Physics
ATAR Year 11
Unit 1 Exam Revision

Name: ________________________

Physics ATAR Year 11, Unit 1 Exam Revision

The following is from the Western Australia School Curriculum and Standards Authority. It has been shortened to show the Unit 1 indicators of the Year 11 Physics course.

Unit 1 – Thermal, nuclear and electrical physics

Unit content

Science as a Human Endeavour

Heating processes

The development of heating technologies that use conduction, convection, radiation and latent heat have had, and continue to have, significant social, economic and environmental impacts. These technologies include:

- passive solar design for heating and cooling of buildings
- the development of the refrigerator over time
- the use of the sun for heating water
- engine cooling systems in cars.

Science Understanding

Heating processes

- the kinetic particle model describes matter as consisting of particles in constant motion, except at absolute zero
- all substances have internal energy due to the motion and separation of their particles
- temperature is a measure of the average kinetic energy of particles in a system
- provided a substance does not change state, its temperature change is proportional to the amount of energy added to or removed from the substance; the constant of proportionality describes the heat capacity of the substance

  This includes applying the relationship
  $Q = mc\Delta T$
- change of state involves separating particles which exert attractive forces on each other; latent heat is the energy required to be added to or removed from a system to change the state of the system

  This includes applying the relationship
  $Q = mL$
- two systems in contact transfer energy between particles so that eventually the systems reach the same temperature; that is, they are in thermal equilibrium. This may involve changes of state as well as changes in temperature
- a system with thermal energy has the capacity to do mechanical work [to apply a force over a distance]; when work is done, the internal energy of the system changes

- because energy is conserved, the change in internal energy of a system is equal to the energy added by heating, or removed by cooling, plus the work done on or by the system
- heat transfer occurs between and within systems by conduction, convection and/or radiation
- energy transfers and transformations in mechanical systems always result in some heat loss to the environment, so that the usable energy is reduced and the system cannot be 100 percent efficient

  This includes applying the relationship

$$\text{efficiency} \quad \eta = \frac{\textit{energy output}}{\textit{energy input}} \times \frac{100}{1}\ \%$$

Science as a Human Endeavour

Ionising radiation and nuclear reactions

Qualitative and quantitative analyses of relative risk (including half-life, absorbed dose, dose equivalence) are used to inform community debates about the use of radioactive materials and nuclear reactions for a range of applications and purposes, including:

- radioisotopes are used as diagnostic tools and for tumour treatment in medicine
- nuclear power stations employ a variety of safety mechanisms to prevent nuclear accidents, including shielding, moderators, cooling systems and radiation monitors
- the management of nuclear waste is based on the knowledge of the behaviour of radiation.

Science Understanding

Ionising radiation and nuclear reactions

- the nuclear model of the atom describes the atom as consisting of an extremely small nucleus which contains most of the atom's mass, and is made up of positively charged protons and uncharged neutrons surrounded by negatively charged electrons
- nuclear stability is the result of the strong nuclear force which operates between nucleons over a very short distance and opposes the electrostatic repulsion between protons in the nucleus
- some nuclides are unstable and spontaneously decay, emitting alpha, beta (+/-) and/or gamma radiation over time until they become stable nuclides
- each species of radionuclide has a half-life which indicates the rate of decay

  This includes applying the relationship

$$N = N_0 \left(\frac{1}{2}\right)^n$$

- alpha, beta and gamma radiation have different natures, properties and effects
- the measurement of absorbed dose and dose equivalence enables the analysis of health and environmental risks

  This includes applying the relationships

$$\text{absorbed dose} = \frac{E}{m}, \qquad \text{dose equivalent} = \text{absorbed dose} \times \text{quality factor}$$

- Einstein's mass/energy relationship relates the binding energy of a nucleus to its mass defect

  This includes applying the relationship

  $$\Delta E = \Delta m\, c^2$$

- Einstein's mass/energy relationship also applies to all energy changes and enables the energy released in nuclear reactions to be determined from the mass change in the reaction

  This includes applying the relationship

  $$\Delta E = \Delta m\, c^2$$

- alpha and beta decay are examples of spontaneous transmutation reactions, while artificial transmutation is a managed process that changes one nuclide into another
- neutron-induced nuclear fission is a reaction in which a heavy nuclide captures a neutron and then splits into smaller radioactive nuclides with the release of energy
- a fission chain reaction is a self-sustaining process that may be controlled to produce thermal energy, or uncontrolled to release energy explosively if its critical mass is exceeded
- nuclear fusion is a reaction in which light nuclides combine to form a heavier nuclide, with the release of energy
- more energy is released per nucleon in nuclear fusion than in nuclear fission because a greater percentage of the mass is transformed into energy

Science as a Human Endeavour

Electrical circuits

The supply of electricity to homes has had an enormous impact on society and the environment. An understanding of electrical circuits informs the design of effective safety devices for the safe operation of:

- lighting
- power points
- stoves
- other household electrical devices.

Science Understanding

Electrical circuits

- there are two types of charge that exert forces on each other
- electric current is carried by discrete charge carriers; charge is conserved at all points in an electrical circuit

  This includes applying the relationship

  $$I = \frac{q}{t}$$

- energy is conserved in the energy transfers and transformations that occur in an electrical circuit

- the energy available to charges moving in an electrical circuit is measured using electric potential difference, which is defined as the change in potential energy per unit charge between two defined points in the circuit

  This includes applying the relationship

  $$V = \frac{W}{q}$$

- energy is required to separate positive and negative charge carriers; charge separation produces an electrical potential difference that drives current in circuits
- power is the rate at which energy is transformed by a circuit component; power enables quantitative analysis of energy transformations in the circuit

  This includes applying the relationship

  $$P = \frac{W}{t} = V\,I$$

- resistance depends upon the nature and dimensions of a conductor
- resistance for ohmic and non-ohmic components is defined as the ratio of potential difference across the component to the current in the component

  This includes applying the relationship

  $$R = \frac{V}{I}$$

- circuit analysis and design involve calculation of the potential difference across the current in, and the power supplied to, components in series, parallel, and series/parallel circuits

  This includes applying the relationships

  series components, I = constant, $V_t = V_1 + V_2 + V_3$ ....
  $R_t = R_1 + R_2 + R_3$ ....

  parallel components, V = constant, $I_t = I_1 + I_2 + I_3$ ....

