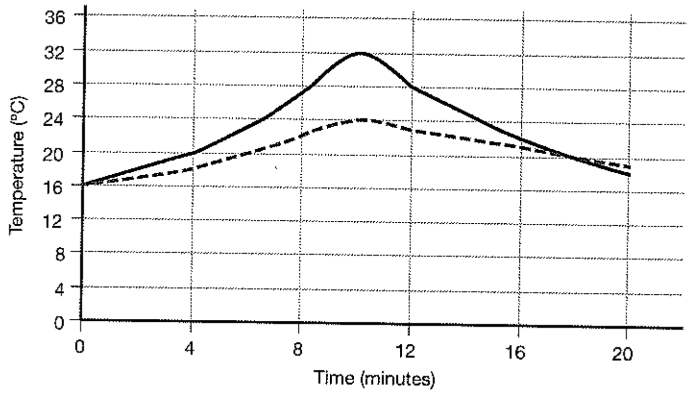
6. (a) Black handles increase the rate at which heat energy is transferred to the air by radiation and so keep the handles cooler for people to hold.

(b) White reflects the heat during the daytime and keeps the house cooler.

(c) It should be bright, silvery white because this is the worst radiator of heat.

Set 10 An Experiment on Heat Radiation

1.



2. For example: the size of the containers, the amount of water in each container, the rate at which each was heated, the material the containers are made of (i.e. same metal).

3. Bright shiny container was container B – it reflected the applied heat better and so heated more slowly. It also radiated its absorbed energy more slowly.

4. To compare the rates at which a dull container and a bright shiny container of water absorb and radiate heat energy.

5. The dull container absorbed and released heat energy faster than the shiny container.

6. The experiment should be repeated with different sized containers, pairs of containers made of other types of metal (both the same metal), with other volumes of water, with volumes of different liquids (but still the same liquid in each container).

Set 11 Work Done and Internal Heat Energy

1. Pa m^3 = N m^{-2} m^3 = kg m s^{-2} m^{-2} m^3 = kg m^2 s^{-2} = joule

2. (a) The external heating source does the work.

(b) Work done = $P\Delta V = 1.8 \times 10^5 \times 2.5/1000$ (change the volume to cubic metres) = 450 Pa m^3 = 450 J

3. (a) Because the volume of the gas does not change, no work has been done on the gas.

(b) From $W = P\Delta V = 180 \times 3.8/1000 = 0.684$ J

4. (a) Work done needs to be estimated by the area under the graph method, i.e. 'counting grid squares' where each grid square is equal to 100 J of work.

Number of squares = 15 = about 1500 J

(b) From $W = \Delta H = mc\Delta T$

So $1.5 = 0.2 \times 1.75 \times \Delta T$ (change 1500 J to 1.5 kJ)

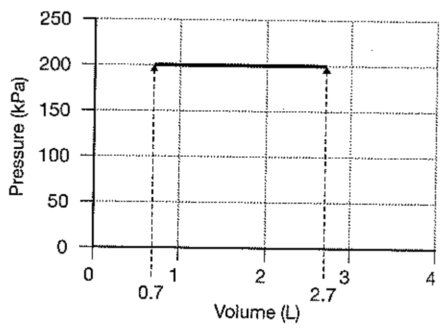
Therefore $\Delta T = 4.3$°C

5. (a) From $W = P\Delta V = 400$ (kJ) $= 200$ (kPa) $\times \Delta V$

Therefore $\Delta V = 2.0$ m^3

So the final volume of the gas = 2.0 + 0.7 = 2.7 m^3

(b)



6. (a) The gas does work against gravity as it expands and pushes the piston up.
(b) 230 J = 605 – 375
(c) The temperature of the gas will increase.
(d) The mass of the gas and its specific heat capacity.

7. From $W = mc\Delta T = 125 \times 4.18 \times (17.8 - 2.5) = 7.99$ kJ

8. (a) From $W = mc\Delta T = 80 \times 0.82 \times (92 - 21) = 4658$ J
(b) $W = mc\Delta T$
$4658 = m \times 4.18 \times (100 - 92)$
Therefore $m = 139.3$ g = 139.3 mL

9. From $W = P\Delta V = 110 \times 3.9 \div 1000 = 0.429$ kJ

10. (a) The work done by the gas against the piston.
(b) From $W = P\Delta V = 200 \times 25 \div 1000 = 5.0$ kJ
(c) 5.0 kJ
(d) As it is heated, it absorbs energy causing its molecules to move faster (its temperature rises) but because the piston is free moving, this additional energy will be used to move the piston as the gas expands hence lowering the temperature of the gas. This will effectively keep the temperature of the gas constant.
As it is compressed back to its initial volume, the temperature will rise as work will be done on it by the piston increasing its internal energy.

11. From ΔE = work done on the system – work done by the system = 2500 – 7500 = –5000 J (i.e, it loses 5 kJ)

12. (a) The temperature of the gas will decrease.
(b) The volume of the gas will decrease and its temperature will rise.
(c) 1500 – 500 = 1000 J added.

13. (a) From $W = P\Delta V = 80 \times -20 \div 1000 = -1.6$ kJ
So 1.6 kJ of work is done by the system.
(b) The internal energy of the system decreases by 1.6 kJ.

Set 12 The Development of Thermodynamics

1. B
2. D
3. B
4. (a) Thermodynamics is the branch of science related to heat energy and its relationship to work.
(b) Thermodynamics developed from a need to increase the efficiency of early steam engines.
5. Thomas Savery (1650-1715). Thomas Savery was an English military engineer and inventor who in 1698, patented the first crude steam engine to pump water out of coal mines. His engine consisted of a closed vessel filled with water into which steam under pressure was introduced. This forced the water upwards and out of the mine shaft. Then a cold water sprinkler was used to condense the steam. This created a vacuum which sucked more water out of the mine shaft through a valve at the bottom of the vessel. This engine was not very efficient as it was limited by the pressure that could be produced by the steam.

Thomas Newcomen (1664-1729). Thomas Newcomen, an English blacksmith, invented the atmospheric steam engine, first used in 1712 to pump water out of a mine. Thomas Newcomen's engine pumped steam into a cylinder. The steam was then condensed by cold water which created a partial vacuum inside of the cylinder. Then atmospheric pressure operated a piston, creating downward strokes. In Newcomen's engine the intensity of pressure was not limited by the pressure of the steam and was therefore more efficient than Savery's engine.

Nicolas Leonard Sadi Carnot (1796-1832). In the early 1820s, Carnot was studying the efficiency of steam engines and conceived a virtual version of a steam engine as a vehicle for thought experiments. In these thought experiments he hypothesised the existence of an engine which ran on a reversible cycle, now known as the Carnot cycle.

Carnot's engine was a fluid-filled cylinder with a piston, which is alternately exchanging heat with a hot and a cold reservoir. When in contact with the hot reservoir, the fluid expands and pushes the cylinder up – the engine receives heat and does work on its surroundings. When the fluid cools, the surroundings do work on the engine by compressing the fluid inside the cylinder, and the resulting heat is given off to the cold reservoir. In other words, there is a cycle of heat energy (then called a caloric fluid) into the engine, then into the surroundings. Carnot's (and Lord Kelvin's) ideas led to the development of the second law of thermodynamics: 'It is impossible for a machine, unaided by an external source of energy, to transfer heat from a body at lower temperature to a body of higher temperature' (i.e. the natural flow of heat energy is from hotter objects to colder objects).

Carnot showed that the work produced by a heat engine such as a steam engine depended on the high and low temperatures between which it operated, and that there was a maximum efficiency that could be achieved between any two temperatures.

James Watt (1736-1819). James Watt was a Scottish inventor and mechanical engineer. He is renowned for his improvements of the steam engine. In 1765, James Watt while working for the University of Glasgow was assigned the task of repairing a Newcomen engine, which was deemed inefficient but the best steam engine of its time. Instead, he improved on the design, designing, in 1769, a separate condenser connected to a cylinder by a valve. This condenser could be kept cool even though the cylinder of the engine was hot, improving the efficiency of the engine significantly. Watt's steam engines helped bring about the Industrial Revolution.

Set 13 The Internal Combustion Engine

1. (a) An internal combustion engine converts chemical energy into useful mechanical energy by burning fuel. Chemical energy is released when the fuel-air mixture is ignited by the spark in the combustion chamber. The gas produced in this reaction rapidly expands forcing the piston down the cylinder on the power stroke.
   (b) A 4-stroke engine is an internal combustion engine in which the piston completes four separate strokes during two separate revolutions of the engine's crankshaft, and one single thermodynamic cycle.
   (c) Intake stroke, compression stroke, power stroke and exhaust stroke.
   (d) Cars, motorbikes, lawnmowers, aircraft, helicopters, boats, trains.
   (e) Petrol, diesel, LPG, natural gas, ethanol, biofuels.
2. (a) A = compression stroke
   B = power stroke
   C = exhaust stroke
   D = intake stroke
   (b) X = exhaust valve showing combustion products being pushed out of the cylinder as the piston rises.
   Y = intake valve showing air and fuel mixture being drawn into the cylinder as the piston moves down.
   (c) A = piston moves upwards to compress the air/fuel mixture.
   B = about to move down as the expanding combustion gases do work on it to turn the crankshaft.
   C = upwards to push exhaust gases out of the cylinder.
   D = downwards to draw air/fuel mixture into the cylinder.
   (d) P = exhaust valve
   (e) Q = intake valve
   (f) P is open to allow release of exhaust gases, Q is closed.
   (g) Both valves need to be closed during the compression and power strokes so that gases do not escape from the cylinder. This would make the engine less efficient and cause damage.
   (h) Much of the compressed combustion product would escape out of the valve making the engine far less efficient as the power moving the piston down would be less.
   (i) Intake stroke:
   - The piston starts at the top of the cylinder and moves downward.
   - The intake valve opens allowing a fresh charge of mixed fuel and air into the cylinder.

   Compression stroke:
   - Once reaching the bottom the piston moves back up.
   - The intake valve closes sealing the mixture inside the cylinder.
   - The mixture compresses making the soon to come explosion more powerful and efficient.

   Power stroke:
   - When the piston reaches the top of its stroke the fuel mixture is ignited by the spark plug.
   - The gasoline charge in the cylinder explodes with great power.

   Exhaust stroke:
   - Once the piston reaches the bottom of its stroke the piston again moves upward.
   - The exhaust valve opens and the burnt gases are forced out of the cylinder.

Set 14 The Energy Balance of Earth

1. The greenhouse effect is a natural process whereby the atmosphere reflects heat energy attempting to radiate out into space back to the lower atmosphere and Earth's surface. This results in more energy being retained than if there were no greenhouse gases (CO_2 and H_2O).
2. Because the effect is similar to a gardener's glass greenhouse in which the glass (or plastic) walls and roof trap the Sun's heat energy inside the greenhouse. (The thin 3 mm glass of the greenhouse plays the same role as 10 km of atmosphere).
3. (a) Carbon dioxide.
   (b) Methane and chlorofluorocarbons (CFCs).
4. The greenhouse gases in the atmosphere prevent reflected and radiated heat energy from the Earth's surface from escaping into space. Consequently it stays in the atmosphere and slowly increases its temperature.
5. Answers will vary, for example:
   - Global warming.
   - Increased rate of melting of the ice sheets.
   - Increased rate of melting of glaciers and snowfields.
   - Rising sea levels.
   - Climate change.
   - Changes in ocean currents.
   - Shifts and changes in ocean populations.
   - Changes in patterns for migrating birds.

6. There is evidence for similar temperature rises in the Earth's past history (before the effect humans have had) which resulted from other, perhaps natural changes. Some collected data does not show a direct link between global temperature rises and carbon dioxide levels in the atmosphere.

7. The ocean heat conveyor belt refers to the ocean currents that flow from the North Atlantic Ocean south to the Indian and Pacific oceans then cycling around them before going back to the North Atlantic region.

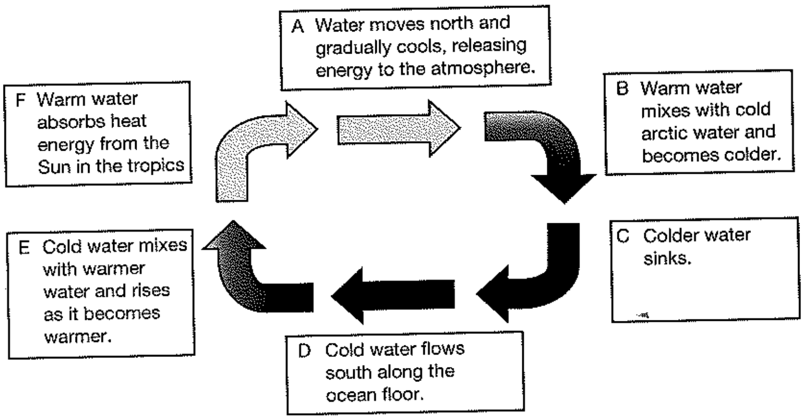
8. The conveyor belt analogy refers to the continuous cycle around the globe much like a real conveyor belt simply keeps cycling round and round.

9. The ocean heat conveyor belt is a huge series of convection currents driven by changes in density of the ocean water as it heats or cools. Cooler water in the north is lower density and sinks to a lower level within the ocean and travels south to replace warmer waters rising and moving north to replace the cooler water.

10. The ocean heat conveyor belt helps to distribute heat energy around the world, maintaining the average temperatures we know in various parts of the world.

11. Most climate change models predict that global warming will slow the rate of the movement of the ocean heat conveyor belt. If that happens the colder water will stay in northern Europe and the warmer water in the tropics. Cold places will become colder, warm places warmer. Changes that alter ocean currents will eventually lead to changes in ecosystems on land and in the waters of the Earth. For example, the melting of polar ice could reduce the salinity and thus density of polar waters, which could weaken the rate at which this water sinks. This would alter the movement of heat around the globe.

12.



Set 15 Energy Sustainability

1. (a) An unlimited supply with no possibility of running out.
(b) Coal, natural gas and oil.
(c) No, they are not sustainable because they are all in limited supply and will eventually be depleted.
(d) The Sun.
(e) Any four of:
Solar technology is still expensive.
Solar cells are relatively inefficient at converting the Sun's energy to electricity.
They don't work well on cloudy and rainy days.
They don't work at all at night.
They are subject to damage by hail.
(f) The Sun.
(g) Solar energy is the only inexhaustible free, and non-polluting source of energy.
(h) Wind energy and tidal energy both rely on the Sun, as does biofuel in a different way (via photosynthesis). Another source dependent on the Sun is hydroelectricity.

2. (a) Solar, wind, ocean waves, tidal, geothermal, hydro, biomass.
(b) Solar, hydro, wave, biomass, wind.
(c) Tidal by the gravitational force between the Moon and the Earth by the combined gravitational forces of the Moon and Sun.
Geothermal from the heat energy in magma conducted upwards into subsurface rocks.

3. D Oil – nearly 40 per cent of world energy use was oil. Coal and natural gas were second and third, respectively.

4. B Coal – it is projected that coal will just barely win the top spot here, with about 29% of world energy share. Oil is next, with almost the same, followed by natural gas with about 23%.

5. C In Japan, passengers in Tokyo train stations generate energy every time they take a step. Special flooring tiles capture the vibrations generated by footfalls, which can be stored as energy. Enough energy is captured during the day to light up electronic signboards.

6. (a) About $4.289 \times 10^9 \times 3600 \times 24 \times 365 = 1.3525 \times 10^{17}$ kg per year
(b) $(1.3525 \times 10^{17} \div 1.98855 \times 10^{30}) \times 100 = 6.802 \times 10^{-12}$ %

(c) $100 \div 6.802 \times 10^{-12} = 1.47 \times 10^{13}$ years

(d) 1.3525×10^{17} kg per year $\times\ 9 \times 10^{9}$ years $= 12.17 \times 10^{26}$

(e) $12.17 \times 10^{26} \div 1.98855 \times 10^{30} \times 100 = 0.061\%$

(f) $(5 \times 10^{9}$ years $\div\ 1.47 \times 10^{13}$ years$) \times 100 = 0.034\%$

(g) At the end of its lifetime as an energy source for Earth, the Sun will still have 100 – 0.034 = 99.966% of its mass according to the figures in (f) or 100 – 0.061 = 99.939% according to (e). Its supply of energy for humans is certainly sustainable.

(h) The mass lost during the hydrogen fusion reaction in the Sun's core which produces the energy we receive from it is due to a *mass defect* in the fusion process which also forms helium as a matter product. The mass defect is only a very small percentage of the overall mass in the reaction, so, overall, 99.966% of the mass remains after 9×10^{9} years. The Sun's use to us ceases around that time because the concentration of hydrogen in the core is not enough to sustain the hydrogen fusion process, so the Sun will collapse into itself under gravitational forces, the core will become extremely hot and helium fusion will commence. The Sun will then expand rapidly to form a red giant star which will engulf all the inner planets in the process.

(i) The Sun's energy is sustainable as far as the life of the Earth is concerned.

7. (a) Millions of tonnes of oil equivalent.

(b) About 85%

(c) About 80%

(d) It should caused concern because so much of the fossil fuel reserves are being used each year. It would suggest they have limited sustainability.

(e) Top symbol = nuclear energy
Second top = coal
Third = oil
Last = natural gas (methane)

(f) It suggests that the remaining reserves of fossil fuels are extremely limited.

(g) This section of the figure does not have units. It may be that only 0.0001% is used each year, in which case the reserves will last for ages. On the other hand, if 1% is used per year, then they will only last another 4 to 8 years (this is *not* the case!).

8. (a) The 5% increase graph, although the situation may well be worse than this. The current rate of energy usage coupled with the world's population increase would suggest an even higher rate of increase in fossil fuels (see answers to (b) and (c)).

(b) 14% (the sum of 2020 values – sum of 2010 values ÷ sum of 2010 values = 515 – 445 = 70 ÷ 515 = 14%)

(c) 15% (similar calculation to (b))

(d) The rate at which fossil fuels will be used will be at least 3 times greater than the graph predicts. It suggests that the data in the graph is extremely optimistic.

(e) It suggests that unless we do something rapidly to replace fossil fuel derived energy with renewable sources, the world's energy sustainability is very limited.

(f) We need rapid development of multiple sources.

(g) It would seem to be unreliable as different data from different sources gives quite different predictions in terms of the details involved. However, it is reliable in that, like all other similar data, it does predict a dire need to start taking the need for developing renewable sources seriously.

(h) The increased number of people in the world requiring energy in all living processes, increased economic growth of people in the world resulting in greater use of energy using appliances, increased development of infrastructure in developing countries (roads, rail, power supply).

(i) As fossil fuel availability decreases their prices will increase limiting the amount people can afford; increased development of alternate sources of energy may start to impact on the use of fossil fuels.

9. (a) Yes.

(b) All predict the reduction in the availability of fossil fuels as a source of energy.

(c) The big picture prediction is reliable, the timeline details differ significantly, so only partly reliable.

(d) Answers will vary, for example: There are all sorts of possible reasons for this. Change involves huge scientific and engineering works and this costs money. While computer modelling and a proportion of the scientific world speaks against global warming, the politicians who control many of the purse strings and who need to develop legislation to direct the directions of change, are unwilling to commit their support to an expensive, vote losing path which would see little result for many years. Companies producing greenhouse gas producing devices (cars are a great example) will not change to other technologies (such as electric or solar) until they are forced to, or until the technologies become more efficient and cheaper.

10. The overall figures for renewable energy remain fairly constant as a percentage of the total use of energy. In other words, the total use of energy is increasing at a faster rate than the improvement in renewable energy sources which started from a very low base.

Set 16 The Nuclear Model of the Atom

1. The formation of atomic spectra could not be explained.
The variations in the intensities of spectral lines could not be explained.
The splitting of spectral lines into finer lines by a magnetic field could not be explained.
Radioactivity of some elements could not be explained.
Patterns of discharges in gas discharge tubes could not be explained.

2. That an atom has a small, dense nucleus surrounded by mostly empty space in which electrons are in orbit around the nucleus.

3. (a) The alpha particle (gold foil) scattering experiment.

(b) Geiger and Marsden.

(c) Its nuclei are heavy and it can be beaten into very thin sheets.

(d) The atom consisted of a small, dense central, positively charged nucleus with electrons in orbit around it at a relatively significant distance.

(e) It did not explain atomic spectra.

It did not explain the differing inrensities of spectral lines.

It did not explain the effect of a magnetic field on spectral lines (the Zeeman effect).

That if electrons orbited like planets they should radiate EMR, lose energy and spiral into the nucleus in 10^{-8} seconds thus the atom should cease to exist!!

Bohr soon pointed out that the model was only good for hydrogen and helium? and useless for all the other elements.

4. (a) V = electron orbit for gold atom.

W = nucleus of gold atom.

X = alpha particle having a close approach to a nucleus and deflected sideways.

Y = alpha particle passing through gold sheet undeflected having missed any nuclei.

Z = alpha particle on a head-on path deflected backwards by gold nucleus.

(b) Alpha particles are helium nuclei, symbol ^4_2He.

(c) Particle Y occurred much more frequently than particles X and Z. This led Rutherford to conclude that the gold atom was mostly empty space.

In conjunction with the high number of undeflected particles and the very low number of particles deflected back on their path (particles Z), Rutherford proposed that in the centre of the gold atoms was a small, dense nucleus.

Deflections like those shown by particle X led to the idea that the nucleus was positively charged because Rutherford proposed the deflection was caused by an electrostatic force of repulsion rather than a glancing collision like that of two billiard balls.

5. (a) X = continuous

Y = emission

Z = absorption

(b) Continuous: All spectral lines appear in the spectrum; our eyes do not have the resolution to see them as separate lines – the spectrum appears continuous as many elements produce many overlapping lines.

(c) Emission: In a hot gas thermal energy causes electrons to jump to an excited state. Upon return to their ground state a photon is emitted at a particular wavelength. Only a few jumps are allowable so bright lines show these. The dark areas show areas where no jumps can occur so no light is released.

(d) Absorption: Light passes into a cool gas, certain photon wavelengths are absorbed causing electrons to jump to a higher energy level. When the electron returns to its ground state the same light energy is emitted in all directions. Only a tiny portion reaches the observer thus it appears darker than the unabsorbed wavelengths.

(e) The low frequency (long wavelength) end of each is the red colour – the right-hand end, as in the diagram.

6. On models that have electrons in energy levels, it is proposed that electrons can absorb energy and rise to higher, 'excited' levels and then re-emit that energy when they fall back to their original level. This concept can account for the lines in absorption and emission spectra of all elements. It was the existence of spectra that stimulated Bohr to develop an atomic model (the first energy level model) which accounted for those spectra.

7. It was Planck who coined the term quanta to explain why different materials gave the same energy emission graph when heated to the same temperatures. He imagined quanta as specific packets of energy associated with and emitted by specific oscillations of the atoms in hot substances. This idea was used by Albert Einstein to produce his Nobel Prize winning paper explaining the photoelectric effect, and it was also part of the stimulus used by Bohr to develop his atomic model.

8. The photon model of light arises from Planck's work on black body radiation and considers light to consist of discrete packets of energy rather than a continuous stream of energy. Each photon carries energy specific to its frequency ($E = hf$), and electron transfers absorb or emit exactly the amounts of energy difference between the particular levels they transfer to and from. It is these exact energy amounts that give rise to the spectral lines, and their consistency with elements is strong evidence for the levels model of the atom.

9. Each spectrum line represents an energy value for a specific transition of the single electron. It can be excited from $n = 1$ (its ground state) to any energy level $n = 2, 3, 4$ etc and fall back to the ground state by one step or numerous steps. Each transition back represents an emission spectrum line.

10. The relatively cooler outer atmosphere of the Sun has hydrogen atoms which absorb and re-radiate energy as per Question 5 (d) above. In this way we get an absorption spectrum – hence the dark lines.

11. (a) X = absorption

Y = emission

(b) Emission spectrum shows only single bright lines which exactly correspond to the dark lines in the absorption spectrum. The rest of the emission spectrum is black. The absorption spectrum is a continuous spectrum *minus* the lines corresponding to the frequencies absorbed by the hydrogen gas.

(c) Emission spectrum shows the light given out by the excited atoms of the substance, so all electron transitions occurring at that temperature will be present. Absorption spectrum shows the spectrum of white light with some of the transition lines from the substance missing because as the light travels through the gaseous substance, these photons have been absorbed by the atoms.

12. Each element has its own unique arrangement of electrons in shells determined by the forces between the nucleus and the electrons. Thus electron energy levels and photon input/output are unique to that element.

13. (a) Emission spectrum.

(b) Emission spectra form when radiation emitted as electrons fall from higher energy levels back to lower energy levels is passed through a prism/diffraction grating and the emitted radiation lines observed.

14. (a) The discovery of the neutron.

(b) He bombarded a sheet of beryllium (Q) with alpha particles (P) to produce an unknown radiation (R). After passing it through a block of paraffin wax (S) they produced protons (T). By using conservation of momentum laws and kinematics on the protons he deduced the mass of the neutron.

(c) Neutrons would later be used as uncharged 'bullets' to fire at atomic nuclei to further study the detailed structure of atoms.

Set 17 The Strong Nuclear Force

1. 1.87×10^{-34} N
2. 230.4 N
3. $1.23 \times 10^{36} : 1$
4. 1.23×10^{36} times greater.
5. Any nucleus with more than one proton should be unstable. It should explode apart due to the electrostatic repulsion between the protons.
6. Repulsive force would be greater. If 15 protons, then each proton would repel each other proton with a force of 230.4 N. The total repulsive force would therefore be far greater than 230.4 N.
7. (a) The strong nuclear force has strongest attraction at the distance of separation of nucleons in the nucleus. At closer distances it rapidly decreases to zero, then becomes repulsive. At larger distances it decreases to zero at about 2.8×10^{-15} m.

(b) The more protons in the nucleus, the more repulsive force there would be to make it unstable. If there were no strong nuclear force a nucleus could not exist as there would be nothing to overcome repulsive forces.

(c) Attractive but reducing.

(d) Zero.

(e) Attractive down to about 0.3×10^{-15} m, then increasingly repulsive at closer distances than 0.3×10^{-15} m.

(f) Beyond 2.8×10^{-15} m.

8. (a) There must be a force to overcome the electrostatic force of repulsion between protons if nuclei are to be stable.

(b) It holds all nuclear particles together, whether charged or uncharged.
It is much stronger than electrostatic forces.
It is attractive over only a very small distance (about 10^{-15} m).
It becomes repulsive at small distances (less than the diameter of a nucleon).

9. (a) Electrostatic force between proton and neutron is zero.

(b) Electrostatic force between neutrons is zero since neutrons are not charged.

(c) Repulsive.

(d) Neutron is not charged.

Set 18 Isotopes

1. (a) Isotopes are atoms of elements which have the same number of protons (and therefore represent the same element) but different numbers of neutrons in their nuclei (and therefore have different mass numbers).

(b) The atomic mass of an element takes into account the fact that some elements have different isotopes and that not all atoms of that element will have the same mass number. Some isotopes occur more often in nature than others, so the atomic mass is the *average mass* of the atoms of an element.

(c) The mass number is the total number of protons and neutrons in a particular isotope of an element.

(d) The existence of isotopes does not affect atomic number because all the isotopes of each element will have the same number of protons in their nuclei. Isotopes are not dependent on the number of protons.

2.

Element	Number of			Mass number	Atomic number	Name	Atomic symbol
	Protons	Neutrons	Electrons				
X	3	4	3	7	3	Lithium	Li
Y	5	6	5	11	5	Boron	B
Z	7	7	7	14	7	Nitrogen	N

3.

Isotope	Number of protons in each nucleus	Number of neutrons in each nucleus	Number of electrons orbiting nucleus	Atomic number of element	Mass number of element
Chlorine-33	17	16	17	17	33
Chlorine-34	17	17	17	17	34
Chlorine-35	17	18	17	17	35
Chlorine-36	17	19	17	17	36
Chlorine-37	17	20	17	17	37
Chlorine-38	17	21	17	17	38

Set 19 Nuclear Decay

1. (a) About 15.

(b) Isotopes of each element which are stable.

(c) These are no stable nuclides with atomic numbers above 82.

2. (a) 28

(b) 37

(c) It will be unstable.

(d) It has too many neutrons compared to the number of protons.

(e) It will undergo beta decay as a neutron transmutes into a proton and a beta particle.

3. (a) 27

(b) 21

(c) It will be unstable.

(d) It does not have enough neutrons in its nucleus.

(e) It will undergo positron decay as a proton transmutes into a neutron and a positron.

4. (a) The nucleus will decay by beta emission as a neutron changes into a proton and the beta particle to try to balance the strong nuclear force against the electrostatic forces of repulsion between protons.

(b) The nucleus will decay by positron emission as a proton changes into a neutron and the positron to try to balance the strong nuclear force against the electrostatic forces of repulsion between protons.

(c) Larger nuclei have more protons and therefore higher forces of electrostatic repulsion. To balance this, more neutrons are needed to provide a larger strong nuclear force. However, because the strong nuclear force acts only over very small distances, about the size of the nucleons, more and more neutrons need to be added as more protons are added. The nucleus becomes larger in physical size and it eventually becomes unstable because while the strong nuclear force can hold adjacent nucleons together, the nucleus as a whole becomes more unstable.

(d) It is attractive only over a very small distance of separation between nucleons.

5. (a) Electrostatic forces or repulsion between protons.

(b) The strong nuclear force.

(c) By increasing the number of neutrons in the nucleus.

6. Alpha, beta, positron and gamma decay.

7. (a) Alpha: ${}^{A}_{Z}X \rightarrow {}^{Z-2}_{A-4}X + {}^{4}_{2}He$

(b) Beta: ${}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}X + {}^{0}_{-1}e + {}^{0}_{0}\overline{\nu}$

(c) Positron: ${}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}X + {}^{0}_{-1}e + {}^{0}_{0}\overline{\nu}$

8. (a) Antineutrinos always accompany beta decay.

(b) Neutrinos accompany positron decay.

(c) Gamma radiation usually accompanies alpha and beta decay, but not always. You would have to know whether or not gamma radiation was emitted because it does not affect the atomic structure, although it will not be emitted unless a nuclear transformation occurs.

9. (a) The nucleus of the atom.

(b) The breaking of bonds within the nucleus of the atom.

10. (a) Transformation, nuclear decay, radioactive decay, nuclear reaction (fission and fusion are not as good because each excludes the other).

(b) The atomic bombs produced by the Manhattan Project during World War II.

(c) A – Elements emit radioactive particles to change into other elements.

(d) Most elements have different isotopic forms. Isotopes are atoms of the same element which have different numbers of neutrons and therefore different masses. Atomic mass is a measure of the average mass of the atoms of a particular element and the isotopes result in non-integral averages.

(e) A nuclear transmutation occurs when an atomic nucleus is split into two smaller nuclei (nuclear fission) or when two nuclei are fused to form a larger nucleus (nuclear fusion). It also occurs in a radioactive decay.

11. (a) It represents the positions of nuclides with equal numbers of protons and neutrons in the nucleus.
(b) A = beta decay
B = positron decay
C = alpha decay
(c) Number of neutrons in the nucleus exceeds the number of protons, neutron/proton is >1 (up to 1.5).
(d) Number of neutrons in the nucleus exceeds the number of protons, neutron/proton is >1 (actually > 1.5).
(e) Number of neutrons in the nucleus is less than the number of protons, neutron/proton is < 1.
(f) During alpha decay, the mass number of the nuclide decreases by 4 units (2 protons and 2 neutrons) and the atomic number decreases by 2 (the same 2 protons).
(g) During beta emission, the net effect is that a neutron becomes a proton by ejecting an electron from the nucleus. The overall mass of the nuclide remains constant, since a proton and a neutron have approximately the same amount of mass. However, the number of neutrons goes down by one while the number of protons goes up by one, so the mass number remains constant but the atomic number increases by 1
(h) Positrons have the same mass as an electron, but have a +1 charge. When a positron is ejected from the nucleus, the neutron to proton ratio increases. The net effect is that a proton turns into a neutron. The mass number remains unchanged, but the atomic number decreases by 1.
(i) Alpha and beta decay occurs in nuclei where the neutron/proton ratio is greater than 1 (the line of stability number), and the decay lowers the ratio closer to 1. Stability increases.
Positron decay occurs in nuclei where the neutron/proton ratio is less than 1. The decay increases this ratio, indicating a more stable nucleus.
(j) The ratio of neutrons to protons in carbon-14 is higher than 1 to 1. This nuclide would be above the band of stability.
(k) The graph shows that there are no stable nuclides with an atomic number above 82. Uranium is thus likely to emit an alpha particle.
(l) This nuclide obviously falls on the equal neutron/proton line and will be below the line of stability. It would become more stable by undergoing positron emission.

Set 20 The Stability of Nuclides

1. The nucleus of an atom is held together by converting a little of the mass of the particles of the nucleus into a binding energy to produce the strong nuclear force. This is needed to keep positively charged protons close to each other. For light elements, if the number of protons and the number of neutrons are the same, all the forces acting in the nucleus (electrostatic repulsion and strong force attraction) are balanced and the nucleus is stable. However, if there are too many neutrons or protons, then the nucleus will be unstable and will decay until an approximate 1 : 1 neutron to proton ratio is achieved. This is observed as the emission of energy, or radiation. At higher atomic numbers, there are so many protons, more than 1 neutron per proton is needed to hold the nucleus together.

2. (a) The concept of entropy is that 'things in nature seek their lowest energy state'. In their lowest energy state, things are most stable ... less likely to change.
(b) Stable atoms have low energy states. Unstable atoms will try and become stable by getting to a lower energy state. They will typically do this by emitting some form of radioactivity and transmute in the process.

3. (a) If the distance between protons is too small then the strong nuclear force is repulsive. The neutrons help create these ideal distances. If there are too few neutrons, or too many neutrons, the nucleus becomes unstable. A proton to neutron ratio of 1 : 1 seems to indicate the highest stability. Nuclei with ratios higher or lower are less stable.
(b) Keep in mind that the stability or instability of nuclei cannot really be explained. We can only observe trends and relate stability or instability to these trends. For atoms with more than 82 protons, it is simply a fact that however many neutrons there are there are not enough to make the nucleus stable. Remember also that the bigger a nucleus becomes (increasing the number of neutrons contributes to this), the less stable it tends to be.
(c)

Number of protons	Number of neutrons	Number of stable nuclides with this combination	Stability of these nuclides
Odd	Odd	4	Least stable
Odd	Even	50	More stable
Even	Odd	57	Even more stable
Even	Even	168	Most stable

4. (a) Isotopes with certain numbers of protons or neutrons tend to be more stable then the rest. These certain numbers are known as the magic numbers.
(b) The magic numbers correspond to the filling of proposed shells in the structure of the nucleus. These shells are similar in principle but different in detail to those found in electronic structure.
(c) Note that some numbers are missing for both protons and neutrons. These have not yet been shown to be 'magic' for these nuclides.

Magic numbers of protons	2	8	20	28	50	82	114	-	-
Magic numbers of neutrons	2	8	20	28	50	82	-	126	184

(d)

Nuclei has magic number of protons	Nucleus has magic number of neutrons	Relative stability of nucleus
No	No	Least likely to be stable
Yes	No	Less likely to be stable
No	Yes	Less likely to be stable
Yes	Yes	Most likely to be stable

(e) (i) $^{101}_{51}$Sn has a magic number and $^{102}_{51}$Sn doesn't.

(ii) $^{64}_{32}$Ge because it has both an even number of protons and an even number of neutrons.

Set 21 Properties of Radioactive Particles

1. (a) Radioactivity refers to the spontaneous disintegration of unstable nuclei by emitting a small particle (e.g. an electron, proton) or gamma radiation.

(b) High speed particles are damaging to biological tissue. The spent fuel of a nuclear reactor, and any material that comes in direct contact with it, is highly radioactive for many thousands of years. That means it must be carefully disposed of and kept from the environment for a very long time.

2.

Radiation	Charge	Mass	Penetrating power	Ionising power	Path through electric field	Path through magnetic field	What is it?
Alpha	2+	4 amu	Very low	Very high	Parabolic towards negative	Circular	Helium nucleus
Beta	–1	1/1837 amu	Low	High	Parabolic towards positive	Circular	Electron
Gamma	None	None	Very high	Low	Unchanged	Unchanged	Electromagnetic radiation

3. (a) Alpha particles are helium nuclei, chemical symbol = He^{2+}, common symbol = α (perhaps $^{4}_{2}$He)

(b) Beta particles are electrons, chemical symbol e^-, common symbol = β (perhaps $^{0}_{-1}$e)

(c) Gamma radiation is high frequency electromagnetic radiation, common symbol = γ

4. (a) Gamma radiation.

(b) Alpha particles.

(c) Beta particles, being electrons, have only about one eight thousandth of the mass of an alpha particle, so their impact on a surface is much less than that of an alpha particle (assuming velocity is the same).

(d) They have no charge or mass.

5. (a) Y must be gamma radiation. Being uncharged, it is not affected by the magnetic field. X represents beta particles. The magnetic field has had most effect on the direction of their travel so presumably X is the lightest of the two particles. That would make Z the alpha particle.

(b) Using the right hand palm rule, the magnetic field is perpendicularly out of the page.

6. (a) X = alpha particle

Y = gamma ray

Z = beta particle

(b) Alphas, having more mass, will have a path with greater radius. Gammas, with no charge, will pass through undeflected.

7.

Radiation	Charge	Penetrating power	Ionising power	Path through electric field	Path through magnetic field	What is it?
X	None	Very high	Very low	Undeflected	Undeflected	Gamma
Y	Positive	Very low	Very high	Towards negative potential	Deflected indicating positive charge	Alpha
Z	Negative	Low	Low	Towards positive potential	Deflected indicating negative charge	Beta

8. (a) Ionisation occurs when electrons are removed from atoms.

(b) Ionised atoms and free electrons can destroy molecules in living tissue.

(c) Alpha radiation is more massive and higher charged than beta radiation, and therefore, for an equivalent speed, carries much more energy.

9. The ultraviolet light photons carry enough energy to eject some electrons from some zinc atoms in the sheet. Electrons from the electroscope move up into the zinc leaving less charge in the electroscope so the leaves collapse.

10. W = beta particles, X = gamma rays, Y = alpha particles, Z = neutron beam

11. (a) He was assuming that photons of the red light carried enough energy to cause ionisation of zinc atoms.

(b) The energy carried by the red light photons was insufficient to cause ionisation (the frequency of red light was too low to cause ionisation).

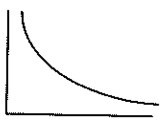
(c) Light with a higher frequency may do the job (perhaps blue light or UV). The energy carried by photons is directly proportional to its frequency (Planck's quantisation, $E = hf$).

Set 22 Writing Equations for Nuclear Decay Reactions

1. (a) Alpha: ${}^{A}_{Z}X \rightarrow {}^{Z-2}_{A-4}X + {}^{4}_{2}He$
   (b) Beta: ${}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}X + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$
   (c) Beta decay is always accompanied by the emission of antineutrinos.
   (d) Gamma radiation usually accompanies alpha and beta decay, but not always. You would have to know whether or not gamma radiation was emitted because it does not affect the atomic structure, although it will not be emitted unless a nuclear transformation occurs.
2. (a) An atom of Y will have 2 protons and 2 neutrons less than an atom of X.
   (b) Emission of an alpha particle removes two protons from the atom involved, so Y will have an atomic number 2 less than X. It will be two elements before X on the periodic table.
   (c) Lead. (d) Polonium.
3. (a) Uranium.
   (b) 7 alpha particles and 4 beta particles. Mass number decreases by 28 which indicates that 7 alpha particles have been released. This would decrease the atomic number by 14, but it has only decreased by 10, so 4 betas must have been released.
   (c) Atomic number down 1, mass number down 4. Decays involve ${}^{0}_{-1}e$ and ${}^{4}_{2}He$ which decreases the mass number by 4, and decreases the atomic number by 1.
4. (a) ${}^{9}_{4}Be + {}^{4}_{2}He \rightarrow {}^{12}_{6}C + {}^{1}n_{0}$ (b) Z is an antineutrino. (c) ${}^{222}_{85}At$
   (d) ${}^{207}_{81}Tl$ (e) Antineutrino.
5. (a) U-238 $\rightarrow$ Th-234 + alpha (b) 88 protons, 142 neutrons. (c) Radium.
6. (a) Three beta particles (and three antineutrinos). (b) 8 (c) 6
   (d) ${}^{210}_{81}Tl \rightarrow {}^{210}_{82}Pb + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$ (e) ${}^{230}_{90}Th \rightarrow {}^{226}_{88}Ra + {}^{4}_{2}He$ (f) ${}^{210}_{83}Bi \rightarrow {}^{210}_{84}Po + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$
   (g) ${}^{210}_{84}Po \rightarrow {}^{210}_{82}Pb + {}^{4}_{2}He$ (h) 4 alpha particles and 3 beta particles (i) 2 alpha particles and 2 beta particles
7. (a) ${}^{214}_{84}Po \rightarrow {}^{200}_{82}Pb + {}^{4}_{2}He$ (b) ${}^{210}_{81}Tl \rightarrow {}^{210}_{82}Pb + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$ (c) ${}^{212}_{82}Pb \rightarrow {}^{212}_{83}Bi + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$
   (d) ${}^{212}_{83}Bi \rightarrow {}^{212}_{84}Po + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$ (e) ${}^{212}_{84}Po \rightarrow {}^{208}_{82}Pb + {}^{4}_{2}He$ (f) ${}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$
   (g) ${}^{232}_{92}U \rightarrow {}^{228}_{90}Th + {}^{4}_{2}He$ (h) ${}^{24}_{11}Na \rightarrow {}^{24}_{12}Mg + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$ (i) ${}^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$
   (j) ${}^{137}_{55}Cs \rightarrow {}^{137}_{56}Ba + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$ (k) ${}^{24}_{11}Na \rightarrow {}^{24}_{12}Mg + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$ (l) ${}^{8}_{4}Be \rightarrow {}^{4}_{2}He + {}^{4}_{2}He$
   (m) ${}^{211}_{83}Bi \rightarrow {}^{207}_{81}Tl + {}^{4}_{2}He$ (n) ${}^{207}_{81}Tl \rightarrow {}^{207}_{82}Pb + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$ (o) ${}^{239}_{92}U \rightarrow {}^{239}_{93}Np + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$
   (p) ${}^{239}_{93}Np \rightarrow {}^{239}_{94}Pu + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$ (q) ${}^{235}_{90}Th \rightarrow {}^{235}_{91}Pa + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$
   ${}^{235}_{91}Pa \rightarrow {}^{235}_{92}U + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$

Set 23 The Half-life of Nuclides

1. (a) A nuclide is an atom characterised by the number of protons and neutrons in the nucleus.
   (b) Isotopes are specific nuclides which have the same proton number but a different neutron number.
   (c) They have different numbers of neutrons in the nucleus.
   (d) No
   (e) No
2. (a) They are atoms of the same element because there are the same number of protons in the nuclei (3).
   (b) Element number 3 is lithium.
3. We cannot predict this. The decay of a radioactive nucleus is a completely random event, although the rate of decay is proportional to the number of radioactive atoms in the sample.
4. The atoms within a radioactive substance are undergoing radioactive decay at a measurable rate. While the decay of a particular atom cannot be predicted, the probability that some atoms will decay within a period of time can be calculated or measured (from half-life). The more radioactive atoms there are in the sample, the higher the probability that some of them will decay sooner.
5. The fewer radioactive atoms there are in a sample, the lower the probability that any will undergo decay in a particular time simply because there are fewer of them likely to undergo decay.
6. Exponential; label the axes – y is % and x is time.