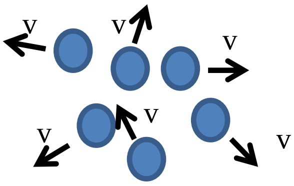
  $$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots$$

- there is an inherent danger involved with the use of electricity that can be reduced by using various safety devices, including fuses, residual current devices (RCD), circuit breakers, earth wires and double insulation
- electrical circuits enable electrical energy to be transferred and transformed into a range of other useful forms of energy, including thermal and kinetic energy, and light

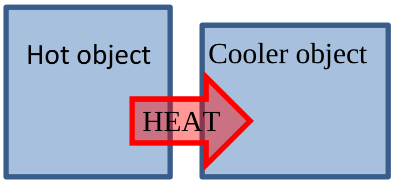
Heating Processes

Kinetic Molecular Theory states that all matter is made of atoms or molecules (particles) which are in constant motion.
In a solid the particles are vibrating about fixed positions. They vibrate more violently when the material is heated. If enough heat is applied the bonds between the particles are broken, the particles have more energy and can slide past each other. The solid has now changed to a liquid. More heat will give the particles more energy which makes them move faster. If particles receive enough heat they can gain enough energy to escape the liquid and become a gas.

Temperature is a measure of the average random kinetic energy of the particles in a body. Measured in degrees Celcius (ºC) or Kelvin (K).



Heat is a transfer of energy from one body to another due to a difference in temperature.
Heat is energy, measured in Joules (J)



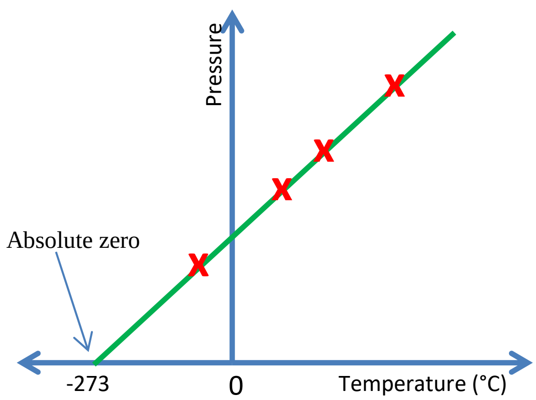
Internal Energy of a body is a measure of the total kinetic and potential energy stored in that body. Measured in Joules.

Note that internal energy depends on the mass and specific heat capacity of the body as well as its temperature. This means that the hottest object does not always have the highest internal energy.

The Celcius Scale uses the melting point of pure ice as zero and the boiling point of pure water as 100º.

The problem with the Celcius scale is that temperatures can be below zero so scientists tried to find what the lowest possible temperature could be.

They did this by changing the temperature of a gas while measuring the pressure.
Increasing temperature increases the speed of the particles so they hit the sides of the container harder and more often. This increases the pressure.
If the pressure decreases to zero, the particles are not moving so they have no heat energy at all. This will be the lowest possible temperature.



The Kelvin scale starts at absolute zero (-273ºC). The divisions of the Kelvin scale are the same size as those on the Celcius scale.

To convert Celcius to Kelvin: **K = ºC + 273**

Specific Heat Capacity (c) is the amount of heat required to raise the temperature of 1.00 kg of a substance by 1.00 ºC

Q = mcΔT

Q = heat energy (J)
m = mass of substance (kg)
c = specific heat capacity (J $kg^{-1}K^{-1}$)
ΔT = temperature change (K)

Latent Heat is the amount of heat required to change the state of 1.00 kg of a substance without any change in temperature.