7. The radioactive half-life of a sample of radioactive material is the time it takes for half the radioactive atoms in the sample to decay.
8. (a) 6.25 counts per minute (b) 100 years (c) 6.25 counts per minute
   (d) 50 years (e) The Sr-90

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9. 120 years (40 to 20 to 10 to 5 to 2.5 = 4 half-lives = 4 × 30 = 120)

10. Six months is short compared to the half-life and so the number of plutonium nuclei does not change appreciably; activity is proportional to the number of plutonium nuclei present.

11. $\lambda = \ln 2/18 = 0.039\ d^{-1}$

Therefore, from $A = A_0e^{-\lambda t}$, $A = 4.5 \times 10^4$ Bq

12. (a) It has a long half-life so it is unlikely that the reactor would have to be refuelled during its useful life.

(b) The main two problems are the risk of radioactive contamination in the working environment and subsequent danger to the scientists involved, and the production of non-useful waste product which need to be safely stored until their radiation counts have decreased to a minimum amount.

(c) Sodium-24 has a short half-life and therefore would not be a danger to the patient for a long period if it stayed in the bloodstream (it is also not a gamma emitter). Cobalt-60 is used to kill cancers mainly because it is a gamma emitter and the gamma rays kill cancer cells (and normal cells) quickly.

(d) Irradiating foods before storage kills bacteria on and within them and so their shelf life is increased dramatically.

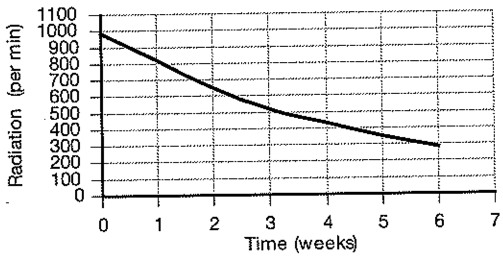
13. (a) 46

(b) The background radiation count will be recorded during the experiment as well as the count from the test material, so a correction needs to be made for the background radiation.

(c)

Week	Total radiation counts recorded (counts min^{-1})	Radiation due to X (counts min^{-1})
0	1031	985
1	848	802
2	698	652
3	566	520
4	476	430
5	395	349
6	328	282

(d)



(e) About 3.3 or 3.4 weeks – i.e. about 23 or 24 days.

(f) About 740.

(g) About 120 (you need to extrapolate your graph to nearly 11 weeks).

14. (a) X is a proton, ${}^1_1H$.

(b) No more C-14 (in carbon dioxide) is taken in when the tree dies. The amount of C-14 determines the activity of the charcoal from the tree (C-14 is radioactive), so the amount present decreases over time.

(c) From $\lambda = \ln 2/T = 1.3 \times 10^{-4}$ year^{-1}

Therefore, since $A \infty N$, then $A = A_0e^{-\lambda t}$

So $e^{-(0.000130T} = 2.1/9.6 = 0.22$

From which $t = 1.2 \times 10^4$ years

(d) 70 000 represents about 12 half-lives which reduces the radioactive count to about 0.02% of the initial count in the living organism. Given the low amount of C-14 present initially, the count will be smaller and less reliable after this time.

15. 6.25 g

16. 6.25 g

17. Number of half-lives = $(2.5 \times 10^9) \div (4.46 \times 10^9) = 0.56$

So mass remaining = $2.0 \times (0.5)^{0.56} = 1.36$ g

18. After 1 day = 5.0 g, two days = 2.5 g, 7 days = 0.078 g

19. 24.52 years $(1/2)^n = 0.25$, solve for n.

20. 1.28×10^{22} atoms

21. 4 days

22. 53.4 days

23. 3.34 s (note 10 half-lives is the time accepted for negligible amount to remain)

24. 155.6 hours

25. 15.3 days

26. 1.46×10^9 disintegrations per second

27. 5.05 g

28. 5.08×10^{21}
29. 0.0626
30. 11.47 days

Set 24 Effects of Radiation

1. (a) Rays and particles which damage cells.
   (b) Initial radiation refers to the radiation people may be exposed to at the instant of the nuclear event and while it occurs. Residual radiation refers to radiation which stays in the air and soil, even after a long period of time after the event..
2. (a) Radiation simply refers to the number of disintegrations per second in a radioactive material.
   (b) Absorbed dose (also known as total ionising dose, TID) is a measure of the energy deposited in a medium by ionising radiation per unit mass.
   (c) The equivalent absorbed radiation dose, usually shortened to equivalent dose, or formerly dose equivalent, is a computed average measure of the radiation absorbed by a fixed mass of biological tissue.
   (d) Refers to the total radiation a person has been exposed to during an incident.
3. (a)

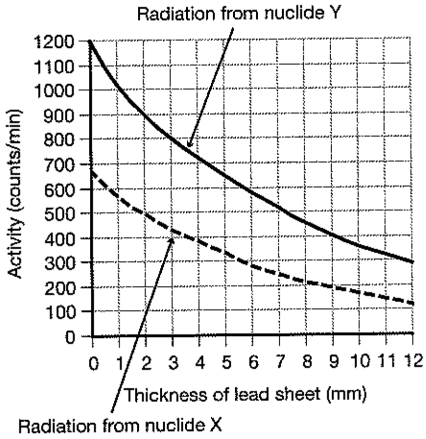
	Radioactivity	Absorbed dose	Dose equivalent	Exposure
Common unit	Curie (Ci)	Rad (rad)	Rem (rem)	Roentgen (R)
SI unit	Becquerel (Bq)	Gray (Gy)	Sievert (Sv)	Coulomb/kilogram ($C\ kg^{-1}$)

   (b) A becquerel is one radiation count per second (one disintegration per second).
   (c) One curie is 3.7×10^{10} becquerel (disintegrations per second).
   (d) 1 gray = 100 rad.
   (e) 1 sievert = 100 rem
   (f) 1 $C\ kg^{-1}$ = 3880 roentgen
4. Higher frequency photons carry more energy than lower frequency photons.
5. Absorbed dose is the total energy absorbed by matter while dose equivalent takes into account the effect this dose will have on the matter absorbing that energy.
6. Older people are less sensitive to radiation damage because their tissue does not reproduce as quickly as the tissue in young people.
7. (a) There is the same number of photons in each beam but the photons in the X-ray beam have more energy than the photons in the beam of red light.
   (b) From quantum theory ($E = hf$), and knowing that the frequency of X-rays is much higher than that of red light, the energy of the X-rays is much higher. They are therefore more penetrating and more dangerous to human tissue.
8. (a) Total dose = 1.25 mR.
   (b) 9 minutes.
9. These values indicate that the intensity (energy) of radiation coming from Co-60 is about triple the intensity of the radiation coming from the Ir-192. From a radiation safety point of view, this difference in intensity is important because the Co-60 has more material penetrating power and, therefore, is more dangerous and requires more shielding.
10. (a) 160 mSv.
    (b) About 24 mSv.
    (c) Gamma radiation from space and radioactive decay of elements in the crust.
11. (a) Type of radiation involved. The main difference in the ability of alpha and beta particles and gamma and X-rays to cause health effects is the amount of energy they have. Their energy determines how far they can penetrate into tissue and how much energy they are able to transmit directly or indirectly to tissues. The higher the frequency of the radiation, the more damage they can do.
    (b) Size of dose received. The higher the dose of radiation received, the higher the likelihood of health effects.
    (c) Rate at which the dose is received. Tissue can receive larger dosages over a period of time. If the dosage occurs over a number of days or weeks, the results are often not as serious if a similar dose was received in a matter of minutes.
    (d) Part of the body exposed. Extremities such as the hands or feet are able to receive a greater amount of radiation with less resulting damage than blood forming organs housed in the torso.
    (e) The age of the individual. As a person ages, cell division slows and the body is less sensitive to the effects of ionising radiation. Once cell division has slowed, the effects of radiation are somewhat less damaging than when cells were rapidly dividing.
12. Ionisation of living tissue causes molecules in the cells to be broken apart. This interaction can kill the cell or cause them to reproduce abnormally.

    Cell damage due to direct action occurs when the radiation affects a cell's essential molecules (DNA). The radiation energy may damage cell components such as the cell walls or the deoxyribonucleic acid (DNA). When radiation interacts with a cell wall or DNA, the cell either dies or becomes a different kind of cell, possibly even a cancerous one.

    Cell damage due to indirect action occurs when radiation interacts with the water molecules in cells. The energy absorbed by the water molecule can result in the formation of free radicals. These free radicals may form compounds, such as hydrogen peroxide, which may initiate harmful chemical reactions within the cells. As a result of these chemical changes, cells may undergo a variety of structural changes which lead to altered function or cell death.

13. (a) See graph.



(b) HVL X = about 5 mm

HVL Y = about 6 mm

(c) The radiation from Y penetrates more into the lead sheeting, so its intensity is greater than that from X.

14. (a) The child, having the lower mass, has the higher absorbed dose. Absorbed dose is measured in J kg^{-1} (or grays).

(b) The child, having the lower mass, also receives the higher dose equivalent = absorbed dose × quality factor. Since they both receive doses of gamma radiation, the quality factor is 1 for each of them.

(c) Again, the child has the higher absorbed dose since this is a measure of energy per kg (= 260/20 = 13 Gy, compared to the adult = 120/100 = 1.2 Gy).

(d) The dose equivalent for the child is 13 × 1 = 13 Sv and that for the adult is 1.2 × 20 = 24 Sv, so the adult has the higher dose equivalent.

15. (a) Neutrons (especially those with energies ranging from 100 keV to 2 meV, and alpha particles).

(b) There is an optimum energy range for which neutrons can collide with tissue molecules and transfer large amounts of their energy to those molecules. If they have relatively smaller amounts of energy or large amounts of energy they will collide with tissue molecules without transferring as much energy.

(c) Gamma rays and electrons have virtually no mass and mass is an important factor in the ionising capability of a radiation. The other radiations (protons and neutrons) have about 2000 times the mass of an electron (beta particle).

(d) 2.0 Sv

(e) 2.0 Gy

(f) 5.0 mSv

(g) 9.5 mSv

16. The danger is a slight increase in the risk of cancer. But, from a health standpoint, dental X-rays have a much bigger benefit than risk. Note that the dentist will not stay in the same room as you. His/her leaving and the lead apron that you may be asked to wear are measures to reduce all of the doses so that they are as low as reasonably achievable.

17. Mobile phones radiate and receive electromagnetic radiation in the band of 800 to 900 MHz. This is non-ionising radiation, but thought by some to have adverse health effects. The most recent research information currently does not show a link to cancer from the use of mobile phones.

18. (a) Inhalation (breathing it in if it is in gaseous form or particles of radioactive dust).

Ingestion (through the mouth, or administered as a drug by injection).

Absorption (through the skin).

(b) The source of the radiation is outside the body, for example, background radiation, fallout from nuclear events, cosmic gamma rays, X-rays.

19. (a) There is negligible danger from radiation from viewing a TV. The dose to a person from watching TV for a year is less than 1 mrem. 1 mrem is about 1/10 of the dose from a chest X-ray, or about the same amount you get in 1 day from natural radiation.

(b) TVs work by accelerating electrons using a high voltage source, and aiming them at the screen. The phosphors on the screen emit light when struck by the high speed electrons. One by-product of the electron interactions are X-rays.

(c) About 6% of the first colour TVs were measured to emit radiation above the recommended standard of 0.5 mrem/hr. The more modern (now out of date) colour tube TVs used new screens and lower voltage, and so the amount of radiation (given off as X-rays) was not detectable above background radiation unless very sensitive X-ray counting equipment was used.

20. (a) Radiation therapy uses high-energy radiation such as X-rays or gamma radiation to shrink tumours and kill cancer cells.

(b) Radiation therapy kills cancer cells by damaging their DNA. Radiation therapy can either damage DNA directly or create charged particles within the cells that can in turn damage the DNA.

(c) No, radiation therapy can also damage normal cells, leading to side effects.

(d) External-beam radiation does not make a patient radioactive. Implanted material will be radioactive for several days, weeks, or months after the radiation source is put in place. During this time, the patient is radioactive. However, the amount of radiation reaching the surface of the skin is usually very low. Some types of internal radiation therapy may temporarily make a patient's bodily fluids (such as saliva, urine, sweat, or stool) emit a low level of radiation.

21. (a) Food is irradiated to destroy insects, fungi or bacteria that cause food to spoil or cause human disease and to make it possible to keep food longer and in better condition in warehouses, shops and homes.

(b) No. The irradiation process involves passing food through an irradiation field; however, the food itself never contacts a radioactive substance. Also, the ionising radiation used by irradiators is not strong enough to disintegrate the nucleus of even one atom of a food molecule.

(c) No. This has been verified by hundreds of government and other scientific studies.

(d) Any kind of treatment causes chemical changes in food (like cooking), but only a chemist with extremely sensitive lab equipment may be able to detect changes caused by irradiating it. There is no scientific reason for believing irradiated food is dangerous.

Set 25 Nuclear Reactions

1. When a heavy nucleus of elements like uranium or plutonium is split or when the lighter elements such as hydrogen or deuterium is used to form a heavy element, the total mass of products is less than that of participating atoms. This difference in mass, the mass defect, is converted into energy according to Einstein's equation $E = mc^2$.

2. (a) Fission reactions occur when a single large nucleus splits into two pieces. Fusion reactions occur when two small nuclei join together into a single larger nucleus.
   (b) Fission releases energy only if the original nucleus is heavier than iron. Fusion releases energy only if the product is lighter than iron.

3. (a) Much less energy is involved in chemical processes than in nuclear reactions.
   (b) The bonding energy between atoms in the compounds involved.
   (c) The binding energy between nucleons in the nuclei of atoms.
   (d) It requires very much more energy to break open a nucleus than to break a chemical bond.

4. (a) Mass defect refers to the difference in the mass of the products compared to the mass of the reactants in a nuclear reaction.
   (b) It is the conversion of the mass that represents the mass defect, into energy that provides the energy produced in the nuclear reaction.
   (c) Same as in a nuclear process, except that in a chemical reaction, the mass defect is negligible because the energy difference in the chemical bonds involved is very small by comparison.
   (d) Much much less in chemical processes and by the law of conservation of mass we essentially ignore mass defect in chemical reactions.
   (e) The energy involved in chemical processes is much much less than in nuclear processes.
   (f) Binding energy.

5. (a) Mass has an energy equivalent and energy has a mass equivalent.
   (b) $E = mc^2$.
   (c) The larger the nucleus, the larger the mass defect when it decays because more energy is needed to bind the nucleons together.

6. (a) False.
   (b) The mass of the nucleus is less than the mass of the proton plus the mass of the neutron.
   (c) The binding energy does not contribute to the mass of a nucleus – this is in fact why there is a mass defect – some mass has been converted into the energy which holds the atom together. So the mass of the nucleus is less than the sum of the masses of the proton and the neutron.

7. The first statement is the correct one. The other is incorrect because the total masses must take into account any radioactive particles or neutrons emitted (or absorbed) as well as the masses of the atoms of the elements involved.

8. $2.5 \times 9 \times 10^{16}$ J $= 2.25 \times 10^{17}$ J

9. From $E = mc^2$ if the mass of fuel used is the same, then the same amount of energy would be produced. (Note that nuclear energy is not produced by direct conversion of total mass, but by conversion of mass defect – see Set 17 Question 5 for more details.)

10. (a) Binding energy is the energy changed from mass when a nucleus is formed from its constituent nucleons. Binding energy can also be defined as the energy required to split a nucleus into its component nucleons.
    (b) The mass deficit represents the mass converted to energy when nucleons bond to form nuclides. It is the difference in the total mass of the nucleons of the reacting nuclei and the total mass of the nucleons in the product nuclei.
    (c) The energy resulting from the mass deficit is the energy binding the nucleons together and is calculated from Einstein's mass energy equation, where $E = \Delta mc^2$. If we wanted to break up a nucleus, this is the amount of energy which would be needed to do that.
    (d) The binding energy per nucleon for a nucleus is simply the binding energy of that nucleus divided by the total number of nucleons (protons + neutrons).
    (e) Binding energy per nucleon gives us an immediate indication of the stability of the nucleus. The higher the binding energy per nucleon, the more stable the nucleus is. The total binding energy of a nucleus might be small or large, but without knowing the number of nucleons in each nucleus, that information is not as useful.
    (f) The higher the binding energy per nucleon, the more energy needed to 'take apart' that nucleus. Therefore nucleus X is more stable than nucleus Y.

11. (a) The $^{56}_{26}$Fe has the greater total binding energy. From the graph we can see that the binding energy per nucleon for the iron nucleus is greater than the binding energy per nucleon for lithium, and iron has 56 nucleons to lithium's 7, so its total binding energy is much greater.
    (b) The $^{56}_{26}$Fe has the greater binding energy per nucleon. The $^{56}_{26}$Fe is higher up on the graph line.
    (c) This suggests that the $^{56}_{26}$Fe is more stable as each nucleon is held to the other nucleons by stronger forces.

12. 1784 MeV

13. It is difficult to get an accurate reading off the graph. Estimate 1 s about 2.9 MeV per nucleon, so then multiply by 3 to get 8.7 MeV.

14. (a) Elements with mass numbers less than 56 have a lower binding energy per nucleon than heavier elements. Their fusion therefore produces nuclei which would be more stable than them, while their fission would produce less stable nuclei. Their tendency would be to move towards higher stability than lower stability.
    (b) Elements with mass numbers greater than 56 have a higher binding energy per nucleon than elements more massive than them. Fission of these nuclei would therefore produce nuclei which would be more stable than them, while fusion would produce less stable nuclei. Their tendency would be to move towards higher stability than lower stability.

Set 26 Mass Defect and Nuclear Energy

1\. (a) The mass of the products from a nuclear fission process (and most fusion reactions) is always less than that of the reactants. The difference is called the mass defect.

(b) The energy released results from the conversion of the strong nuclear force which appears as mass in an intact nucleus, into energy as some of the nucleons are separated from others.

(c) Given that the mass defect is the result of converting the strong nuclear force into energy, it can also be correctly referred to as the binding energy of the nucleus.

2\.

(a)	297.72 MeV	4.76×10^{-11} J	(b)	8.56 MeV	1.37×10^{-12} J
(c)	−1.25 MeV	-2×10^{-13} J	(d)	17.41 MeV	2.79×10^{-12} J
(e)	25.93 MeV	4.15×10^{-12} J	(f)	268.71 MeV	4.3×10^{-11} J
(g)	194.58 MeV	3.1×10^{-11} J	(h)	3.27 MeV	5.2×10^{-13} J
(i)	6.05 MeV	9.68×10^{-13} J	(j)	9.53 MeV	1.52×10^{-12} J
(k)	9.06 MeV	1.45×10^{-12} J	(l)	−5.02 MeV	-8.03×10^{-13} J
(m)	−8.9 MeV	-1.42×10^{-12} J			

(n) The negative answer indicates an increase in mass, that is, the reaction requires an input in energy. These reactions will not occur spontaneously

3\. (a) Mass defect = (3 × 1.007825) + (4 × 1.0087) − 7.0160 = 0.042275 u.

(b) Energy in MeV = mass defect in amu × 931.5 = 0.002388 × 931.5 = 2.224 MeV.

(c) Energy in J = mass in kg × c^2 = 0.001 × 9 × 10^{16} = 9 × 10^{13} J.

(d) Mass defect in u = energy in MeV ÷ 931.5 = 2.50 ÷ 931.5 = 0.0026838 u.

(e) From $E = mc^2$, $6.3 \times 10^{-14} = m \times 9 \times 10^{16}$, so $m = 7.0 \times 10^{-31}$ kg ÷ $1.661 \times 10^{-27} = 4.214 \times 10^{-4}$ *u*.

4\.

(a)	2.53×10^{-3} amu	(b)	3.82×10^{-3} amu
(c)	1.02×10^{-2} amu	(d)	1.08×10^{-2} amu
(e)	1.46×10^{-2} amu	(f)	2.47×10^{-3} amu
(g)	5.17×10^{-3} amu	(h)	5.25×10^{-3} amu
(i)	6.96×10^{-3} amu	(j)	1.00×10^{-2} amu

Set 27 Spontaneous and Artificial Transformations

1\. (a) Spontaneous transformations occur naturally. Artificial transformation occur only with human intervention, such as the bombardment of a nucleus with high speed neutrons to cause a nuclear reaction.

(b) Background radiation.

2\. (a) ${}^{14}_{7}N + {}^{4}_{2}He \quad {}^{17}_{8}O + {}^{1}_{1}H$

(b) There was no oxygen in the reaction container at the start, but there was at the end.

3\. Aluminium is bombarded with alpha particles to produce phosphorus and release neutrons.

4\. (a) P = ${}^{1}_{0}n$

(b) Q = ${}^{1}_{0}n$

(c) R = ${}^{14}_{7}N$

(d) S = ${}^{2}_{1}H$

(e) T = ${}^{206}_{82}Pb$

5\. (a) Atoms with equal numbers of protons and neutrons in their nuclei tend to be more stable.

(b) Nuclei which have an excess number of protons over neutrons, or neutrons over protons tend to be less stable and more likely to undergo spontaneous transformation.

(c) The more protons there are in a nucleus, the greater the forces of electrostatic repulsion. To balance this more neutrons are needed to provide a larger strong nuclear force. However, because the strong nuclear force acts only over very small distances, the nucleus will get larger and larger as more protons and neutrons are added. It will eventually become unstable because while the strong nuclear force can hold adjacent nucleons together, the nucleus as a whole becomes more unstable.

6\. (a) Given that stability of nuclei decreases as the numbers of protons and neutrons increase, this stability is not able to be explained in terms of a stronger nuclear force.

(b) These are only ideas, but it is thought that there are ‘magic numbers’ of protons and neutrons which mean the nuclide is stable, much like the total number of electrons in the inert gases could be called ‘magic numbers’ of electrons. It is also thought that protons and neutrons may be arranged in energy shells within the nucleus and this structure can provide for the unexpected stability of the higher mass nuclides.

(c) Logically, the forces involved in disintegration must only be marginally larger than the forces holding the nuclei together. The large nuclei concept however would suggest fast decay. Currently this remains unexplained, but more research on magic numbers and energy levels within nuclei may provide theories in the future.

7. (a) Nuclear fission and nuclear fusion.

(b) In nuclear fission, larger nuclei are bombarded with high speed particles and are split into two daughter particles. In nuclear fusion, two smaller nuclei are forced together to form a larger nucleus.

(c) Nuclear fission releases radioactive particles, nuclear fusion does not.

8. (a)

Element	Symbol	Type of decay	Atomic number	Transmutation equation
Uranium	^{238}U	Alpha	92	$^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He$
Thorium	^{234}Th	Beta	90	$^{234}_{90}Th \rightarrow ^{234}_{91}Pa + ^{0}_{-1}e$
Protactinium	^{234}Pa	Beta	91	$^{234}_{91}Pa \rightarrow ^{234}_{92}U + ^{0}_{-1}e$
Uranium	^{234}U	Alpha	92	$^{234}_{92}U \rightarrow ^{230}_{90}Th + ^{4}_{2}He$
Thorium	^{230}Th	Alpha	90	$^{230}_{90}Th \rightarrow ^{226}_{88}Ra + ^{4}_{2}He$
Radium	^{226}Ra	Alpha	88	$^{226}_{88}Ra \rightarrow ^{222}_{86}Rn + ^{4}_{2}He$
Radon	^{222}Rn	Alpha	86	$^{222}_{86}Rn \rightarrow ^{218}_{84}Po + ^{4}_{2}He$
Polonium	^{218}Po	Alpha	84	$^{218}_{84}Po \rightarrow ^{214}_{82}Pb + ^{4}_{2}He$
Lead	^{214}Pb	Beta	82	$^{214}_{82}Pb \rightarrow ^{214}_{83}Bi + ^{0}_{-1}e$
Bismuth	^{214}Bi	Alpha	83	$^{214}_{83}Bi \rightarrow ^{210}_{81}Tl + ^{4}_{2}He$
Thallium	^{210}Tl	Beta	81	$^{210}_{81}Tl \rightarrow ^{210}_{82}Pb + ^{0}_{-1}e$
Lead	^{210}Pb	Beta	82	$^{210}_{82}Pb \rightarrow ^{210}_{83}Bi + ^{0}_{-1}e$
Bismuth	^{210}Bi	Beta	83	$^{210}_{83}Bi \rightarrow ^{210}_{84}Po + ^{0}_{-1}e$
Polonium	^{210}Po	Alpha	84	$^{210}_{84}Po \rightarrow ^{216}_{82}Pb + ^{4}_{2}He$
Lead	^{206}Pb		82	Lead is the stable nuclide at the end of the sequence

Set 28 Neutron Induced Fission

1. (a) Research into radioactivity started in the late 1890s with Becquerel in 1896 but neutrons were not discovered until 1932.

(b) Positively charged particles are pushed away by the positively charged atomic nuclei, since like charges repel each other, so it takes a lot of energy to get these particles to overcome the repulsion and strike the nuclei, and so nuclear reactions were difficult to initiate.

(c) Enrico Fermi.

(d) Since they had no charge, but did have significant mass, they were not repelled by nuclei, and were able to enter them easily.

(e) Having no charge they could not be accelerated, so their speed had to be produced from whatever nuclear transformation produced the neutrons themselves. Fortunately, relatively slow moving neutrons can induce fission.

2. (a) When the nitrogen-14 is hit with an alpha particle of sufficient energy, the alpha particle is absorbed into the nitrogen nucleus while one proton from the nitrogen is knocked out of the nucleus.

(b) They were unable to accelerate particles to high enough speeds so that they had sufficient energy to induce the reactions.

(c) Reactions observed before this were induced by particles produced by spontaneous nuclear decay reactions. This was the first to artificially accelerate the bullet particle to higher energy levels.

3. (a) The light water or paraffin atoms absorbed some of the neutron's energy without absorbing the neutrons themselves. The neutrons were therefore slowed down to move at about the normal speed of molecules at room temperature. These slower neutrons stayed in the vicinity of the target nucleus a longer fraction of a second and were more likely to be absorbed than fast neutrons were.

(b) Thermal neutrons.

4. (a) If oxygen-16 gained a neutron it would become oxygen-17.

(b) The O-18 would become radioactive oxygen-19 (X). That isotope would emit a beta particle and become stable fluorine-19 (Y).

(c) In 1934, Fermi wondered that if he bombarded heavy elements, like uranium with neutrons whether he could produce atoms more massive than uranium. None existed at this stage of discovery.

(d) The elements heavier than uranium were discovered, and it was discovered that the fission of uranium resulted in two highly radioactive daughter products about half the size of uranium. The nuclear fission of uranium had been discovered. (In this period of time scientists in Europe, concerned about research in Germany towards the release of energy from atoms convinced Einstein to write his famous letter to president Roosevelt and from this developed the Manhattan Project and the first atomic bombs in 1945.)

(e) The possibility was that of a nuclear chain reaction resulting in the release of horrendous amounts of energy.

(f) The Manhattan Project was initiated to develop the world's first atomic bombs.

Set 29 Controlled and Uncontrolled Chain Reactions

1. (a) A chain reaction is a nuclear fission reaction which, once initiated, produces sufficient energy and collision particles (for example, neutrons) so that the reaction can proceed without further input of energy.

(b) Neutrons.

2. (a) A controlled nuclear reaction is one in which the amount of energy produced is limited and can be contained without an explosion.
(b) In a reactor, excess neutrons are absorbed by control rods rather than initiating additional fission reactions. The more are absorbed, the less fission occurs and the less energy results.
(c) By removing some of the control rods from the reactor until the required increase in energy output is reached.
(d) Each fission produces only one neutron with sufficient energy to initiate another fission, or any additional neutrons are absorbed by control rods so that the controlled reaction results.

3. (a) In an uncontrolled nuclear reaction, energy is rapidly produced in ever increasing amounts leading to an explosion.
(b) By limiting the amount of fuel and making sure that the control rods are inserted into the reactor an appropriate distance.
(c) In atomic bombs and the occasional nuclear reactor meltdowns that have occurred.
(d) Each fission must produce more than one neutron with the energy needed to initiate other fissions. One neutron per fission will sustain a nuclear reaction at its current level. More than one will increase the rate at which fission occurs – this is the minimum requirement for an uncontrolled nuclear reaction.
(e) Depends where the reaction occurs – in a nuclear reactor, the reactor would eventually melt down and/or explode (e.g. Chernobyl) or, in the case of limited amounts of fissile material (fuel) in a confined space, an explosion (atomic bomb) can result.

4. (a) Not all neutrons have the energy required to initiate another fission – some have too much, some have too little. Fermi's experiment showed that if 2.5 neutrons are produced per fission (on average), then one only will have the required energy.
(b) C More neutrons per fission are produced in this reaction than in the others, so it is more likely that further fissions will occur.
(c) It will slow down and eventually stop. A minimum of one neutron with appropriate energy is required to keep a reaction going at the same level, so if the average is less than one neutron per fission, the reaction will slow down and eventually stop.

5. (a) X represents an uncontrolled reaction and Y a controlled reaction.
(b) Daughter products of the fission reaction.
(c) Most likely to be neutrons.

6. (a) The reaction would not sustain itself and would die out.
(b) A steady, controlled nuclear reaction would result.
(c) If the excess neutrons were not absorbed, an uncontrolled nuclear reaction would result.

7. (a) Reaction C as it produces the most neutrons per transmutation.
(b) The energy of the neutrons produced.
(c) A = 268.71 MeV
B = 365.79 MeV
C = 192.58 MeV
(d) Reaction B.
(e) 9.366×10^{26} MeV = 1.5×10^{14} J

8. (a) Uncontrolled.
(b) Fission.
(c) The krypton and barium nuclides.
(d) They are usually highly radioactive.
(e) It has no solution at the moment. The nuclear waste problem is a growing problem, with all storage methods having strengths and weaknesses.
(f) The radioactivity of many daughter products has half-lives in the thousands of years so they will be radioactive for a very long time, and more and more are being produced as nuclear generators continue to be built by more and more countries.
(g) No symbols for energy release are shown, but neither are the neutrons which are emitted in each fission, and which have insufficient energy to cause an additional fission.

Set 30 Nuclear Fission Reactions

1. (a) ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3({}^{1}_{0}n)$
(b) 0.28847 amu
(c) 268.71 MeV

2. The mass defect between products and reactant nuclei.

3. (a) neutrons
(b) fission, smaller or less
(c) energy
(d) binding, energy
(e) higher, lower
(f) mass, energy
(g) gamma
(h) nuclear, reactor, coolant

4. (a) 0.0316 u
(b) 29.43 MeV
(c) 7.36 MeV (4 nucleons in the nucleus)

5. 2.03×10^{19}

Set 31 Nuclear Fusion

1. The mass defect between products and reactant nuclei.

2. (a) small, larger (b) per, nucleon, total (c) split
(d) high, stable, lower (e) higher (f) stable

3. (a) The proton-proton chain converts 4 hydrogen nuclei into a helium nucleus and releases a lot of energy. It does this in a series of steps using only hydrogen nuclei and products produced in the reactions.

(b) The size of the product nucleus increases by one additional nucleon.

(c) Fusion requires two nuclei to approach each other with enough energy that one can break open and merge with the other. The natural electric repulsion between nuclei prevents this from happening under normal conditions of temperature and pressure.

(d) The nuclear repulsion can be overcome by the very high speeds which occur at temperatures in excess of ten million degrees e.g. the Sun's core is 14 million degrees Celsius.

4. (a) Two protons and two neutrons.

(b) Step Z.

(c) O

(d) Step 1: ${}^{1}_{1}H + {}^{1}_{1}H \rightarrow {}^{2}_{1}H + {}^{0}_{+1}e$

Step 2: (W) ${}^{2}_{1}H + {}^{1}_{1}H \rightarrow {}^{3}_{2}He$

Step 3: (X) ${}^{3}_{2}He + {}^{4}_{2}He \rightarrow {}^{7}_{4}Be$

Step 4: (Y) ${}^{7}Be_{4} + {}^{0}_{-1}e \rightarrow {}^{7}_{3}Li$

Step 5: (Z) ${}^{7}_{3}Li + {}^{1}_{1}H \rightarrow {}^{4}_{2}He + {}^{4}_{2}He$

(e) Reaction 1: 0.0014941 u

Reaction 2: 0.0059000 u

Reaction 3: 0.0017000 u

Reaction 4: 0.0009849 u

Reaction 5: 0.018616 u

(f) Total mass defect for the 5 reactions is 0.028695 u

(g) Total mass defect is equivalent to 26.73 MeV

Set 32 Comparing Fusion and Fission

1. (a) Nuclear fission occurs when a large nucleus undergoes radioactive decay to form two (or more) smaller nuclei. Nuclear fusion involves the fusion or merging together of two smaller nuclei to form a larger nucleus. Both processes result in the release of large amounts of energy and fission also produces radioactive products and radiation.

(b)

Source of nuclear energy	Advantages	Disadvantages
Nuclear fission	Able to be done on Earth. Provides huge amount of energy.	Produces radioactive particles. Produces radioactive daughter products. Waste disposal is a problem. Accidents could have disastrous consequences.
Nuclear fusion	Provides enormous amounts of energy. No radioactive products.	Plasma is difficult to keep stable for a long enough time. Unable to sustain and contain the reaction mixture at the temperatures required for it to proceed.

2. Fusion produces energy in stars because light nuclei are the most common on stars, and it is the lighter elements that undergo fusion reactions. The high temperatures required to overcome the electric repulsion between nuclei is a natural by-product of the gravitational collapse that formed the star. Fission is used to produce energy on Earth because the reactions are easier to start, control and sustain. We cannot currently maintain the temperatures required for fusion.

3. Nuclear fission occurs in many isotopes because the neutron number is so high that the nucleus is naturally unstable. In artificial fission reactions, nuclei absorb bombarding neutrons and become unstable as the additional neutrons upset the balance of forces in it. In nuclear fusion, a lot of energy is needed to overcome the electrostatic force between protons so that the two nuclei can fuse and the combined nucleons can all come under the influence of the strong nuclear force.

4. (a) A and D.

(b) Energy will be released in a nuclear transformation if the binding energy per nucleon increases. In other words, there will be a mass defect in the reaction. If the binding energy decreases, then, theoretically, the reaction would be endothermic.

5. (a) The fission reaction. The figures show a mass defect of 0.02 u for the fusion reaction and 0.2 u for the fission reaction.

(b) The fusion process. In this example 1 kg of fuel produces nearly 3.5 times the energy of the fission process.

(c) The mass defect figures represent the mass defect *per* nucleus. Given the relative masses of the nuclei involved, there are many more nuclei per kg in 1 kg of the fusion fuel than in the fission fuel (just over 47 times as many) so the mass defect per nucleus is far outweighed by the number of nuclei involved.

6. (a) The ratio is 1 : 14.2.

(b) For hydrogen fusion in the Sun, 4 amu gives 27 MeV.
Therefore 1000 g will give $(27 \times 1000) \div (4 \times 1.66 \times 10^{-27} = 4.06 \times 10^{30}$ MeV
And 1000 g of uranium will give $(200 \times 1000) \div (235 \times 1.66 \times 10^{-27} = 5.13 \times 10^{29}$ MeV
So, energy from H : energy from U = $4.06 \times 10^{30} : 5.13 \times 10^{29} = 7.9 : 1$

(c) Answers will vary, for example: The apparently small amount of energy released by the Sun compared to the nuclear reactor does not take into account the relative masses of the hydrogen and uranium atoms. The energy released per unit mass shows that the fusion reaction in the Sun is much more energetic that the fission reaction in the reactor.

7. (a) X shows the fusion of nuclear components to form a nucleus.
Y shows the fission of a nucleus to form its component nucleons.

(b) Binding energy.

(c) Binding energy.

(d) Nuclei are tightly bound together by the strong nuclear force and each nucleus has a characteristic binding energy. This is the amount of energy it would take to completely break up a nucleus and separate all the neutrons and protons in it.

(e) The release of nuclear energy derives from the differences in binding energy between the initial nucleus (or nuclei) and relative to the end products of the nuclear reaction, such as fission or fusion. Therefore when a nucleus undergoes a nuclear reaction, if the binding energy per nucleon of the products is higher than the binding energy per nucleon of the reactants nuclei, their total nucleonic mass is lower. The net result is that some of the mass is converted into energy.

(f) Since all spontaneous nuclear reactions move towards a more stable state for the nuclides involved, then both fission and fusion reactions will release energy.

8. (a) Nuclear fission will occur spontaneously only if the binding energy per nucleon of the products is higher than the binding energy per nucleon of the original nucleus. In other words, the product nuclei of the process are more stable than the original nucleus.

(b) Nuclear fusion will occur if the binding energy per nucleon in the product is higher than the binding energies per nucleon in the reactants. Again, the product nucleus is more stable than the reactant nuclei.

Set 33 Radioisotopes and Radiometric Dating

1. (a) Radiometric dating is a technique based on a comparison between the observed abundance of a naturally occurring radioactive isotope and its decay products, using known decay rates. More simply it is a technique used to give an absolute age to a specimen. It does this by comparing the amounts of parent and daughter products and using decay rates to obtain the age.

(b) Radiometric dating is used to date materials like rocks, fossil remains, ancient artefacts, and historical records.

(c) Ernest Rutherford in 1905.

(d) He attempted to measure the age of the Earth.

2. (a) It relies on the fact that radioisotopes decay at a known rate according to their particular half-lives, and that their concentration in an organism or artefact was known when it was made. The amount remaining in the organism or artefact can be used to calculate the age of the object using an appropriate equation connecting this with the half-life of the radioisotope being measured.

(b) The age of the artefact will determine which radioisotope is appropriate to use. Older objects will require the use of radioisotopes with longer half-lives.

(c) 10 to 11 half-lives.

(d) Beyond this time the concentration of the radioisotope remaining is becoming too small to measure accurately.

(e) Suppose the initial count of a radioisotope is 100. Over a sequence of 11 half-lives, this drops to:
100 – 50 – 25 – 12.5 – 6.25 – 3.125 – 1.56 – 0.78 – 0.39 – 0.195 – 0.98 – 0.049

3. (a) Carbon-14 is continually being formed through collisions of neutrons generated by cosmic rays with nitrogen in the upper atmosphere and remains at a near-constant level on Earth. The carbon-14 ends up as a small component in atmospheric carbon dioxide (CO_2). All organisms take in carbon during their lifetimes, plants through photosynthesis, and animals by eating plant and other animal tissue and through breathing. When an organism dies, it ceases to take in new carbon-14, and the existing isotope decays with a characteristic half-life (5730 years). The proportion of carbon-14 left when the remains of the organism are examined provides an indication of the time elapsed since its death.

(b) Non-living objects do not take in carbon from the atmosphere.

(c) While the formation of atmospheric C-14 is almost constant, events such as the eruption of volcanoes can give off large amounts of carbon dioxide which does not contain C-14. This lowers the average C-14 concentration in living organisms in that area or at that time in history. Significant events in the past can lead to reduced local concentrations of carbon-14 and inaccurate dating.

(d) The releases of carbon dioxide into the atmosphere since the growth of industrialisation also lowers the proportion of carbon-14 by a few per cent. Conversely, the amount of carbon-14 in the biosphere was increased by the atmospheric atomic bomb tests that were conducted into the early 1960s. These effects must be considered and correction factors built into any radiocarbon dating scale.

4. (a) In radiometric dating methods for rocks, we assume that the radioactive isotopes in them were formed when the material of the Earth was part of a shell burning red giant or part of the gas cloud formed by a nova explosion. It is in these types of situations that elements heavier than iron were formed. So, we assume that the heavy parent isotopes were produced in the supernovas that resulted in the formation of the Solar System shortly thereafter. We use the same principle to date the rock as explained in the answer to Question 1 (a).

(b) (i) 4.5 billion years.

(ii) Each measurement will have its own error. Having two measures reduces the error associated with each one, provided of course that they both give approximately the same reading.