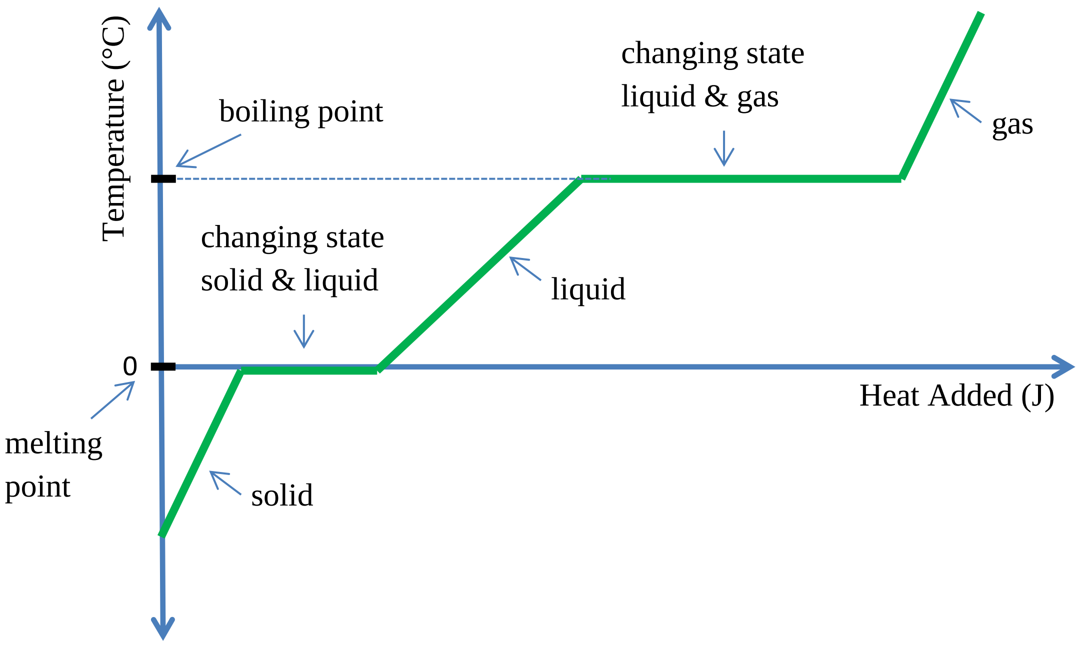
Q = mL

Q = heat energy (J)
m = mass (kg)
L = latent heat (Jkg^{-1})

There are two latent heat values for each substance.

- Latent heat of fusion (**L_f**) – solid → liquid
- Latent heat of vaporisation (**L_v**) – liquid → gas

The following graph is a heating curve which shows how the temperature of an object changes as heat is added.
This graph is used by scientists to determine the specific heat capacity and latent heat of a substance.



The gradient of the rises is related to the specific heat capacity, the steeper the rise, the lower the specific heat capacity.

The longer the flat sections, the greater the latent heat.

Evaporation causes a cooling effect. As a liquid is evaporated it must absorb heat (latent heat) from its surroundings. This principle is used in fridges, air conditioners, sweat cools us down, etc.

Thermal Equilibrium will result after a period of time if a hot object gives its heat energy to a cooler object.

Heat Lost (by hotter object) = Heat Gained (by cooler object)

Heat Transfer

- **Conduction** is the process of heat transfer without the transfer of the substance itself. Metals are very good conductors due to their free electrons.
- **Convection** is the transfer of heat energy due to the mass movement of a hot fluid (liquid or gas) from one place to another.
- **Radiation** is the transfer of heat energy by electromagnetic waves. This occurs mainly in the infra-red part of the electromagnetic spectrum.

You must be able to explain the role of each of these methods of heat transfer when explaining heating, and explain how each is reduced by insulation.

The table below contains values of specific heat capacity and latent heat for some materials commonly seen in calculations.

Specific Heat Capacity ($J\ kg^{-1}\ K^{-1}$)		Latent Heat ($J\ kg^{-1}$)
Water	4 180	Water
Steam	2 000	- Fusion 3.34×10^5
Ice	2 100	- Vaporisation 2.25×10^6
Copper	390	
Lead	130	Lead
Glass	840	- Fusion 2.51×10^4
Aluminium	880	
Air	1 000	Ethanol
Steel	445	- Fusion 1.05×10^5
Human body	3500	- Vaporisation 8.41 x 105

Power is also a measure of how quickly heat can be delivered

$$P = \frac{Q}{t}$$

P = Power (Watts – W)
Q = Heat Energy (Joules – J)
t = time (seconds)

$$\textbf{Efficiency (\%)} = \frac{\text{Useful Energy Output}}{\text{Energy Input}} \times 100$$

Exam Questions

Question 1 **(13 marks)**

A 45.5 g block of ice is heated from a temperature of -30.4 °C until it melts completely at 0.00 °C. Heat continues to be applied until the resulting liquid begins to boil at 1.00 x 10^2 °C.

(a) Calculate the amount of energy required to heat the block of ice from -30.4 °C until it begins to melt. (2 marks)

(b) Calculate the amount of energy required to melt the ice. (2 marks)

(c) Calculate the amount of energy required to heat the liquid from 0.00 °C to 1.00 x 10^2 °C. (2 marks)

(d) Once the liquid had reached its boiling point, calculate the amount of energy required to boil it all off. (2 marks)

(e) A Bunsen burner supplied all of the heat in this example. Briefly describe how you could estimate the power output of the Bunsen burner, indicating any additional measurements that may be required to make this estimation. (2 marks)

(f) If it was determined that the Bunsen burner had a power output of 1.24 kW, calculate the amount of time taken for the solid ice (which was initially at -30.4 °C) to be completely boiled off using this Bunsen burner. (3 marks)

Question 2 **(13 marks)**

A Styrofoam cup has a mass of 48.7 g. After water was added, the combined mass of the cup and the water was 167.3 g. The water had an initial temperature of 25.5 °C. A 23.2 g mass of a metal was heated to a temperature of 99.0 °C and added to the water in the cup. The water and the metal reached thermal equilibrium at a temperature of 26.8 °C.

(a) Calculate the specific heat of the metal. (5 marks)

(b) After the metal and water had reached thermal equilibrium, the metal was removed from the water and the metal and the water were both heated separately such that they each received an additional 555 J of heat energy. Assuming no heat energy is lost to the environment, when the metal is placed back in the water, will the metal and the water still be in thermal equilibrium? Explain your answer by including a calculation (if you did not determine the specific heat of the metal in part (a), use a value of 4.00×10^2 J kg^{-1} K^{-1}). (4 marks)

(c) If the Styrofoam cup was not a perfect insulator, how would this affect the determination of the specific heat capacity of the metal (assuming the temperature of the room was lower than that of any of the materials being used)? Explain your answer. (4 marks)

Question 3 **(11 marks)**

Many homes use solar energy to heat water. One design uses solar collectors to directly heat water by the sun. The heated water is then stored for later use. There are two main components to these types of solar hot water systems:

- A solar collector, through which water passes and absorbs thermal energy from the sun. The water typically runs through copper tubes, which transfer the sun's energy; and
- A storage tank that stores hot water from the solar collector.