Set 34 The Manhattan Project

1. A
2. B
3. C
4. D
5. A critical mass of fissile material.
6. As a moderator and radiation shield.
7. Control rods absorb neutrons and so take them out of the chain – in this way the reaction can be controlled.
8. By inserting his cadmium control rods fully.
9. The control rod atoms absorb neutrons and so take them out of the fission chain.
10. The need to develop an atomic bomb before Germany. It was eventually dropped on Japan, as the war in Europe had ended before the bomb was developed. This forced Japan's surrender and brought a stop to World War II.
11. Your answer should look at the for and against side of this argument. For example, the war in Europe was already over and Japan was on the point of ending hostilities, so the bombs were unnecessary and did not warrant the cost in human life. Proponents maintain the cost in life in continued conventional warfare with Japan would have been just as great. Many believe the bombs were a political statement to Russia and that only the threat of nuclear war kept the peace over the next twenty years.
12. Hiroshima's bomb was an enriched uranium bomb, Nagasaki's used plutonium. The uranium bomb was triggered by fusing two subcritical masses with a chemical explosive. The plutonium bomb had compressive explosives that increased the density of a subcritical amount of plutonium, thereby making it critical.
13. It was initially present as two separate subcritical masses.
14. The destructive potential of atomic bombs had been grossly underestimated by the theoretical scientists – once tested, many of the scientists working on them campaigned to have the work stopped. Once used, their effects appalled most people. Einstein obviously felt guilty at being significantly responsible for their development.
15. (a) The writer is simply saying that the previous 40 years of seemingly harmless research into the structure of matter in an attempt to explain chemical behaviour and emerging physics led to the atomic age with all the dangers and devastation of atomic warfare – a totally unexpected outcome.

    (b) Your answer should include cathode rays; discovery of the electron; black body radiation; the idea of quanta; Thomson, Rutherford and Bohr models of the atom; discovery of the proton, neutron; accidental discovery of radioactivity, the work of Becquerel and Rutherford and eventual discovery of nuclear fission – in fact, just about anything you have studied in this topic.
16. (a) During the 1940s – only the scientific community really knew what was going on until 1945 and they were excited and concerned about this new field of study with enormous energy potential, but at the same time, enormous destructive potential. After 1945, shock, horror and outcry over the devastation of the bombs and the subsequent radiation sicknesses, which were mostly unexpected; comfort for many because it ended the war and brought soldiers home from hostilities.

    (b) Over the subsequent 30 years – fear over who might have the bomb and who might be developing it; the age of international spies; politically the Cold War; atmospheric testing, a nuclear 'stand-off'; development of nuclear power stations; lots of cheaper energy; radioisotopes with potential cures for many diseases; nuclear submarines for greater military potential; concern about nuclear accidents; radioactive fallout from nuclear testing.

    (c) At the present time – concern about nuclear accidents and disposal of wastes; concern that small militant nations have nuclear capability – that the nuclear technology is out of control; applications to medical science – cures for cancers, life extended; agriculture – disease-resistant plants, better food storage, longer shelf life, cheaper produce; industry – easier detection of flaws and leaks, cheaper services, more reliable structures; much more control over nuclear development; concern about age of current reactors particularly following Chernobyl and Fukushima.
17. Many areas 'out of bounds' due to radioactivity from past bomb testing; the few nuclear accidents have caused genetic problems in plants and animals near them (Chernobyl); people also affected by fallout; increased cancer rates; shorter life; more resources have to go into medical support; less pollution from power stations – better air to breathe, healthier people.

Set 35 Nuclear Reactors

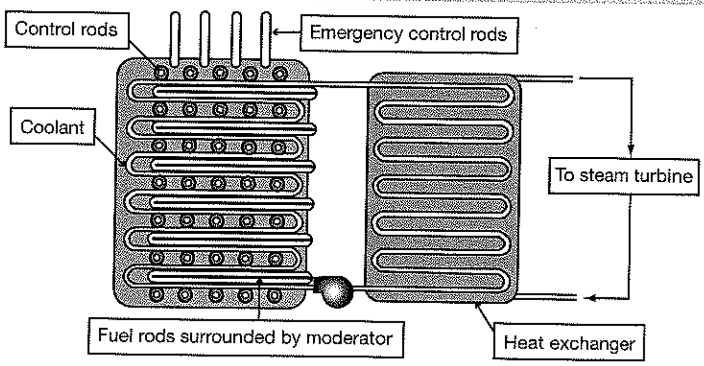
1. Fuel, control rods, moderator rods, coolant, radiation shielding.
2. Fuel is the fissile material to supply the energy.

   Control rods absorb neutrons to slow down or stop the chain reaction.

   Moderator rods slow neutrons down so they have the appropriate amount of energy to produce fission.

   Coolant absorbs the released energy and transfers it to (say) steam to run electricity-producing turbines.

   Shielding protects the environment from stray radiation.
3. See diagram.



4. To slow the neutrons down they need to collide with other particles about the same size, so water is good, but it will also absorb neutrons (forming heavy water) and so take them out of the chain. Heavy water is stable; it can absorb neutrons to form tritium oxide, but this seldom happens under these conditions. However, heavy water is expensive. Carbon is plentiful and cheap, and while it absorbs some neutrons, this can be compensated for by increasing the U-235 enrichment percentage.

5. A fission reaction is one event in a chain reaction. Not all fission reactions produce chain reactions. Fission reactions occur naturally wherever there are some radioactive isotopes, regardless of their concentration. Chain reactions can occur only if there is sufficient (critical) mass of fissile material.

6. There must be a minimum mass of fissile material (at least the critical mass). If it is to be controlled, then there must also be moderator rods and coolant.

7. In the form of a flat sheet, many neutrons escape into the air/surroundings and are therefore not available to sustain the reaction.

8. Enriched uranium has had the proportion of U-235 increased from the naturally occurring amount (0.7%) to 5 to 15%.

9. U-238 is not radioactive and the number of neutrons produced by natural uranium (0.7% U-235) is not enough to sustain a chain reaction.

10. A controlled reaction is producing as many neutrons capable of fission as are being used in fission and so produces a manageable, steady amount of energy, while in an uncontrolled nuclear reaction the number of fissions escalates enormously, producing a huge, uncontrollable amount of energy in a very short time.

11. Nuclear bombs.

12. Number of viable neutrons produced per fission equals 1.

13. More than one viable neutron per fission produced.

14. Critical mass is the minimum amount needed to produce enough neutrons to sustain a chain reaction. If the mass is less than critical, fission will still occur, but it will not be self-sustaining – it will simply occur at the natural rate of radioactive decay.

15. It would stop.

16. A self-sustaining chain reaction will occur.

17. The fuel is in separate, small amounts, each less than the critical mass, but close enough so that neutrons from one pellet can cause fission in others – they are separated by control rods which can be inserted or withdrawn to control the amount of fission occurring.

18. The concentration of fissile material (U-235) is not high enough.

19. As a moderator. The fuel pellets were scattered amongst the graphite blocks. Also to protect the scientists from stray radiation – there was no other form of shielding in this reactor.

Set 36 Nuclear Waste

1. (a) Stone and bricks will contain radioactive nuclides.
   (b) In fact it is negligible, but data like this can give people the impression that it permeated every aspect of our lives and is therefore quite dangerous.
   (c) Media hype? But it is long-lived.

2.

Nuclear waste type	What constitutes this waste type?	How is it disposed of?
Exempt or very low level	The concentration of radionuclides is so low that it can be considered to have negligible radiological hazard. It consists mainly of demolished material (such as concrete, plaster, bricks, metal, valves, piping) produced during rehabilitation or dismantling operations on nuclear industrial sites.	Can be disposed of by normal waste management.
Low level	Generated from hospitals and industry, as well as the nuclear fuel cycle. Low level wastes include paper, rags, tools, clothing, filters, and other materials which contain small amounts of mostly short-lived radioactivity.	Some high activity LLW requires shielding during handling and transport but most LLW is suitable for shallow land burial, ocean depth disposal or incineration. Isolation of LLW, depending on the radionuclides, could be several hundred years.
Intermediate level	Contains higher amounts of radioactivity and in some cases requires shielding. Intermediate level wastes includes resins, chemical sludge and metal reactor nuclear fuel cladding, as well as contaminated materials from reactor decommissioning.	It may be solidified in concrete or bitumen for disposal. As a general rule, short-lived waste (mainly non-fuel materials from reactors) is buried in shallow repositories, or ocean depth disposal, while long-lived waste (from fuel and fuel reprocessing) is deposited in underground tunnels in stable geological areas at depths greater than 100 m.
High level	Produced by nuclear reactors. It contains fission products and highly radioactive transuranic elements generated in the reactor core.	Storage of HLW in deep geological storage areas (at least several hundred to at least a thousand metres) is considered the most appropriate strategy.
Transuranic waste	Waste that is contaminated with alpha-emitting transuranic radioisotopes with half-lives greater than 20 000 years. It arises mainly from weapons production or decommissioning, and consists of clothing, tools, rags, residues, debris and other items contaminated with small amounts of radioactive elements (mainly plutonium).	TRUW is stored in deep geological storage areas.

3. No answer provided here. The idea is for students to get together and discuss the pros and cons of the proposal and strengthen their ideas by listening to each other and to opposing argument.

4. (a) It reduces the volume of material containing the HLW and the TRUW so that there is not as much to dispose of.

   It allows the HLW and the TRUW to be disposed of in appropriate but different ways.

   It allows unused uranium and plutonium to be recycled for further use.

   (b) Initially the waste material from the reactor is very hot and highly radioactive. Storage (usually under water) allows it to cool down and the highly radioactive short half-life isotopes to decay so that the remaining material is safer to handle.

   (c) No. (Unless by 'normal' burying you understood this to be in casks underground at least 100 m, in which case, your answer and explanation could be 'yes'.) After 30 to 40 years the used fuel assemblies are ready for encapsulation or loading into casks ready for indefinite storage or permanent disposal underground.

   (d) (i) It is possible that future generations might consider the buried waste to be a valuable resource and have developed the technology to handle it safely.

   (ii) Permanent closure might increase long-term security of the facility and decrease the opportunity for, say, terrorist activity which might be tempted to use the material for their activities.

   (e) (i) After being buried for about 1000 years the radioactivity of the HLW and the TRUW will have decreased to the point that the remaining radiation hazard would be similar to that of the naturally-occurring uranium ore from which it originated.

   (ii) No, because the concentration of the radioactive material would be far higher than in the original ore.

Set 37 The Birth of Stars

(a) The Universe started at intense heat and has been cooling down since the Big Bang as expansion occurs. (G)

(b) The Universe was initially compressed into zero volume and has been expanding since the Big Bang. (D)

(c) The temperature of the Big Bang is estimated at 10^{32} K. Matter as we know it cannot exist at this temperature. (M)

(d) Only pure energy existed initially. As the Universe cooled, the energy started changing into matter. (A)

(e) The first particles formed would have been the fundamental particles – the leptons, neutrinos and quarks – and massless particles like gluons and photons. (Q)

(f) As the temperature fell further, the quarks started combining to form the hadrons, initially as isolated particles. (B)

(g) The next phase, 10^{-6} s, is thought to have been a time during which hadrons and antihadrons combined, releasing leptons and energy in the form of gamma rays. (O)

(h) However, due to an excess of matter over antimatter, some hadrons remained. (H)

(i) The energy produced by the annihilation of the matter-antimatter combinations was enough to allow fusion of some of the remaining hadrons into heavier nuclei, mainly deuterium, helium and traces of lithium and beryllium. (P)

(j) Gravity collected (accreted) the newly forming particles together to form huge gas clouds or nebulae. (F)

(k) This resulted in a 'lumpy Universe'. (C)

(l) Small, but growing clumps of denser matter started to form within the larger matter cloud. (K)

(m) As more matter started to be drawn closer into the cloud, its speed of rotation increased. (I)

(n) This spinning motion caused the cloud to flatten out and form a disc perpendicular to the axis of the spin. (E)

(o) Most of the galaxies we observe in the Universe are flattened spiral galaxies – so formed because of this spinning motion. (L)

(p) As their density increased and more matter accumulated at each point, the 'lumps' of matter collapsed further, becoming compressed and hotter. (N)

(q) Eventually a core of matter hot enough to sustain nuclear fusion reactions formed – stars, composed mainly of hydrogen were born, and galaxies formed. (J)

Set 38 The Hertzsprung-Russell Diagram

1. An HR diagram is a plot of the luminosity of stars against their temperature, which also represents their colour ranges and spectral classes.
2. That the stars were arranged in obvious patterns and groups on the diagram and not just scattered randomly.
3. Both colour and spectral class are determined by the temperature of the star.
4. A
5. B
6. B
7. C
8. B
9. A
10. D (Note that Z is hotter than X and so will be more likely to be blue-white despite its small size.)
11. D

Set 39 Types of Stars

e the absolute proposed final stage for any star. Given that they are 'black' because they are cold and not
it would be practically impossible to detect them. In addition, it is thought that the age of the Universe is too
gh time to have passed to form a black dwarf.

stars are so classified because their energy source is core hydrogen fusion to form helium.

stars occupy the top left to bottom right diagonal of the HR diagram.

nous the star on the main sequence, the more massive it is.

left of the main sequence are blue and hot, having luminosity up to about 10^6 times that of the Sun, and
nass.

ottom, right, are red and cooler, one thousandth the luminosity of the Sun and one hundredth its mass.

iddle are about the same size as the Sun, although their masses and luminosities vary.

	Energy producing process(es)
	Hydrogen fusion to form helium
	Helium fusion in the core, hydrogen fusion in shell surrounding core
	Hydrogen fusion in outer shell with heavier element fusion in inner shells up to iron in core
	No fusion reactions occur

(b) Red dwarfs (c) Red dwarfs
(e) Red dwarfs (f) Red dwarfs

roduced by the fusion reactions in stars causes them to expand outwards while their gravitational force pulls their
rds. The star is stable when these two forces balance and are said to be in hydrostatic equilibrium.

star starts to produce less energy from fusion gravitational forces will cause it to collapse inwards and become smaller.

fusion energy produced increases beyond the ability of the gravitational force to oppose it, the star will either
nd slowly, or explosively.

happens with a main sequence star when the proportion of hydrogen in its core decreases sufficiently. Gravitational
collapses it inwards.

collapsing main sequence star collapses, the temperature in its core increases and eventually reaches the helium
point when helium fusion starts. This causes a rapid expansion of the star to form a red giant because the force
the thermal expansion is greater than gravitational force inwards.

ing occurs when a star is hot enough for several layers of fusion to occur. In the outermost layer of the core,
fuses to form helium, then in shells approaching the centre, helium fuses to carbon, helium and carbon to neon,
oxygen, oxygen to silicon (and magnesium), then silicon to iron (and nickel).

s (and blue giants).

not fuse elements heavier than iron. Fusing iron doesn't release energy. It uses up energy. Fusion requires the nuclear
o be producing sufficient energy to keep it going.

y, the iron core of a shell burning star reaches a critical mass, which is about 1.4 times the mass of the Sun. Once iron
core collapses and rebounds as the supernova explosion. If the core that remains is greater than 1.4 solar masses it
black hole. Less than 1.4 and a neutron star/pulsar forms. At this point, the inwards pressure is so great that the core
s. Two things happen: protons and electrons are pushed together to form neutrons and neutrinos and higher atomic
elements result. Eventually the pressure build-up is so great that the star will nova or supernova (depending on its size).
nts explode as supernovae and fuse all known elements. New second generation stars condense out of this matter.

Set 40 Life Cycles of Stars

as nebula or cloud which condenses into a protostar – not yet fusing H to He.

ain sequence star when fusion begins.

ss.

un is on the main sequence for at least the second time. A previous, much larger main sequence star (the first generation)
one through a cycle of red or blue giant or supergiant and the nebulae material left after the nova or supernova of this
has had sufficient mass to accrete to form a new main sequence star – our Sun.

pectrum of our Sun shows up to 67 elements. These can only have been formed in a previous stage as a giant star.

ld have been much more massive and hotter.

3.

4.

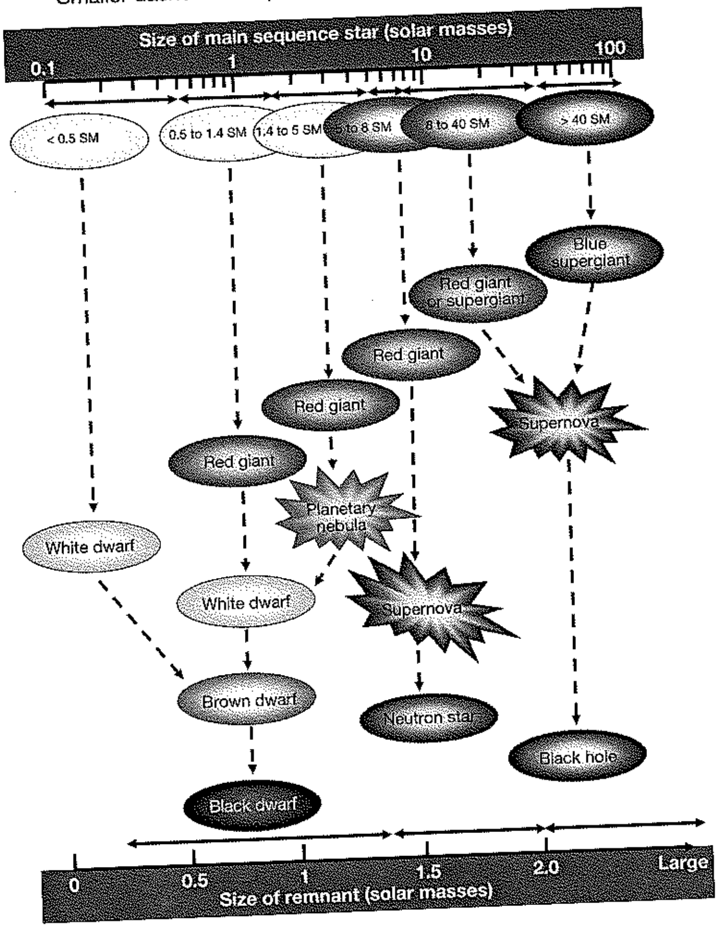
5.

(a) Diagram is showing the life cycle of a typical star of mass equal to that of our Sun. As its helium core contracts and hydrogen fuel diminishes, the star cools down and moves off the main sequence. It contracts as it cools and the increased pressure in the core raises the core temperature so that it starts to fuse helium and becomes a red giant. As helium fusion heats it up again, it moves back towards the main sequence. It later becomes a red giant again, fusing helium to carbon. It becomes hotter, but does not increase its luminosity as its mass it decreasing. When helium supply becomes depleted, the star shrinks and becomes a white dwarf.

(b) A Supergiants
B Second generation red giant
C First generation red giant
D Main sequence star
E White dwarfs

(a) 1 = protostar
2 = main sequence star
3 = red or blue giant
4 = white dwarf

(b) Larger dashed line represents the evolutionary pathway for a star with less than 0.5 solar masses.
Full line represents the evolutionary pathway for a star with about 5 solar masses.
Smaller dashed line represents the evolutionary pathway for a star with to 8 to 10 solar masses.



Set 41 The Charge Model for Electric Current

1. (a) Charged objects are objects which have lost or gained electrons.
(b) By gaining electrons (having an excess of electrons).
(c) By losing electrons (having a deficiency of electrons).
(d) Friction.
(e) By chemical reactions (as in a battery), by applying a potential difference across the ends of the object.
(f) Positive.
(g) Negative.
(h) Protons are firmly held in the nuclei of atoms. They do not move from here unless energy sufficient to break the nucleus (nuclear reaction energy) is involved.

2. (a) The coulomb, symbol C. (b) One coulomb is equal to the charge on 6.25×10^{18} electrons.
3. (a) 6.25×10^{15} C electrons removed. (b) 1.562×10^{13} C electrons added.
(c) 5×10^{11} C electrons removed. (d) 2.81×10^{10} C electrons added.
4. (a) $+4.5 \times 10^{-10}$ C (b) -9.6×10^{-11} C
(c) $+2.24 \times 10^{-7}$ C (d) -1.44×10^{-12} C
5. (a) An electric current (conventional) consists of a flow of positive charge from high potential to lower potential.
(b) One ampere of current consists of a flow of 6.25×10^{18} electrons per second (= 1 coulomb per second).
(c) $Q = It$
(d) Electric current in solid conductors is a flow of electrons through the conductor from the negative terminal to the positive terminal. Conventional current, defined before the nature of current was known, was, and still is, defined as a flow of positive charge from positive terminal to the negative terminal.
6. (a) 76.8 mA (b) 3.84 mA (c) 1.6 mA
(d) 85.3 mA (e) 1.024 A
7. (a) 1.5625×10^{18} (b) 9.375×10^{18} (c) 3.75×10^{19}
(d) 1.25×10^{13} (e) 2.5×10^{10}
8. 4.875×10^{20} electrons
9. 22.3 days
10. (a) The current passing through A is the same as the current passing through B.
(b) The current passing through A is the same as the current passing through C.
(c) The current passing through A is the same as the current passing through D.
(d) The current passing through D is the same as the current passing through E.
11. (a) The number of electrons flowing through P is the same as that flowing through Q.
(b) The number of electrons flowing through P is the same as that flowing through R.
(c) The number of electrons flowing through P is the same as that flowing through S.
(d) The number of electrons flowing through P is the same as that flowing through T.
(e) The number of electrons flowing through Q is the same as that flowing through S.
12. (a) The current through each point would double, but it would still be the same through each point.
(b) The currents would be the same, but triple the original amount.
(c) The number of electrons passing through each point would be doubled, but still the same through each point.
(d) The number of electrons passing through A and B would be tripled, but still the same through each point.
13. (a) 1.875×10^{16}
(b) 3 mC
14. 44.4 A
15. 9.6 A

Set 42 Electrical Potential Difference 1

1. (a) Electrical potential difference is equal to the work done per unit charge moving through the potential difference.
(b) $\Delta V = \dfrac{\Delta W}{Q}$. On rearranging, $W = \Delta VQ$
(c) Joules per coulomb (J C^{-1})
(d) 1 joule per coulomb = 1 volt (V)
2. 166.67 V
3. 66.67 V
4. (a) 6×10^{-4} J (b) 750 V m^{-1} means 75 V potential difference per 10 cm.
5. 20 V
6. 15 625 V
7. 1800 J
8. 6 V
9. (a) On the top side (the uncharged side) because here it will experience an electric force towards the positively charged side.
(b) 7.2×10^{-4} J
10. (a) 3.2×10^{-15} J (b) 8.38×10^{7} m s^{-1} (c) 4.8 s
11. (a) 15 V (b) 2×10^{-3} A
12. (a) 3.55×10^{5} V
(b) 10 000 V
(c) X is at the higher potential because the alpha particle gains energy as it moves 'freely' (i.e. no applied force) through the field.