(a) In one design, the storage tank is located above the solar collector. Water circulates from the collector to the storage tank without the use of a pump. Explain how this happens.

(3 marks)

(b) Calculate the internal energy of the water in the system if, over a period of an hour, the sun adds an amount of energy equal to 3.65 MJ to the water, but the system loses 1.40 MJ of its energy to the surroundings. (2 marks)

(c) Calculate the efficiency of the energy storage system from part (b). (2 marks)

(d) If the hot water system holds 3.00×10^{2} L of water, calculate the increase in temperature of the water in one hour if the system absorbs 3.45 kW of solar energy (assuming all efficiency losses have been taken into account).

(2 marks)

(e) Heating the water using an electrical heating element would consume 22.0 MJ of energy. If it costs 25.7c per kWhr, how much would it cost for the water to be heated to the same temperature using an electrical heating element. (2 marks)

Answers to Exam Questions

Question 1

(a) $\Delta Q = cm\Delta T$

$\Delta Q = (2100)(0.0455)(0 - (-30.4)) = 2904.72\ J = 2.90\ kJ$

(b) $\Delta Q = mL$

$\Delta Q = (0.0455)(334 \times 10^3) = 15197\ J = 15.2\ kJ$

(c) $\Delta Q = mc\Delta T$

$\Delta Q = (0.0455)(4180)(100 - 0) = 19019\ J = 19.0\ kJ$

(d) $\Delta Q = mL$

$\Delta Q = (0.0455)(2260 \times 10^3) = 102830\ J = 103\ kJ$

(e) The amount of energy to perform any one of the stages of the experiment has been calculated in the previous questions. If the amount of time was measured for at least one of these stages, the power of the Bunsen can be estimated using: P = E / t

(f) Calculate total energy needed to heat the solid (part (a)), melt the solid (part (b)), heat the liquid (part (c)), and boil off all the liquid (part (d)):

$Q_{total} = (a) + (b) + (c) + (d)$

$Q_{total} = 2.90 \times 10^3 + 15.2 \times 10^3 + 19.0 \times 10^3 + 103 \times 10^3 = 140.1\ kJ$ or $1.40 \times 10^5\ J$

P = E / t => t = E / P

$t = 140.1 \times 10^3 / 1.24 \times 10^3$

t = 112.98 s

t = 113 s or 1 minute 53 seconds

Question 2

(a) Mass of water = 167.3 - 48.7 = 118.6 g
Heat gained by the water = heat lost by the metal
$m_{water}c_{water}\Delta T_{water} = m_{metal}c_{metal}\Delta T_{metal}$
$(0.1186)(4180)(26.8 - 25.5) = -(0.0232)(c_{metal})(26.8 - 99)$
$644.472 = c_{metal}(1.67504)$
$c_{metal} = 644.472 / 1.67504 = 384.750\ J\ kg^{-1}\ K^{-1}$
(which roughly corresponds to the specific heat of zinc)
$c_{metal} = 385\ J\ kg^{-1}\ K^{-1}$

(b) The change in temperature is inversely proportional to the product of specific heat and the mass of the substance (i.e., $\Delta T = \Delta Q / mc$). Given that both the mass and the specific heat of the metal are smaller than that of the water, the temperature of the metal will increase more than the water if the same amount of energy is applied.

Specifically: For water: $\Delta Q = mc\Delta T$ => $\Delta T = \Delta Q / mc$
$\Delta T = 555 / (0.1186)(4180)$
$\Delta T = 1.12\ °C$

For metal: $\Delta Q = mc\Delta T$ => $\Delta T = \Delta Q / mc$
$\Delta T = 555 / (0.0232)(385)$
$\Delta T = 62.1\ °C$

(or $\Delta T = 59.8\ °C$ if the $4.00 \times 10^2\ J\ kg^{-1}\ K^{-1}$ value was used)

Therefore, if the same amount of heat energy is applied to each of the water and the metal, the metal will increase in temperature by a larger amount. The metal and the water will therefore not be in thermal equilibrium any longer.

(c) If the Styrofoam cup was not a perfect insulator, some heat energy will be lost to the environment and the equilibrium temperature (T_{final}) will not be as high.

From $m_{water}c_{water}\Delta T_{water} = m_{metal}c_{metal}\Delta T_{metal} \Rightarrow c_{metal} = m_{water}c_{water}\Delta T_{water} / m_{metal}\Delta T_{metal}$

Reduction in equilibrium temperature (i.e., T_{final}) means that ΔT_{water} will be smaller, and ΔT_{metal} will be greater => c_{metal} will appear to be smaller than it really is.

Question 3

(a) The warmer water will be less dense as the particles have moved further apart from each other due to thermal expansion. This warmer water will be displaced by the denser colder water and will therefore be pushed upwards to the storage tank

(b) $\Delta Q_{internal} = W_{work\ done} - \Delta Q_{lost}$

$\Delta Q_{internal} = 3.65 \times 10^6 - 1.40 \times 10^6 = 2.25$ MJ

(c) Efficiency = useful work done (i.e., energy stored) / energy input x 100%

Efficiency = $2.25 \times 10^6 / 3.65 \times 10^6 \times 100\% = 61.6\%$

(d) m_{water} = 300 kg (1 L = 1 kg of water)

$E = Pt = 3.45 \times 10^3 \times (60 \times 60) = 12.42$ MJ

$\Delta Q = mc\Delta T \Rightarrow \Delta T = \Delta Q / mc = 12.42 \times 10^6 / (300)(4180) = 9.90$ °C