13. 416.67 V

14. (a) 4×10^{-17} J (b) 9.37×10^{7} ms^{-1}

(c) They would be the same. The energy gain is given by $W = E_k = \frac{1}{2}mv^2$ and the work done ($W = QV$) will not change. The answers to (a) and (b) will be the same. The electrons will simply accelerate more slowly in the weaker field. The distance between the plates is not a variable in this case.

15. (a) 8 V (b) 9.38 V

16. (a) 12 J (b) 1.92×10^{-16} J

17. 385 J

Set 43 Electrical Potential Difference 2

1. (a) The electrical potential difference between two points in a conductor carrying a current is equal to the product of the current flowing and the resistance of the conductor between the two points.

(b) $\Delta V = RI$

(c) Ohm ampere (ΩA)

(d) One ohm ampere = 1 volt

2. 36 V
3. 45 V
4. 180 V
5. 22.5 V
6. 270 V
7. 1000 V
8. 49 V
9. 54 000 V
10. 192 V
11. (a) 12 V (b) 24 V
(c) 8 V (d) 36 V
(e) 44 V (f) 32 V
(g) 44 V
12. (a) 3 V (b) 0
(c) 6 V (d) 9 V
(e) 6 V (f) 9 V
(g) 15 V (h) 3 V

Set 44 The Nature of Electrical Resistance

1. (a) Electrical resistance is the ratio of the potential difference across an electrical component to the current flowing in the component.

(b) The resistance of a conductor opposes the current through it by reducing the kinetic energy of the charge carriers.

(c) Electrical resistance is a combination of two factors, the strength with which valence electrons are held to their atoms, and secondly, the energy current electrons lose when they undergo collisions with other particles in the conducting material.

(d) The ohm.

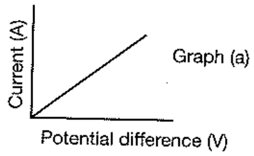
(e) One ohm is the resistance of a conductor if a potential difference of 1 volt applied across the ends of the conductor causes a current of one amp to flow through it, symbol Ω.

(f) $\text{Resistance} = \frac{\text{voltage}}{\text{current}}$ or $R = \frac{V}{I}$

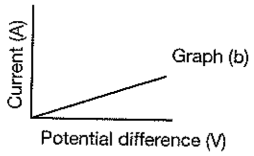
(g) $\text{Current} = \frac{\text{voltage}}{\text{resistance}}$ or $I = \frac{V}{R}$

(h) $V = RI$

2. (a)

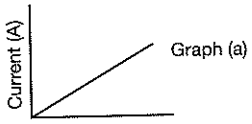


(b)



(c) Gradient in graph (a) will be double that of the graph (b) because the current produced by similar potential differences will be double that in (b) will be the resistance of the double length wire in (b) will be twice the resistance of wire (a).

(d)



(e) Gradient will be less than (a) because at the higher temperature the resistance of the wire will be larger.

3. (a) The length of the conductor, its temperature, its cross-sectional area, the material it is made of.

(b) Length: The longer the conductor is, the more particles there will be for the current electrons to collide with and the more energy they lose (or need) to be able to pass through the conductor.

Cross-sectional area: The thinner a conductor is the more resistance it has. Current electrons have less room to pass through it and this restriction increases the number of collisions they have.

Temperature: The hotter a material, the higher its resistance. This is because the particles in the conductor are moving more violently at higher temperatures, so more collisions will occur with current electrons, and more energy will be lost during those collisions.

Type of substance: The stronger the forces holding valence electrons to the atoms of the material, the higher its electrical resistance.

4. (a) A conductor is a material which will allow electrical current to pass through it freely.

(b) A resistor is a material which resists the flow of electricity through it.

(c) An insulator is a material which will not allow electrical current to pass through it.

(d) All conductors have some electrical resistance (except superconductors below their critical temperatures which you will learn about in a later topic). Making an arbitrary sub classification at some resistance value to distinguish between conductor (with lower resistance) and resistors (with higher resistance) is bad physics.

5. 6.67 A

6. 4 Ω

7. 13.5 V

8. (a) Heat. (b) Gravitational potential energy. (c) Sound.
(d) Kinetic. (e) Light.

9. (a) Light globe. (b) Loudspeaker. (c) Coil in an electric jug.
(d) Motor. (e) Electric crane.

Set 45 Ohmic and Non-ohmic Conductors

1. (a) An ohmic conductor obeys Ohm's law – that is, the current flowing through the conductor is directly proportional to the applied voltage. This does not hold true for a non-ohmic conductor.

(b) No. Conductors are ohmic only over a limited range of temperature because as the current flowing through them increases, their temperature and therefore their resistance will rise. When this starts to occur, they will no longer obey Ohm's law.

2. (a) A is ohmic. The graph for A shows a direct proportionality between applied voltage and current flowing.
(b) 10 A (c) 10 A (d) 5 V
(e) About 6.5 V (f) About 11.5 V (g) About 13.5 A
(h) About 13.5 A (i) About 7 V (j) About 20.5 V
(k) About 16 A (l) About 15 A (m) About 31 A
(n) $R = V/I = 20/31 =$ about 0.65 Ω

Set 46 Electrical Potential Difference 3

1. (a) The electrical potential difference between two points in a conductor carrying a current is equal to the power dissipated in a resistor per unit current

(b) $\Delta V = \dfrac{P}{I}$. On rearranging, $P = \Delta VI$

(c) Watts per ampere (W A^{-1})

(d) One watt per ampere = 1 volt

2. 15 V

3. 160 V

4. 100 V

5. (a) 22.5 watts (b) 4050 J

6. 4.7×10^{-4} A

7. (a) 6.25 A (b) 142 500 J or 142.5 kJ

8. (a) 5 C (b) 120 V
(c) 600 J (d) 120 J

9. (a) 3600 C (b) 240 V (c) 720 W
10. 0.045 J
11. 2500 V
12. 266.7 V

Set 47 Electrical Power

1. (a) Power is a measure of the ability of a device to do work (change energy) being equal to the rate at which that work is done.
   (b) Watts (W) = joules per second (J s^{-1})
   (c) Kilowatt hours (kWh).
   (d) The kWh is a more sensible unit. One kWh is equal to 3 600 000 W and is sold commercially (currently at just over 20 cents per kWh. Charging per watt would make the unit cost ridiculously small.
2. (a) 1125 W (b) 6.075×10^7 J
3. (a) 144 W (b) 864 J (c) 24.2 kWh
4. (a) 2.08 A (b) 115.2 Ω (c) 50 hours
5. 335 V (rounded)
6. (a) 80 W (b) 144 000 J
7. (a) 384 W (b) 1.8×10^7 J
8. 8640 J from $P = I^2R$
9. (a) 0.104 A (b) 2304 Ω (c) 20 V
   (d) The globe would overheat rapidly and burn out.
10. (a) You need to calculate the resistance of the jug element first. It is a constant and will determine the current and therefore the power with a new voltage = 48 Ω, from which power = 252.1 W.
    (b) The jug develops only 21% of its designed power. It is therefore quite inefficient. It will take over 5 times as long to boil any water in it.
    (c) 5 A (d) 2.3 A
11. (a) 0.25 A (b) 960 Ω (c) 48.98 V
    (d) The current flowing through it would be too high and the filament would overheat, melt and break the circuit. The globe would 'blow'
12. 48 Ω

Set 48 Components in Simple Electric Circuits

1. (a) An electric circuit is a selection of electrical components joined together to each other and a power supply.
   (b) Electric circuits are used to change electrical energy into other forms, and to transmit electrical energy over large distances.
2.

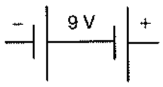
(a)	Conductor (with resistance)	To convert electrical energy into other forms.
(b)	Variable resistance conductor	To convert electrical energy into varying amounts of other forms.
(c)	Two conductors in series	To allow two devices to convert energy at the same time.
(d)	Two conductors in parallel	To allow two devices to convert more energy at the same time.
(e)	Fuse	To protect a circuit if a current overloads.
(f)	Ammeter	To measure the current flowing in amperes (A).
(g)	Milliammeter	To measure the current flowing in milliamperes (mA).
(h)	Microammeter	To measure the current flowing in microamperes (μA).
(i)	Voltmeter	To measure the potential difference across a conductor in volts (V).
(j)	Galvanometer	To measure the current flowing in milli or microamperes (A).
(k)	Ohmmeter	To measure the resistance.
(l)	Globe	To convert electrical energy into light energy.
(m)	1.5 V DC cell	To supply 1.5 V DC potential difference.
(n)	3 V DC battery	To supply 3 V DC potential difference.
(o)	12 V DC battery	To supply 12 V DC potential difference.
(p)	Variable DC power supply	To supply variable DC potential difference.
(q)	DC power supply	To supply DC potential difference.
(r)	AC power supply	To supply AC potential difference.
(s)	Coil (heating element)	To convert electrical energy into heat energy.
(t)	Transformer	To increase or decrease potential difference supplied to a circuit.
(u)	Closed switch	Allows current to flow through a circuit.

(v)	Open switch	Stops current flowing through a circuit.
(w)	Circuit wire (zero resistance)	Used to build electrical circuits.
(x)	Circuit wires crossing, not joined	Electrical circuit information diagram.
(y)	Circuit wires joined	Electrical circuit information diagram.
(z)	Earth or ground	Carries electrical current to earth in case of fault in circuit.

3. (a) A closed circuit is one which is complete. It has no breaks in it. An open circuit is one which is not complete. An open circuit will have a break in it. The most common break will be an open switch, that is, a switch which is not switched on.

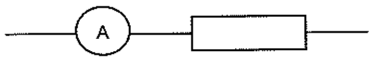
(b) A short circuit exists when there is an alternative path with negligible resistance in parallel (see later) with a path which does have resistance.

4.



5. (a) Ammeters are connected into circuits in series with a conductor so as to read the current in that conductor.

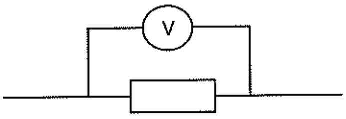
(b)



(c) Ammeters have very low electrical resistance so that they do not significantly affect the current in the circuit and need to be in series so that the same current passes through them as through the conductor.

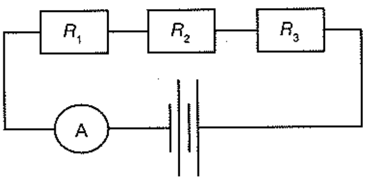
6. (a) Voltmeters are connected across the conductor to measure the potential difference across it.

(b)



(c) Voltmeters have very high electrical resistance so that only enough current passes through them to operate their mechanism. If connected in series they would stop most current flowing. They are connected in parallel because they compare the electrical potential at each end of the conductor.

7.



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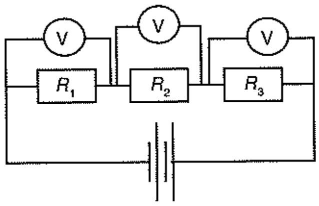

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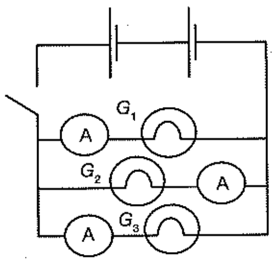

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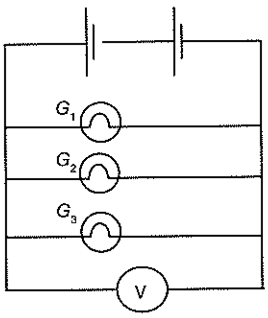

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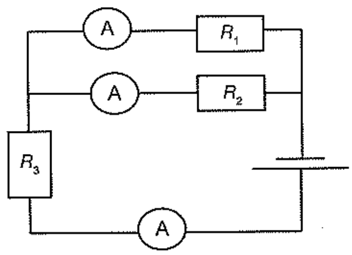

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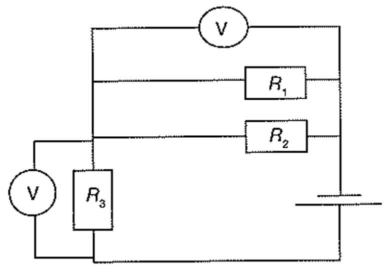


Set 49 Using Ammeters and Voltmeters

Ammeters

1. (a) To measure the current flowing in amperes (A).

(b) To measure the current flowing in milliamperes (mA).

(c) To measure the current flowing in microamperes (μA).

2. (a) 1000 (b) 1 000 000 (c) 1000

3. (a) A (b) mA (c) μA

4. (a) One ampere is equal to the flow of 1 coulomb of charge (6.25×10^{18} electrons) per second through a circuit.

(b) One milliamp are equal to the flow of 1 millicoulomb of charge (6.25×10^{15} electrons) per second through a circuit.

(c) One microamp are equal to the flow of 1 microcoulomb of charge (6.25×10^{12} electrons) per second through a circuit.

5. (a) One amp are the current flowing through a conductor of resistance one ohm when a potential difference of one volt is applied across its ends.

(b) $I = V/R$

Voltmeters

1. A battery is a source of electrical energy.
2. A battery is often described as an electron 'pump'.
3. A battery is a source of electrons.
4. Electrons flow through a circuit from a battery because of forces of electrostatic repulsion.
5. The ability of a battery to 'pump' electrons through a circuit is called its voltage.
6. Voltage is a measure of how much energy a battery can supply to a circuit.
7. The instrument used to measure voltage is the voltmeter.
8. Voltmeters measure electrical potential difference across two points in a circuit.
9. To do this they must be connected across those two points.
10. Voltage can also be expressed as joules per coulomb.
11. Anything connected across two points in a circuit is said to be connected in parallel.
12. Voltage is measured in volts.
13. The symbol for voltage is V.
14. The electrical potential difference between two points is the change in energy per unit charge moving from one point to the other.

Set 50 Conductors in Series and in Parallel

1. (a) Series connections are one after the other, like the carriages of a train connected together.

Parallel connections branch from a single connecting wire and provide alternate pathways for current to flow, then rejoin into a single connecting wire like a main road with branches into several smaller roads to pass through a town before these roads reconnect to re-form the single main road on the other side of town.

(b) The same current passes through any conductors connected in series.

The current passing through conductors in parallel is inversely proportional to the values of their resistances.

(c) The potential difference across series conductors is directly proportional to the values of their resistance.

The potential difference across parallel conductors is the same.

2. A, C, F, G, I = series connections

B, D, E, H = parallel connections

3. (a) We simply add the values of the individual resistances to get the total: $R_T = R_1 + R_2 + R_3 + \ldots$

(b) We determine the inverse of the addition of the reciprocals of the individual resistances.

$R_T = (R_1^{-1} + R_2^{-1} + R_3^{-1} + \ldots)^{-1}$

4. (a) The total voltage is split across each of the conductors in direct proportion to their relative resistances.

$V_T = V_1 + V_2 + V_3 + \ldots$ (where V_1 = potential difference across conductor 1)

(b) The potential difference across a set of conductors in parallel is the same for each conductor in the set.

$V_T = V_1 = V_2 = V_3 = \ldots$ (where V_1 = potential difference across conductor 1)

5. (a) The circuit current flows through each conductor connected in series with the power supply.

$I_T = I_1 = I_2 = I_3 = \ldots$ (where I_1 = current flowing through conductor 1)

(b) The total current is split across each of the conductors in inverse proportion to their relative resistances.

$I_T = I_1 + I_2 + I_3 + \ldots$ (where I_1 = current flowing through conductor 1)

6.

A = 8 Ω	B = 2 Ω	C = 12 Ω
D = 3 Ω	E = 4 Ω	F = 6 Ω
G = 12 Ω	H = 4 Ω	I = 6 Ω

7. The conductors in circuits B, D, E, H (the ones where they are connected in parallel).

8. (a) The conductors in circuits A, C, F, G and I (they are all in series with each other and the power supply) and those in circuit E.

(b) Because the two parallel conductors in circuit E have the same resistance, so the circuit current will split evenly between them.

9. (a)

A = 2 Ω	C = 4 Ω	E = 3 Ω	G = 2.5 Ω
B = 4 Ω	D = 3 Ω	F = 4.5 Ω	H = 2 Ω

(b) The correctness of the expression is shown by reworking the total resistances of the circuits using this expression and comparing your answers with those in (a).

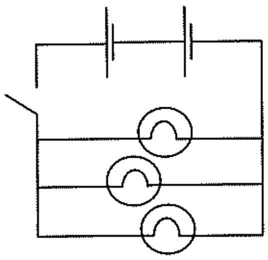
(c) The correctness of the expression is shown by reworking the total resistances of the circuit B, E, F, G and H using this expression and comparing your answers with those in (a).

10. (a)

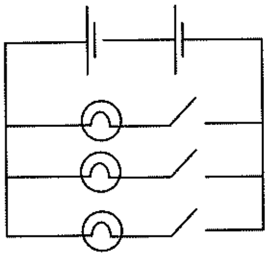
A = 1 Ω	C = 6 Ω	E = 1.5 Ω	G = 0.5 Ω
B = 2 Ω	D = 50 Ω	F = 2 Ω	H = 2 Ω

(b) The correctness of the expression is shown by reworking the total resistances of the circuits using this expression and comparing your answers with those in (a).

11. (a)



(b)



(c) The only option to have all the lights on is available with series circuits. If the switch is off, all lights will be off and vice versa. Only one switch is needed.

12. (a) Series connections allow all the devices in the circuit to be operated by a single switch.

(b) Less circuit wiring is required, but if one device fails, it is more time consuming to determine which one of the devices in the circuit is the faulty one.

(c) Almost the only series connections in homes will be sections of strings of lights as in fairy lights.

(d) Parallel connections allow all the devices in the circuit to be individually switched and operated independently of all other devices in the circuit.

(e) In parallel circuits, if one device fails and breaks its circuit, the operation of the other devices will not be affected. Parallel circuits use significantly more electrical wiring than series circuits.

(f) All lights and power points in homes will be connected in parallel in their respective circuits.