(e) 1 kWhr = 1000 x (60)(60) = 3.6 MJ

Cost = (22 / 3.6) x \$0.257 = \$1.57

Or

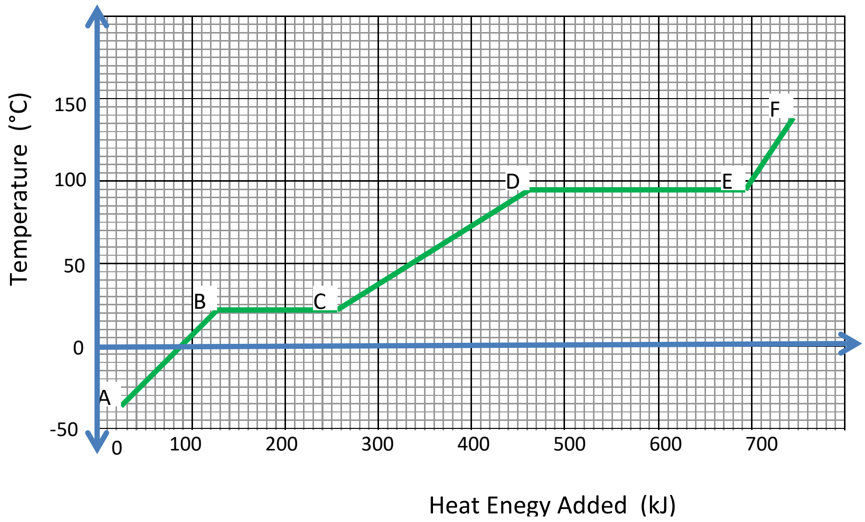
$P = Q/t = 22 \times 10^6 / 3600 = 6.11$ kW in one hour

Cost = 6.11 kWhr x 25.7 c = \$1.57

Heating Processes Questions

1. a) A piece of metal is held in a Bunsen burner flame. Explain what is happening to the metal atoms in terms of kinetic theory.
   b) The metal is then placed in a bucket of cool water. Steam rises up from the bucket as the metal is cooled. Use kinetic theory to explain the movement of the metal atoms and the water molecules.

2. The following graph shows the heating curve for 600 g of a waxy substance.



   a) What are the melting and boiling points of this substance?
   b) In sections BC and DE the temperature does not rise while heat is being added. Explain.
   c) The gradient of AB is greater than that of CD. What does that tell us about the specific heat capacities of the substance in solid and liquid form?
   d) Which is greater, the latent heat of fusion or vaporisation? Estimate these two values from the graph.

3. You boil a kettle containing 2 litres of water. Calculate the heat energy required if the water started at 20 °C. (Note that one litre of water has a mass of one kilogram)

4. A hot water system delivers hot water at 55°C. If the water starts at 21°C and you use 37 litres, how much heat energy is needed for your shower?

5. Calculate the amount of heat energy required to change a 500 g block of ice at -10°C into water at 60°C.

6. A 100 g piece of aluminium at 180°C is dropped into a large beaker containing 1.00 litres of water at 20°C. Assuming that no water evaporates and that no heat is lost to the beaker, what will be the final temperature?

7. An experiment was conducted to find the specific heat capacity of a piece of metal. The mass of the metal was found to be 56.5 g. It was put in an oven overnight. The next day the temperature of the oven was measured at 104°C. A copper calorimeter of mass 105.2 g was filled with 80.5 g of water and the temperature was measured to be 21°C. The metal was taken out of the oven and placed in the calorimeter. Insulating foam was placed over the top while waiting for the temperature to stabilize. The final temperature was measured to be 32°C. Calculate the specific heat capacity of the metal.

8. An inland town such as Kalgoorlie can experience minimum temperatures below zero in winter and maximum temperatures above 45°C in summer. It is also possible for the temperature to change from low, at 6.00 am in the morning to quite high, by 2.00 pm in the afternoon of the same day.
However, Rottnest Island does not experience anywhere near the range of temperatures as Kalgoorlie. The minimum rarely gets down to 5°C and the maximum rarely exceeds 35°C. Explain this in terms of the specific heat capacities of the materials surrounding these places.

9. Explain how you can feel warm while swimming in a pool, but the moment you get out, you feel cold, even though the air is slightly warmer than the water.

10. In hot weather, sweat evaporates from the skin. Where does the energy required to evaporate the sweat come from?

11. Explain how a jumper can keep you warm by reducing heat loss from your body.

12. Explain why most saucepans have plastic, ceramic or wooden handles rather than metal handles.

13. Explain the importance of keeping a lid on a simmering saucepan of water in terms of latent heat of vaporisation.

14. When you get up on a cold morning, the carpet feels much warmer on your bare feet than the tiles in the bathroom. However, the carpet and tiles are at approximately the same temperature. Explain.

Ionising Radiation and Nuclear Reactions

Types of Radiation

Electromagnetic Radiation – Radio waves, Microwaves, Infrared, Visible light, Ultra-violet, X-rays, Gamma rays.

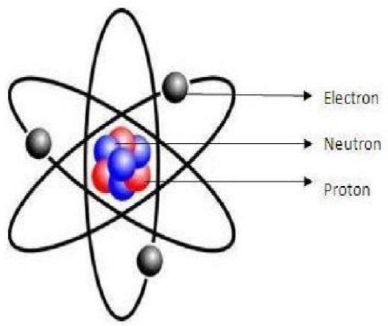
Nuclear Radiation – Produced by changes that occur in the nucleus of some atoms. Includes Alpha particles, Beta particles and Gamma rays.

Environmental Radiation

Cosmic radiation comes from the Sun and stars in space(contributes about 15% of our natural radiation dose).

Terrestrial radiation comes from materials in the Earth's crust and atmosphere (contributes about 85%).

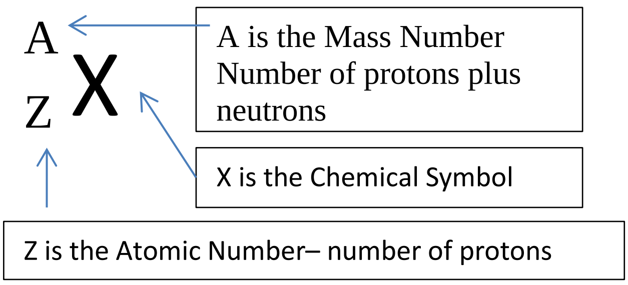
Model of Atom



Protons are positive and found in the nucleus.
Neutrons have no charge, similar size to protons and also in nucleus.
Electrons are negative and move around the nucleus at very high speed in the electron cloud.
Electrons are also much smaller than protons

Isotopes

Isotopes are different types of the same atom with the same number of protons but different numbers of neutrons.
Some isotopes are unstable and break down to try to become more stable by giving off radiation.



Radioactive Decay

- Alpha($^{4}_{2}\alpha$ or $^{4}_{2}He$) decay eg $^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He$

Alpha particles are made up of two protons & two neutrons.
It is the most damaging due to its 2+ charge and large size.
It is the least penetrating, and can be stopped by paper or a metre or two of air.

- Beta decay($^{0}_{-1}\beta$ or $^{0}_{-1}e$)   eg $^{234}_{90}Th \rightarrow ^{234}_{91}Pa + ^{0}_{-1}e + ^{0}_{0}\bar{\nu}$

  where $^{0}_{0}\bar{\nu}$ is an anti neutrino

  Beta is a fast moving electron.
  It is not as damaging as alpha but can penetrate a little further.
  It can be stopped by a thin sheet of metal.
  Positive electrons(positrons) can also be emitted as below;

  eg $^{23}_{12}Mg \rightarrow ^{23}_{11}Na + ^{0}_{+1}e + ^{0}_{0}\nu$

  where $^{0}_{0}\nu$ is a neutrino

- Gamma(γ) decay   eg $^{234}_{91}Pa^{*} \rightarrow ^{234}_{91}Pa + \gamma$

  Gamma has no mass. It is a high frequency, high energy photon travelling at the speed of light. It has similar damaging ability to beta and very large penetrating power.
  Thick lead and concrete can be used to minimise the amount of gamma.

Measuring Radiation – Activity

The activity of a radioactive material is given by the number of nuclei that decay each second. Activity is measured in Bequerels(Bq).

1 Bq = 1 decay per second.

Radioactive Half-life

The time taken for half the radioactive atoms in a sample to decay.

$N = N_0(\frac{1}{2})^n$ where N = number of radioactive nuclei remaining
N_0 = original number of radioactive nuclei

and

$A = A_0(\frac{1}{2})^n$

n = number of half-lives = $t \div t_{\frac{1}{2}}$
t = time passed
$t_{\frac{1}{2}}$ = half-life of material
A = Activity of a radioactive sample (Bq)
A_0 = Original Activity of a radioactive sample (Bq)

Uses of Radioactive Isotopes

Radioactive Isotope	Industrial Applications
Americium-241	For uniform thickness when rolling steel and paper, determine location of oil wells
Sodium-24	Oil well studies and to locate leaks in pipe lines
Iridium-192	Test integrity of boilers and aircraft parts
Uranium-235	Nuclear power plant and naval propulsion systems fuel, production of fluorescent glassware and colored wall tiles
Californium-252	Determine moisture content of soil – important for road construction and building industries

Radioactive Isotope	Applications in Medicine
Cobalt-60	Radiation therapy to prevent cancer
Iodine-131	Locate brain tumors, monitor cardiac, liver and thyroid activity
Carbon-14	Study metabolism changes for patients with diabetes, gout and anemia
Carbon-11	Tagged onto glucose to monitor organs during a PET scan
Sodium-24	Study blood circulation
Thallium-201	Determine damage in heart tissue, detection of tumors
Technetium-99m	Locate brain tumors and damaged heart cells, radiotracer in medical diagnostics (imaging of organs and blood flow studies)

Radioactive Isotope	Application in Research
Carbon-14	Carbon dating of organisms and substances (archeology), research to determine steps involved in plant photosynthesis
Phosphorus-32 Phosphorus-33	Used in research involving biology and genetics
Selenium-75	Protein studies in life science
Strontium-85	Metabolism and bone formation studies
Hydrogen-3 or Tritium	Used to study life science and drug metabolism