Set 51 Potential Around a Series Circuit

1. Potential at W = 0, X = 6 V, Z = 15 V, Y = 27 V

(a) X and Y = 21 V
(b) X and Z = 9 V
(c) W and Z = 15 V
(d) W and Y = 27 V

2. Potential at P = 0 V, Q = 9 V, R = 36 V, S = 36 V

(a) P and Q =9 V
(b) P and S = 36 V
(c) Q and S = 27 V
(d) R and S = 0 V

3. Potential at A = 18 V, B = 45 V, C = 12 V, D = 0 V

(a) A and B = 27 V
(b) C and D = 12 V
(c) A and D = 18 V
(d) C and B = 33 V

4. Potential at E = 0 V, F = 8 V, G = 20 V, H = 60 V, I = 36 V

(a) E and F = 8 V
(b) F and G = 12 V
(c) G and I = 16 V
(d) H and G = 40 V
(e) F and I = 28 V

Set 52 Analysing Series Circuits

1. (a) 10 Ω
(b) 4.5 A
(c) Resistors are in series, so 4.5 A in each.
(d) Across 4 Ω = 18 V
Across 6 Ω = 27 V

2. (a) 5 Ω
(b) 1 Ω
(c) 7 A in each.
(d) Across 4 Ω = 28 V
Across *R* (1 Ω) = 7 V

3. (a) 7.5 Ω
(b) 6 A
(c) 6 A in each.
(d) 45 V
(e) Across 2.5 Ω = 15 V
Across 5 Ω = 30 V

4. (a) 18 Ω
(b) 2 A
(c) 2 A in each.
(d) 36 V
(e) Across 3 Ω = 6 V
Across 6 Ω = 12 V
Across 9 Ω = 18 V

5. (a) 1 : 1 : 1
(b) 2 : 5 : 3 (in order from left to right)

6. (a) 18 Ω
(b) 4 A
(c) 4 A in each – they are connected in series with each other.
(d) 4 Ω = 16 V, 6 Ω = 24 V, 8 Ω = 32 V

7. (a) 10 Ω
(b) 6 A
(c) 6 A in each.
(d) 60 V
(e) 3.5 Ω = 21 V, 4 Ω = 24 V, 2.5 Ω = 15 V

8. (a) 4 A
(b) 4 A in each.
(c) 12 Ω
(d) 4 Ω
(e) 48 V
(f) 5 Ω = 20 V, *R* = 16 V, 3 Ω = 12 V

Set 53 Potential Around a Parallel Circuit

1. Potential at W = 18 V, X = 0 V, Z = 0 V, Y = 18 V
(a) W and X = 18 V
(b) W and Z = 18 V
(c) Y and X = 18 V
(d) Y and Z = 18 V

2. Potential at A = B = C = D = 42 V
E = F = G = H = 0 V
(a) A and E = 42 V
(b) B and F = 42 V
(c) C and G = 42 V
(d) D and H = 42 V
(e) A and H = 42 V

3. Potential at A = B = C = D = 0 V
E = F = G = H = 25 V
(a) A and E = 25 V
(b) B and F = 25 V
(c) C and G = 25 V
(d) D and H = 25 V
(e) A and H = 25 V

4. Potential at P = 16 V, Q = 10 V, R = 16 V, S = 0 V
(a) P and Q = 6 V
(b) Q and S = 10 V
(c) R and S = 16 V
(d) R and Q = 6 V
(e) P and S = 16 V

Set 54 Analysing Parallel Circuits

1. (a) 4 Ω
(b) 15 A
(c) 5 Ω = 12 A, 20 Ω = 3 A
(d) 5 Ω = 60 V, 20 Ω = 60 V

2. (a) 4 Ω
(b) 9 A
(c) 6 Ω = 6 A, 12 Ω = 3 A
(d) 6 Ω = 36 V, 12 Ω = 36 V

3. (a) 2 Ω
(b) 12.5 A
(c) 2.5 Ω = 10 A, 10 Ω = 2.5 A
(d) 2.5 Ω = 25 V, 10 Ω = 25 V

4. (a) 1.5 Ω
(b) 1 A
(c) 4 A
(d) 6 V
(e) 2 Ω = 6 V, 6 Ω = 6 V

5. (a) 1 Ω
(b) 8 A
(c) 12 A
(d) 24 A
(e) 24 V
(f) 6 Ω = 24 V, 3 Ω = 24 V, 2 Ω = 24 V

6. (a) 2 A
(b) 1 A
(c) 1 A
(d) 4 A
(e) *R* Ω = 12 V, 6 Ω = 12 V, 12 Ω = 12 V
(f) 12 Ω
(g) 3 Ω

7. (a) 6 A
(b) 9 A
(c) 18 A
(d) 12 Ω
(e) 6 Ω = 36 V, 4 Ω = 36 V, *R* Ω = 36 V
(f) 2 Ω

8. (a) 2 A each.
(b) 4 A
(c) 1.5 Ω
(d) 12 V
(e) 6 Ω = 12 V, 3 Ω = 12 V, 6 Ω = 12 V

Set 55 Analysing Series and Parallel Circuits

1. (a) 5 Ω
(b) 2.5 A each (current splits equally as resistances are same value).
(c) 5 A
(d) 25 V
(e) 2 Ω = 10 V, 6 Ω = 15 V, 6 Ω = 15 V

2. (a) 6 Ω (b) 2 A (c) 10 A
(d) 10 A (e) 60 V (f) 4 Ω = 40 V, 2.5 Ω = 20 V, 10 Ω = 20 V

3. (a) 7 Ω (b) 4 Ω_1 = 12 A, 4 Ω_2 = 9 A (c) 3 A
(d) 12 A (e) 4 Ω = 48 V, 12 Ω = 36 V, 4 Ω_2 = 36 V (f) 84 V

4. (a) 5 Ω (b) 4 A (c) 2 A each.
(d) 4 A (e) 5 Ω_1 = 10 V, 5 Ω_2 = 10 V, 2.5 Ω = 10 V

5. (a) 12 Ω (b) 1 A each. (c) 2 A
(d) 2 A (e) 6 Ω = 12 V, 12 Ω = 12 V, 12 Ω = 12 V (f) 24 V

6. (a) 8 Ω (b) 5 A (c) 4 A
(d) 1 A (e) 5 A (f) 4 Ω = 20 V, 5 Ω = 20 V, 20 Ω = 20 V
(g) 40 V

7. (a) 4 A (b) 6 A (c) 3 Ω
(d) 5 Ω (e) 6 A (f) 3 Ω = 12 V, 6 Ω = 12 V, *R* Ω = 18 V (given)
(g) 30 V

8. (a) 2 A (b) 4 A (c) 4 A
(d) 9 Ω (e) 8 Ω_1 = 16 V, 8 Ω_2 = 16 V, 5 Ω = 20 V (f) 36 V

Set 56 Transforming Electrical Energy

1. Toaster – heat energy
Fan – kinetic energy
TV – sound and light energy
Light globe – light energy
Electric drill – kinetic energy

2. (a) Toaster, electric jug, heater.
(b) Motor in a fan, heat energy in a DVD or TV, house wiring getting hot.
(c) Heat energy.

3. (a) A step-up transformer.
(b) It increases the potential difference and decreases the current flow.
(c) Energy is converted into non-useful heat energy in transmission lines according to the formula $P_{lost} = I^2R$. Increasing the transmission voltage also decreases the transmission current (by the same factor) and therefore decreases the energy converted to heat energy.

4. (a) The transmission voltages of up to 500 kV are far too high to be used safely or with any household appliances.
(b) A step-down transformer.

5. (a) Step-up transformers increase the input voltage to a higher value. Step-down transformers decrease the input voltage to a lower value.
(b) Step-up transformers have more turns of wire in their secondary (output) coil than they have in their primary (input) coil. Step-down transformers have fewer turns of wire in their secondary (output) coil than they have in their primary (input) coil.

6. (a) Note that the total resistance of the transmission lines is 120 Ω.

	Station A	Station B	Station C	Station D
Power output (W)	40 000 000	40 000 000	40 000 000	40 000 000
Transmission voltage (V)	50 000	100 000	250 000	500 000
Current in transmission lines (A) Use $I = P/V$	800	400	160	80
Power lost during transmission (W) Use $P = I^2R$	76 800 000	19 200 000	3 072 000	768 000
Power reaching consumer (W)	Zero	20 800 000	36 928 000	39 232 000
Power lost (%)	100	48	7.68	1.92

(b) The 500 000 V loses the least amount of energy in transmission, so it would be the best to use of the four given. A higher transmission voltage would be even more efficient.

7.

Electrical device	Input form of energy	Useful output form of energy	Non-useful form of energy also produced
TV	Electricity	Light and sound	Heat
Radio	Electricity	Sound	Heat
Frypan	Electricity	Heat	Radiated heat
Washing machine	Electricity	Kinetic	Heat, sound
Battery charger	Electricity – AC	Electricity – DC	Heat

8.

Electrical device	Input form of energy	Useful output form of energy	Non-useful form of energy also produced
Bar radiator	Electricity	Heat	Light
Light globe	Electricity	Light	Heat
CD player	Electricity	Sound	Heat
Escalator (up)	Electricity	Gravitational potential energy	Sound
Conveyor belt	Electricity	Kinetic energy	Sound
Air compressor	Electricity	Elastic potential energy	Noise, heat
Electric fan	Electricity	Kinetic energy	Sound, heat

9. (a) From $P = VI$

$4800 = 240 \times I$

Therefore $I = 20$ A

(b) Total resistance of wire = $2.5 \times 3 = 7.5\ \Omega$

From $V = RI = 7.5 \times 20 = 150$ V

(c) $240 - 150 = 90$ V

(d) Not very useful. If appliances are designed to run efficiently with a 240 V supply, then this system will not be good enough to run the household appliances. Lights would glow dimly, motors only spin slowly.

(e) The generator needs to be moved much closer to the homestead so that the maximum voltage loss in the lines is, say, 10 to 20 volts. (This means resistance in the lines needs to be around 0.5 to 1 ohm which would put the generator between 160 and 330 metres from the household. The generator shed is often 20 to 30 m away so there is no problem with voltage drop but its noise can be annoying.)

Set 57 Energy Efficiency

1. (a) The efficiency of any device is a measure of the ratio of the amount of energy it produces compared to the amount of energy input into it to run it.

(b) Expressed usually as a percentage.

(c) Efficiency = $\dfrac{\text{energy output} \times 100\%}{\text{energy input}}$

2. (a) The law of conservation of energy.

(b) No. The conservation law still holds, but all forms of energy produced must be taken into account, not just the useful light energy. For example, non-useful heat energy is also produced.

3. (a) 36 W

(b) 126 J

(c) From $GPE = mgh = 4 \times 9.8 \times 0.75$ m $= 29.4$ J

(d) Total energy used = $Pt = VIt = 9 \times 4 \times 3.5 = 126$ J

Efficiency = (output ÷ input) × 100 = (29.4 ÷ 126) × 100 = 23.3%

4. (a) Total force = component of weight force = 800 sin 30° = 400 N

(b) Work = $Fs = 400 \times 15 = 6000$ J

(c) Energy output = 1500 J s^{-1} × 60% = 900 J

(d) Time = 6000 ÷ 900 = 6.67 s

5. (a) 823.2 J

(b) 957.2 J

(c) 0.35 A (use $W = VIt$)

(d) 134 J

6. (a) 51 m

(b) 10 MJ

(c) Total energy supplied by the train = 12.5 MJ

In 300 s, this represents a power of 41 667 W

From $P = VI$, voltage = 2778 V

7. (a) 40 000 J s^{-1}
(b) 30 MJ = 30 000 000 J ÷ (10 × 60) = 50 000 J s^{-1}
(c) 40 000 ÷ 50000) × 100 = 80%

8. (a) Total energy = 30 × 60 × 6 × 3600 = 3.89 × 10^7 J
(b) Energy used by lights = 80% of the supplied energy
So, energy supplied = 3.89 × 10^7 × 100/80 = 4.86 × 10^7 J
(c) Petrol used = (4.86 × 10^7) ÷ 30 × 10^6) = 1.62 L

Set 58 Other Problems with Transmitting

1.

Transmission voltage (V)	30 000	50 000	250 000	500 000
Power generated	4 MW	4 MW	4 MW	4 MW
Current in lines $I = P/V$	133.33	80	16	8
Power loss in lines ($P = I^2R$)	3 555 555	1 280 000	51 200	12 800
Power left after losses (W)	444 444	2 720 000	3 948 800	3 987 200
Power lost (%)	89	32	1.28	0.32

2. Energy losses if transmitted at low voltage make transmission totally ineffective – must be transmitted at high voltages.

3.

Structure	How this protects against lightning strikes
Shield conductors	These are two non-current carrying wires at the very top of the tower. They connect into the earth cable and carry lightning strikes to ground or along their length in preference to transmission lines being hit.
Earth cable	This runs from the top of the pole down into the earth to carry lightning strikes to earth thus protecting the tower and the transmission lines.
Insulation chains	These are saucer-shaped stacks of ceramic material used to insulate transmission lines from the tower and each other at lengths depending in the voltage to prevent electrical discharges between wires and the tower.
Metal tower	Being metal, and set deeply into the ground, the tower itself is an earth protection against lightning strikes.
Distance between towers	The distance between towers is at least 150 m, which is enough to protect each tower from adjacent towers in case one is hit by lightning.

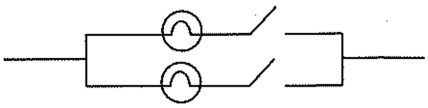
Set 59 Circuits in Homes

1. (a) Lighting circuits, power circuits and dedicated circuits.
(b) Lights and different appliances require different amounts of current to operate efficiently and safely. Dedicated circuits, for one appliance only carry significantly large currents (say 40 A).
(c) Lighting circuits supply energy for all lights.
Power circuits supply energy for appliances plugged into them.
Dedicated circuits provide specific currents for the particular appliance they are connected to.
(d) No. A different circuit will be needed for each appliance which requires larger currents.
(e) Because the wiring in a dedicated circuit carries a higher current, the wire used should be thicker to reduce its resistance and minimise heating effects. It may also be covered by thicker insulating material (safer) of a different colour to distinguish it from the wiring used in lighting and power circuits (again, a safety precaution for electricians doing repairs).

2. (a) None are in series although some components within them (like strings of fairy lights) may be connected in series. All circuits in homes are in parallel with all other circuits so that they operate independently of each other.
(b) All circuits are connected in parallel with each other so that if there is a problem in one circuit it does not affect other circuits.

3. (a) 40 (Determine the current in each first = 0.25 A then × ? = 10.)
(b) 96 would draw 10 amps and be right on the limit to pop the breaker. Even 94 or 95 bulbs would be too close, so less than 94 would be safer.
(c) The circuit would draw too much current from the mains and overheat the fuse/circuit breaker, causing them to break the circuit.
(d) More than one lighting circuit would need to be wired into the house. Most homes have two or three separate lighting (and power) circuits.

4. From $P = VI$
Total power = 240 × 15 = 3600 W

5. (a) They have been wired in parallel so they can have separate switches for independent use.
(b)


Science Press

6. (a) 4

(b) The toaster, the TV, the rice cooker, and either the kettle or the coffee machine.

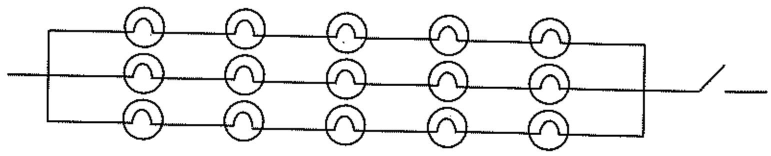
(c) 2

(d) The frypan and either the kettle or the coffee machine.

7. (a) This string will contain 15 parallel connections, each parallel line having 20 fairy globes in it.

(b) The parallel arms mean that if one globe blows, only one of the 15 arms will go out. The other 280 lights will stay on. The reason they are not all in parallel is because of the huge amount of wiring required to do this and their cost would no longer be cheap.

(c)



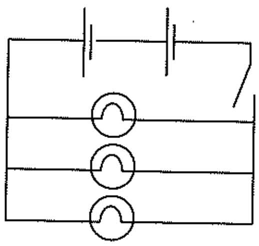
8. (a) To get hot and melt when current exceeds the maximum value for the circuit, or during a sudden short overload, and so protect the home by not allowing the circuit wires in the walls to overheat and cause fires and to protect people from electrocution if some fault occurs in an appliance they are using.

(b) To switch off when current exceeds the maximum value for the circuit, or during a sudden short overload, and so protect the home by not allowing the circuit wires in the walls to overheat and cause fires and to protect people from electrocution if some fault occurs in an appliance they are using.

(c) Circuit breakers respond almost immediately – say 30 ms – to a large current fluctuation whereas fuses need time to melt and cut the circuit. People can still be electrocuted while a fuse melts but unlikely to be if circuit breakers are used.

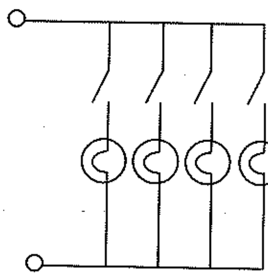
9. (a) The switch is in series with the power supply, but each of the lights is connected parallel to each other light.

(b)



(c) 4

(d)



10. (a) In room X, the swtich turns on both lights at the same time, one light only cannot be turned on. In room Z either light can be turned on and/or off independently of the other. In both cases the switches are connected in series with the lights.

(b) In all rooms, and within rooms X and Z, the lights are connected in parallel to each other.

(c) They are connected this way so that if one globe blows all the others still stay on.

(d) No, because they are connected in parallel to each other.

11. (a) X = lighting circuit

Y = power circuit

Z = dedicated circuit

(b) All connected in parallel to each other in X and Y. In circuit Z it is really a non-question because dedicated circuits only contain a single appliance which is connected in series to its switch and power supply.

(c) Hot water system, air conditioner, oven.

(d) For safety purposes in preventing the overload of a single circuit and convenience in that if the lights go out the Game Boy can still be played.

12. (a) Lights = E and F

(b) Power = H, I, J

(c) Dedicated = B, C, D

(d) It is the main switch to cut power off from the entire house without having to turn off the individual circuits.

(e) The home has a solar hot water system.

(f) The switch will need to be turned on in extended periods of rain or cloud which lowers the efficiency of the solar system.

(g) G is the circuit breaker reset switch. If any circuit in the home causes any individual circuit (lighting power or dedicated) to throw and turn off the power to that circuit, the main circuit breaker switch resets the circuit breaker to restore power to that circuit.

(h) All electricity to the home is turned off.

(i) Fuses work when an overload of current causes the fuse wire to get hot and melt. This takes significantly longer than it takes a circuit breaker to 'throw'. Durng this time a person may be electrocuted. They are therefore not as safe.

(j) The older style fuses are much larger than circuit breakers, so the fuse panel would be significantly larger.

Set 60 Energy Efficiencies of Light Sources

1. (a) Loss of energy as heat energy
   (b) Filament with a high resistance gets white hot as current flows through it and gives off light.
   (c) High energy electromagnetic. UV photons given off by excited mercury atoms cause the phosphor coating on the inside of the tube to emit visible light.
   (d) 600 lumens
   (e) 2000 to 4000 lumens
   (f) The term excited mercury atoms refers to electrons in the atoms being 'excited' or absorbing energy and moving to a higher orbital position. When they fall back to their original positions, they emit the high frequency electromagnetic radiation, i.e. UV.
   (g) The energy of a photon is directly proportional to its frequency ($E = hf$ where h = Planck's constant). High frequency is needed to have enough energy to 'excite' the phosphor atoms sufficiently to produce visible light.
   (h) Electrons in the atoms of the phosphor are 'excited' or absorb energy and move to a higher orbital position. When they fall back to their original positions, they emit the visible light which is at a lower frequency than UV.
2. (a) LEDs. They are the most efficient at producing light, have the lowest carbon emissions, last longer so despite being more expensive to buy, in the long term may be more economical for the consumer, are durable and do not contain toxic mercury.
   (b) It is part of a much wider strategy to reduce carbon emissions and the greenhouse effect.
3. (a) LED > CFL > Halogen > Incandescent.
   (b)

	Power input (Watts, W)							
Light output (lumens, lm)	Incandescent bulb	Efficiency (lm W^{-1})	Compact fluorescent bulb (CFL)	Efficiency (lm W^{-1})	240 V halogen bulb	Efficiency (lm W^{-1})	Light emitting diode (LED)	Efficiency (lm W^{-1})
220	25	8.8	5 to 7	44 to 31.4	18	12.2	2 to 3	110 to 73.3
450	40	11.25	8 to 13	56.3 to 34.6	28	16.1	4 to 5	112.5 to 90
800	60	13.33	13 to 15	61.5 to 53.3	42	19.0	6 to 8	133.3 to 100
1100	75	14.67	18 to 25	61.1 to 44	52	21.2	9 to 13	122.2 to 84.6
1600	100	16.0	23 to 30	69.6 to 53.3	70	22.9	16 to 20	100 to 80
2600	200	13.0	30 to 55	86.7 to 47.3	140	18.6	25 to 28	104 to 92.9

   (c)

Complete for power output 25 W	Incandescent bulb compared to	CFL compared to	240 V halogen bulb compared to	LED compared to
Incandescent bulb		5 to 3.6	1.39	12.5 to 8.33
CFL	0.2 to 0.28		0.28 to 0.39	3.5 to 1.67
240 V halogen bulb	0.72	9.6 to 2.57		6.1 to 4.07
LED	0.08 to 0.12	0.6 to 0.29	0.11 to 0.17	

   (d)

Complete for power output 100 W	Incandescent bulb compared to	CFL compared to	240 V halogen bulb compared to	LED compared to
Incandescent bulb		4.35 to 3.33	1.43	6.25 to 5.0
CFL	0.23 to 0.3		0.33 to 0.43	1.5 to 1.88
240 V halogen bulb	0.7	3.04 to 2.33		4.37 to 3.49
LED	0.16 to 0.2	0.53 to 0.87	0.23 to 0.29	

   (e) There is no clear trend as some globes have increased efficiency compared to some others at higher wattage and vice versa.
   (f) The prediction is not very reliable as only two different wattages have been compared, and the results vary too much for a stable prediction to be made.
4.

Type of bulb	Incandescent	Compact fluorescent (CFL)	240 V halogen	Light emitting diode (LED)
Equivalent wattage (W)	60	13 to 15	42	6 to 8
Cost	$35.48	$7.69 to $8.87	$24.83	$3.55 to $4.73

Set 61 Impacts of Electricity

1. When answering 'impact' questions, give at least two examples and then decide how they affect you and then what other things you can do because of them ... many possible answers, e.g. Electricity allows the use of computerised games and learning (1). This provides entertainment at home and opportunities to reinforce school work (1). This can lead to better results at school and better employment opportunities down the track (1). These in turn will allow a better adult lifestyle (1). Or,

   The domestic use of electricity has enabled me to use many building tools and learn many carpentry skills (1). This has provided a hobby for leisure time as well as allowing me to build useful items which I might otherwise either not have or have to pay for (1). This leaves my pocket money free for other pursuits (1). In the future these skills may save money in adult life allowing for available money to be used on other things – clothes, education for children, leisure activities (1).