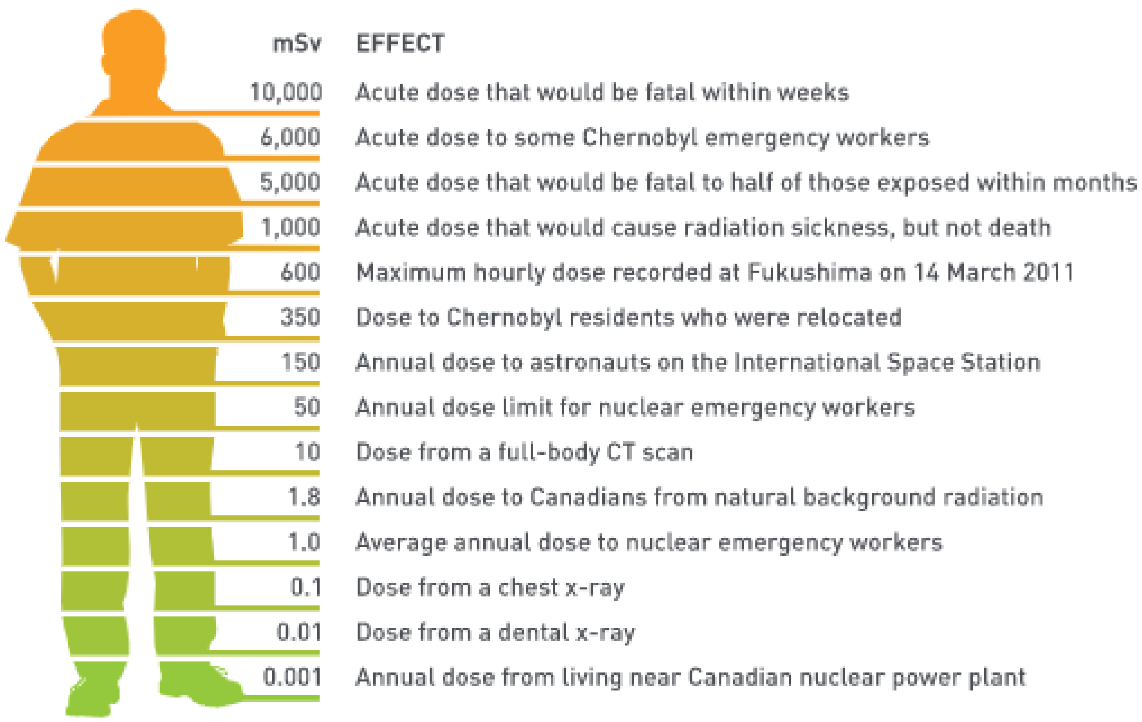
Biological Effects Of Radiation

Ionising radiation can damage living cells, so doses of radiation can be measured.

$$\text{Absorbed Dose} = \frac{\text{energy absorbed}}{\text{mass of tissue}}$$ units - gray(Gy) 1Gy = 1 J/kg

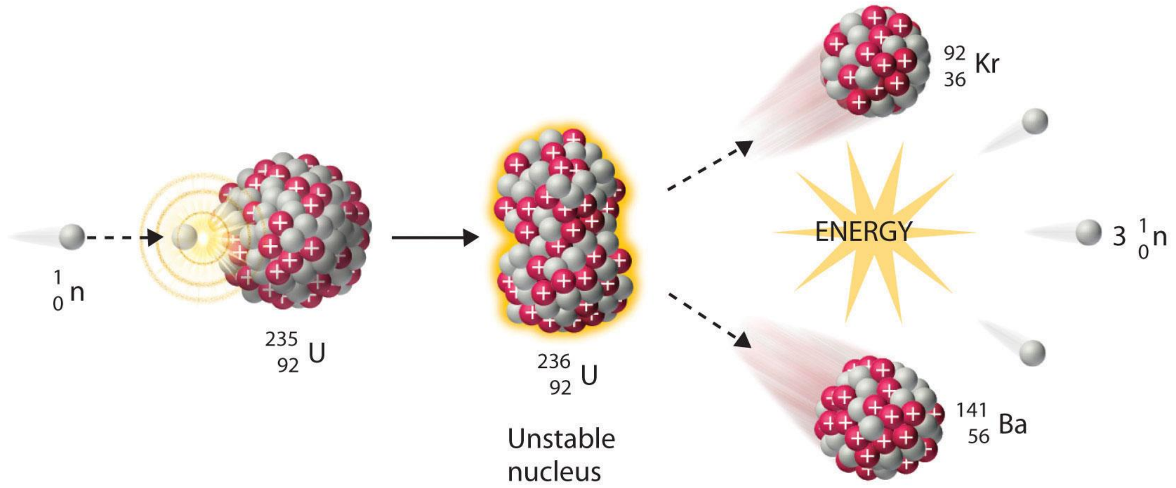
Dose Equivalent = Absorbed Dose X Quality Factor units – sievert(Sv)

Effects of radiation on people

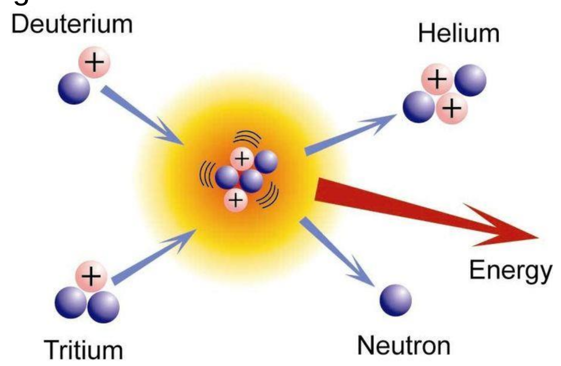


Nuclear Energy

Fission – splitting large atoms in nuclear reactor or bomb.



Fusion – joining small atoms in Sun or stars.



During a nuclear reaction mass is lost (mass defect) and changed into energy. Mass defect, Δm can be found by subtracting the products from the mass of the reactants.
Energy produced can be calculated using Einstein's equation;

$E = \Delta mc^2$ where E = energy (joules)
Δm = mass defect (kg)
c = speed of light = 3×10^8 ms^{-1}

Or

$E(MeV) = \Delta m(u) \times 931$

Binding Energy is the energy required to pull a nucleus apart. The mass of the nucleus of an atom is less than the mass of the protons and neutrons that it contains. The difference in mass (mass defect, Δm) was changed into binding energy to overcome the electrostatic forces repelling the protons and hold the nucleus together. It can be calculated using Einstein's equation, where the mass defect is the difference between the mass of the nucleus and the combined mass of the protons and neutrons that make up the nucleus.