2.
- Easy to transform, and therefore
- Can be transmitted over large distances with minimum energy loss.
- AC motors and generators have fewer moving parts, so cheaper and less maintenance.
- Ability to transform it makes it versatile for different appliances using different voltages from same power source.
- No sparking in generation or motors, so less electrical interference associated with use.

3. Again – many possible answers – for example:

The major impacts electricity has had centre on its use to transmit high voltage/low current electricity to consumers and its ability to be transformed for use in various workplace and domestic appliances requiring higher or lower voltage than the transmitted 240 V. (1)

Lifestyles for people have changed through the use of power tools at home, saving money on hiring others to do maintenance work (1), or in the labour saving devices in the kitchen and home – e.g. frypans, ovens, hotplates, mixers, vacuum cleaners – all which would not be available without the transmission and transformation of AC current to the correct voltages/currents. (1)

Home power tool appliances have, in turn, enabled people to save money and therefore be able to spend on different aspects of life – e.g. leisure, food, education, clothes. (1)

In addition, leisure activities centred around the use of electricity – e.g. TV, CDs, computers, Play Stations, electric trains. (1) – again, all dependent on transformed electricity, have added to the quality of people's lives. (1) Transformers allow transmission of AC over large distances at high voltage and low current and so minimise energy losses. This makes transmission to isolated areas more efficient and has changed the lifestyle of people in these areas drastically as they have all the advantages of electrical power that city people have. (2)

4. Atmospheric pollution has increased enormously as more and more demand for electrical power has been met over the years (1). This will have contributed to asthma problems for many people and reduced the quality of their lifestyle (1), directed available money into medical expenses and reduced spending on other areas such as leisure activities or consumables (1).

Pollution from the burning of fossil fuels to work steam turbines produces heat pollution as well as air pollution (1). Heat pollution from coolant water into natural streams has affected water life adversely. This reduces the ability of all organisms in the waters to survive and affects the quality of the water (1). This in turn reduces the enjoyment many people get from water activities (fishing, swimming) and may have long-term effects on larger food chains (1).

Ugly powerlines crossing the countryside (1), ugly power poles and lines in streets also offering impact sites for accidents so increasing the death toll from transport accidents (1). Ugly transformers in substations and pole-mounted in streets (1). Possible harmful effects from high frequency electromagnetic radiations associated with high AC voltage transmission (1). There is visual pollution due to the transmission lines and towers across the landscape.

The construction of these towers and lines requires the clearing of large corridors of forest and native scrublands and this reduces the habitats for native birds and animals as well as the lines themselves providing a hazard for birds and flying foxes.

The development of hydroelectricity schemes impacted severely on specific areas of the environment, requiring huge dams, flooding of forests, valleys and even towns, disruption to fish migration (1).

5. Many people claim that living near high voltage powerlines is causing a variety of health problems, in particular various forms of cancer including leukemia. (1) We know that our nervous system uses electrical impulses to transfer messages, but as yet we have no mechanism to measure the effects of high voltage electromagnetic radiation on it, or on body tissue. (1) Statisticians have recorded the incidence of various cancers and other diseases in people living under high voltage transmission lines, but currently find no or only very weak differences compared with people not living under these lines. (1) Scientists expose laboratory animals to high levels of high voltage radiation and observe the effects on them. So far, no conclusive results have been recorded (1).

Many people advocate that even the possibility of risk should be avoided. Just because there is no correlation now, who is to say there won't be in the future? (1) We should play it safe and avoid any exposure that could cause problems. To this effect, the power industry is attempting to place transmission lines away from populated areas – but they must eventually enter the towns and cities, so easements (strips of land banned to public access) are regulated to stop people approaching the lines too closely. (1)

Regulations controlling the maximum exposure workers and the public should experience are being developed by bodies like the World Health Organisation and various standards laboratories. These are being implemented by local, state and federal governments in many countries. (1)

Set 62 Scientists Building on Ideas

1. (a) Thomson showed by deflecting cathode rays with both magnetic and electric fields that they were negatively charged particles, and by determining the ratio of their charge to mass showed that they were a previously undiscovered particle. By assuming that their charge was the same magnitude as that of the hydrogen ion, he calculated their mass to be 1.11×10^{-31} kg. He then proposed that they were the particles hypothesised by George Stoney to be responsible for current electricity. They had been named by Stoney as 'electrons'. So Thomson provided details about the nature of cathode rays and linked them as being responsible for electricity. Thomson also produced the plum pudding model of the atom to account for the presence of the electrons in atoms.

(b) Millikan determined the minimum charge carried by charged oil drops and proposed that this was the charge carried by the electron and that all other electric charges were simple multiples of this charge.

(c) Faraday invented the electric motor and accidentally discovered the electric generator, both huge contributions to the developing science of electricity. His induction ring (1831) was the first transformer; although AC technology had not developed to the point that this application was recognised. His experiments with electrolysis linked electrical currents through ionic solutions to the valance electrons from the elements involved. He determined that the amount of electricity needed to form one atomic mass of an element was a constant.

2. Thomson's work (1897) used the technology of the vacuum tube developed by Geissler (1855), and the work of numerous scientists who were attempting to determine the nature of cathode rays before Thomson. Thomson also connected his work to the work of George Stoney who was experimenting with current electricity (1891).

Millikan (1909) equated the downwards gravitational force acting on a charged oil drop (Newton – mid 1600s) to the upwards force produce by an applied electric field (Robert Boyle, 1675) and needed a microscope (Hans Lippershey, 1500s) to make his observations.

Faraday (1831) discovered the induction of electricity in a wire by the effects of electromagnetic radiation from the current in another wire. This ring he used was similar to that used by Hertz (1887) when he discovered radio waves – the first band of the electromagnetic spectrum to be found apart from visible light. Faraday (1839) was also the first to propose that static, current and bioelectricity were not separate things, building on the work of William Gilbert (1600), Stephen Gray (1729) and C F Du Fay (1739), among others. Faraday's first recorded experiment (1812) was as a student assistant to Humphry Davy in building the first voltaic pile (battery).

3. (a) The controversy was whether cathode rays were particles or waves.

(b) It existed because cathode rays were seen to be deflected by magnetic fields (which indicated that they must be charged and therefore must be particles, because waves cannot carry a charge), but were not seen to be deflected by electric fields (which contradicted the first observations).

(c) Thomson was the first scientist to observe the deflection of cathode rays by both magnetic and electric fields, thus confirming their particle nature.

4. (a) He used both magnetic field and electric field deflection apparatus. Previous scientists had used only one or the other.

(b) He deflected the rays using electric fields then cancelled that deflection using a magnetic field. He could then say that the net force on the rays was zero, therefore:

$$F_{\text{electric}} = qE = F_{\text{magnetic}} = Bqv$$

Therefore $v = E/B$

(c) He then deflected the rays using only the magnetic field and measured the radius of curvature of the circular path they traced out. He then represented the magnetic force as a centripetal force:

$$F_B = Bqv = F_{\text{centripetal}} = mv^2/r$$

Then, substituting for v, and rearranging, he came up with the expression:

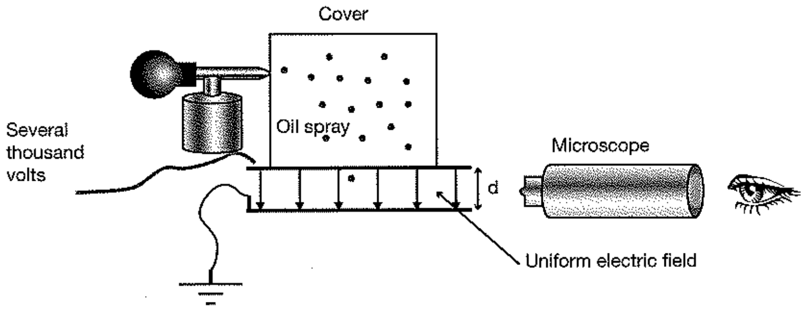
$$q/m = E/(B^2r)$$

(d) The value Thomson obtained for the ratio q/m was 1836 times larger than that determined for hydrogen. This indicated that it was a new and much smaller particle.

(e) Thomson assumed that the charge on cathode rays would be the same as the charge on hydrogen ions, and determined their mass to be 1.1×10^{-31} kg. He also assumed that they were most likely to be the same as the particles proposed by George Stoney as responsible for current electricity. Stoney had named these particles 'electrons'.

5. Millikan sprayed oil drops into an evacuated space. This ensured the drops were small, and that they gained an electrostatic charge as they left the sprayer. They were allowed to fall in the space between parallel electric plates and the voltage was then adjusted to hold them between the plates motionless.

At this point their weight force downwards, mg, was balanced by the electric field upwards, qE. The magnitude of the charges on the drops was calcualed from $mg = qE$ and was found to be integral multiples of 1.9×10^{-19} C.



6. (a) $V = 4/3(\pi r^3) = 4/3 \times \pi \times (0.75 \times 10^{-3})^3 = 1.77 \times 10^{-9}$ m^3

(b) From $D = m/V$

$m = D \times V = 0.75 \times 10^{-3} \times 10^{-6} \times 1.77 \times 10^{-9} = 1.33 \times 10^{-18}$ kg

(c) From $mg = Eq = Vq/d$

$V = mgd/q = 1.33 \times 10^{-18} \times 9.8 \times 0.025/(4 \times 1.6 \times 10^{-19}) = 5.09 \times 10^{-1}$ V

(d) From $mg = Eq = Vq/d$

$q = mgd/V = 1.33 \times 10^{-18} \times 9.8 \times 0.025/2.04 = 1.6 \times 10^{-19}$ C

7. (a) Result (ii) is incorrect as it is not a multiple of the charge on the electron.

(b) If all results were assumed to be correct, then he may have concluded that the basic (smallest) unit of charge was 8×10^{-19} C because this is the highest common multiple for all these readings.

8. $\frac{Q}{12}$ (Need to find the volume and mass of the drop first, then use $mg = QV/d$ where $m = 0.125$ the mass of the original drop and solve for new value of Q.)

9. (a) One coulomb of electric charge is equal to the charge on 6.25×10^{18} electrons.
(b) One mol of a substance is equal to the molar mass of the substance expressed in grams.
(c) One mol of a substance is equal to 6.023×10^{23} atoms or molecules of that substance.
(d) 6.023×10^{23} electrons
(e) 96 368 coulombs (Note that this is often rounded to 96 400, or in some texts, 96 500.)
(f) $2 \times 6.023 \times 10^{23} = 1.2046 \times 10^{24}$ electrons
(g) $2 \times 96\,368 = 192\,736$ coulombs

10. (a) The mass of a substance deposited or dissolved at an electrode during electrolysis is directly proportional to the quantity of electricity transferred at that electrode. Quantity of electricity refers to the quantity of electrical charge, measured in coulombs.
Mass proportional to (charge = current × time)
Therefore mass = constant × $It = Z \times I \times t$
Where Z = the electrochemical equivalent for the substance involved.
(b) The electrochemical equivalent is the mass of the substance deposited (or dissolved) by one coulomb of charge or by one ampere of current passed for one second, measured in kg C^{-1}.
(c) The amount of silver reacting at an electrode during electrolysis when one coulomb of charge is passed through the solution is 0.00112 g. The value of the electrochemical equivalent, Z, of silver is therefore 1.12×10^{-6} kg C^{-1}.
(d) The chemical equivalent of a substance, E, is its electrochemical equivalent expressed in g C^{-1}.
(e) $E = 0.00112$ g C^{-1}
(f) $Z = 5.6 \times 10^{-7}$ kg C^{-1}
(g) $E = 0.00056$ g C^{-1}
(h) Silver with valency 2 requires 2 electrons per atom for reaction, so the coulomb of charge can only involve half as many atoms or ions.

$$\text{Chemical equivalent} = E = \frac{\text{atomic mass}}{96\,400 \times \text{valency}}$$

(i) If the same quantity of electricity is passed through different electrolytes, masses of the substance deposited at the respective cathodes are directly proportional to their chemical equivalents.
$m_1/m_2 = E_1/E_2$
(j) 96 400 represents the number of coulombs required to provide an electric charge equivalent to one mol of electrons. This is referred to as one faraday, symbol F, of electrical charge.

11. Galvani applied the two terminals of an electrostatic machine to dissected frogs legs – the muscles in the legs contracted. He then noticed that the frog's legs contracted if he was touching them with a piece of metal and his electrostatic machine was working somewhere close in his laboratory. He noticed the same contractions during lightning storms provided he was probing the muscle with a piece of metal, such as a scalpel.

In further experiments he noticed that even without the static machine working, if two different metals in contact with each other touched the frog's legs the muscles would also contract. He believed that he was detecting animal electricity generated in the frog's tissue.

12. Volta hypothesised that the source of the electricity Galvani was detecting was the two metals. His idea was that was no such thing as animal electricity – the frog tissue was detecting electricity produced by the metals.

To test his idea, Volta built a voltaic pile – a stack of alternating zinc and brass discs each separated by a disc of cardboard soaked in salt solution. He used the cardboard/salt solution to improve the contact between the discs. He connected two conducting wires to the top and bottom of the stack.

When he touched the ends of the two wires together, he produced sparks. The more discs he used, the stronger the sparks were. The pile continued to produce sparks no matter how many times the wires were touched together. No animal tissue was involved.

13. Galvani thought the source of the electricity was generated within the tissue of the animal – possibly its *life force* – the thing that distinguished living organisms from non-living things.

Volta's idea was that the electricity was generated because two different metals were placed in contact with each other.

14. Both scientists contributed to our understanding of electricity in that they both stimulated other scientists to check and follow up on their work – they aroused the interest of the scientific community. Even though both interpreted their observations incorrectly, Volta's experiments actually did discover a source of electricity from chemical reactions – he just failed to recognise this. His experiments could be regarded as the start of the technology that has since developed batteries, dry cells, solar cells, electrolysis, and many other applications of chemical electricity.

Set 63 Energy Efficiencies of Batteries

1. (a) Carbon-zinc, alkaline cells, nickel-cadmium, nickel metal hydride, lithium.
(b) A battery is a series connection of two or more 1.5 V cells.
(c) Wet and dry cells are classified by the type of electrolyte the battery uses. If the electrolyte is a paste, the cell is referred to as a dry cell. If the electrolyte is a solution, the cell is called a wet cell.
(d) All batteries fall into one of two categories, primary cells and secondary cells. Primary batteries can only be used once and secondary batteries can be recharged repeatedly up to a point.

2. (a) In carbon-zinc cells the carbon is a rod in the centre of the cell and acts as the positive terminal. The case is made from zinc and acts as the negative electrode. The electrolyte is a chemical paste-like mixture between the carbon electrode and the zinc case. When connected into a circuit, current flows through the external circuit as chemical reactions between the electrodes and the electrolyte paste take place.

(b) They are durable not in terms of long lasting but robust and operate in any position and are very inexpensive to produce.

(c) They do not last as long as most other batteries before becoming 'flat'.

3. (a) The alkaline cell is so called because it has an alkaline electrolyte of very pure potassium hydroxide.

(b) Alkaline cells have a longer operating life than a carbon-zinc cell of the same size.

(c) It depends on your definition of 'better'. Alkaline cells are more expensive to manufacture and therefore to buy. Some people may consider this a disadvantage.

4. (a) The cadmium is toxic to the environment, and the batteries have a significant memory effect problem.

(b) Nickel metal hydride cells have largely replaced Ni-Cd cells.

(c) The 'memory effect', refers to the problem that if the battery if not fully discharged, it 'remembers' the level of the discharge and only discharges to that level when recharged in the future.

5. (a) Lithium-ion batteries.

(b) Lithium-ion batteries also have low self-discharge and do not suffer significantly from the memory effect. Their composition is also non-hazardous to the environment.

6. (a) It is communicating that Topjob batteries last 8 times longer than their average competitors and cost up to 10 times less to buy and use.

(b) The names of the average competitors have not been given. This could mean that only very poor batteries have been used in the comparison study.

If the report has been produced by Topjob and not an independent body, the data could be biased in favout of Topjob.

No controls have been mentioned – were the batteries used in identical appliances for example – if not, then the results are invalid.

(c) There is no indication that the comparison between the batteries has been made through any type of study, let alone a controlled, scientific study.

7. (a)

Battery	Voltage loss after 10 hours	Voltage loss after 10 hours (%)
A	0.1	6.15
B	0.11	6.43
C	0.12	7.45
D	0.05	2.76
E	0.08	5.19
F	0.08	4.73

(b)

Battery	Voltage loss after 20 hours	Voltage loss after 20 hours (%)
A	0.24	14.7
B	0.30	17.5
C	0.33	20.5
D	0.28	15.5
E	0.22	14.3
F	0.23	13.6

(c) The total voltage loss figures after 20 hours suggest that battery F will last longer than battery D. If you take into account the accelerated loss of voltage in battery D from 10 hours to 20 hours, then if this trend continues, battery F will definitely last longest with E a close second.

(d) Definitely battery C. The figures suggest that it will be below 1.00 V after about 45 hours. If the rate of discharge increases as it did from 10 hours to 20 hours, then it will last far less time than this.

Data Sheet

Acceleration of free fall, g	9.81 m s^{-2}
Gravitational constant, G	$6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
Avogadro constant, N_A	$6.02 \times 10^{23} \text{ mol}^{-1}$
Gas constant, R	$8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Boltzmann constant, k	$1.38 \times 10^{-23} \text{ J K}^{-1}$
Stefan-Boltzmann constant, s	$5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$
Coulomb constant, k	$8.99 \times 10^{9} \text{ N m}^2 \text{ C}^{-2}$
Permittivity of free space, e_0	$8.85 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$
Permeability of free space, m_0	$4\pi \times 10^{-7} \text{ T m A}^{-1}$
Speed of light in a vacuum, c	$3.00 \times 10^{8} \text{ m s}^{-1}$
Planck constant, h	$6.63 \times 10^{-34} \text{ J s}$
Elementary charge, e	$1.60 \times 10^{-19} \text{ C}$
Electron rest mass, m_e	$9.110 \times 10^{-31} \text{ kg} = 0.000549 \text{ u} = 0.511 \text{ MeV } c^{-2}$
Proton rest mass, m_p	$1.673 \times 10^{-27} \text{ kg} = 1.007276 \text{ u} = 938 \text{ MeV } c^{-2}$
Neutron rest mass, m_n	$1.675 \times 10^{-27} \text{ kg} = 1.008665 \text{ u} = 940 \text{ MeV } c^{-2}$
Atomic mass unit, u	$1.661 \times 10^{-27} \text{ kg} = 931.5 \text{ MeV } c^{-2}$

1 light year (ly) = 9.46×10^{15} m

1 parsec (pc) = 3.26 ly

1 astronomical unit (AU) = 1.50×10^{11} m

1 radian (rad) = $\frac{180°}{\pi}$

1 kilowatt hour (kWh) = 3.60×10^{6} J

1 atm = $1.01 \times 10^{5} \text{ N m}^{-2}$ = 101 kPa = 760 mmHg

Equations

Heating Processes

- $Q = mc\Delta T$
  Q = heat transferred to or from the object, m = mass of object, c = specific heat capacity of the object, ΔT = temperature change
- $Q = mL$
  Q = heat transferred to or from the object, L = latent heat capacity of the material, m = mass of object
- $\eta = \dfrac{\text{energy output}}{\text{energy input}} \times \dfrac{100}{1}\%$
  η = efficiency

Ionising Radiation and Nuclear Reactions

- $N = N_0(\frac{1}{2})^n$ (for whole numbers of half-lives only)
  N = number of nuclides remaining in a sample, n = number of whole half-lives, N_0 = original number of nuclides in the sample
- $\Delta E = \Delta mc^2$
  ΔE = energy change, Δm = mass change, c = speed of light (3×10^8 m s^{-1})

Electrical Circuits

- $I = \dfrac{\Delta q}{t}$
  I = current, Δq = the amount of charge that passes a point in the circuit, t = time interval
- $V = \dfrac{W}{q}$
  V = potential difference, W = work, q = charge
- $R = \dfrac{V}{I}$
  R = resistance, V = potential difference, I = current
  For ohmic resistors, resistance, R, is a constant
- $P = \dfrac{W}{t} = VI$
  P = power, W = work = energy transformed, t = time interval, V = potential difference, I = current
  - Equivalent resistance for series components, I = constant
  - $V_t = V_1 + V_2 + \ldots V_n$
  - $R_t = R_1 + R_2 + \ldots R_n$

  I = current, V_t = total potential difference, V_n = the potential difference across each component, R_t = equivalent resistance, R_n = resistance of each component
  - Equivalent resistance for parallel components, V = constant
  - $I_t = I_1 + I_2 + \ldots I_n$
  - $\dfrac{1}{R_t} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots \dfrac{1}{R_n}$

  V = potential difference, I_t = total current, I_n = current in each of the components, $\dfrac{1}{R_t}$ = the reciprocal of the equivalent resistance, $\dfrac{1}{R_n}$ = the reciprocal of the resistance of each component

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium						

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Elements with atomic numbers 113 and above have been reported but not fully authenticated.
Standard atomic weights are abridged to four significant figures.
Elements with no reported values in the table have no stable nuclides.