Exam Questions

Question 1 **(4 marks)**

The activity of an unknown radioactive source was measured for a period of 5 minutes and 50.0 seconds. At the end of this time, its activity was measured to be 15.0 Bq. If the half-life of the material is 70.0 s, calculate its activity at the start of the measurement period (i.e., when t = 0 s)?

Question 2 **(4 marks)**

A 65.0 kg technician accidentally ingested a source of alpha radiation. Over the next 4.00 hours he absorbed 3.18 J of energy before removing the radioactive materials from his body by vomiting.

(a) Calculate the technician's absorbed dose over the four-hour period (1 mark)

(b) Calculate the technician's dose equivalent over the four-hour period. (1 mark)

(c) Should the technician be concerned about his radiation exposure? (2 mark)

Question 3 **(13 marks)**

Thorium-based nuclear power plants take advantage of the fission of uranium-233, which is produced from thorium decay. The thorium fuel cycle can be represented using the following equations:

$$n + {}^{232}_{90}Th \rightarrow {}^{233}_{90}Th \rightarrow {}^{233}_{91}Pa \rightarrow {}^{233}_{92}U$$

(a) What type of decay does the thorium-233 undergo to form protactinium-233? (1 mark)

(b) What type of decay does the protactinium-233 undergo to form uranium-233? (1 mark)

When used as a fuel, a uranium-233 nucleus can absorb a neutron to form an unstable uranium-234 nucleus, which later decays into zirconium and tellurium:

$$n + {}^{233}_{92}U \rightarrow {}^{93}_{40}Zr + {}^{138}_{52}Te + 3n$$

The masses for the above nuclei, along with a more precise mass for a neutron, are shown below:

mass of a neutron = $1.674929445 \times 10^{-27}$ kg
mass of U-233 = $3.869716824 \times 10^{-25}$ kg
mass of Zr-93 = $1.542749382 \times 10^{-25}$ kg
mass of Te-138 = $2.290370146 \times 10^{-25}$ kg

(c) Calculate the amount of energy in eV released in the above nuclear reaction. (7 marks)

Although there are no existing commercial thorium-based reactors, they may prove to be safer than present reactors by enabling greater control over the rate of fission and reducing the chance of nuclear meltdown.

Two features of current nuclear reactors that allow us to control nuclear reaction rates are the *moderator* and the *control rods*.

(d) Briefly describe the function of:

(i) the moderator (2 marks)

(ii) the control rods (2 marks)

Question 4 **(11 marks)**

The first nuclear weapon used in warfare was the ‘Little Boy’ atomic bomb, which was dropped on the Japanese city of Hiroshima on 6 August 1945 during World War II.

The bomb had an estimated blast yield that was equivalent to 15.0 kilotons of TNT being detonated.

(a) Given that one ton of TNT is equivalent to about 4.18 GJ of energy, calculate the mass of fissile material that would have been converted into energy in the explosion. (3 marks)

The Little Boy atomic bomb contained 64.1 kg of enriched uranium-235.

(b) Calculate the percentage of the mass of the Little Boy’s fissile material that was converted into energy (1 mark)

The Little Boy atomic bomb was a ‘gun-type’ fission weapon. When the bomb was detonated, a 38.5 kg ‘bullet’ of uranium-235 was fired towards a 25.6 kg ‘target’ of uranium-235. The combined uranium-235 then began nuclear fission and energy equivalent to 15.0 kT of TNT was released.

(c) Suggest why the atomic bomb didn’t undergo a fission reaction prior to the ‘bullet’ of U-235 combining with the ‘target’ of U-235. (4 marks)

(d) Today’s most powerful nuclear weapons use a fission reaction to start a fusion reaction. Suggest reasons why nuclear weapons that use a fusion reaction are more powerful than those that only use fission reactions. (3 marks)

Answers to Exam Questions

Question 1

t = (5 x 60) + 50 = 350 s
number half-lives n = 350 / 70 = 5
$N = N_0 (1/2)^n$
$15 = N_0 (1/2)^5$
$N_0 = 15 / (1/2)^5$
$N_0 = 480$ Bq = 4.80 x 10^2 Bq
OR: Can work backwards by doubling 15.0 Bq 5 times
i.e., $N_0 = 15 \times 2^5 = 4.80 \times 10^2$ Bq

Question 2

(a) Absorbed dose = energy absorbed / mass = 3.18 / 65 = 48.9 mGy.
(b) Dose equivalent = absorbed dose x quality factor
Dose equivalent = 48.9 x 10^{-3} x 20 = 0.978 Sv
(c) Yes – he has received a dose equivalent of almost 1 Sv. He will likely suffer from radiation sickness, possibly within days, and a have very high chance of fatal cancers developing later.
Yes – he ingested an alpha source, it has a high ionising ability and could cause damage to living tissue inside the body

Question 3

(a) β^- decay (b) β^- decay
(c) Mass defect is:
n + U-233 – (Zr-93 + Te-138 + 3n)
= 1.674929445 x 10^{-27} + 3.869716824 x 10^{-25} – (1.542749382 x 10^{-25} + 2.290370146 x 10^{-25}
+ (3 x 1.674929445 x 10^{-27})
= 3.886466118 x 10^{-25} – (3.883367411 x 10^{-25})
= 3.098707 x 10^{-28} kg
From $E = mc^2$ => E = 3.098707 x 10^{-28} x $(3.00 \times 10^8)^2$ = 2.7888363 x 10^{-11} J
Convert to eV: 2.7888363 x 10^{-11} / 1.6 x 10^{-19} = 174 302 269 = 174 MeV

(d) (i) The moderator is able to slow down neutrons, which facilitates absorption by the fissile material (e.g., U-235) to allow fission to occur.
(ii) Control rods can absorb neutrons, so their presence can slow down the cascading reaction that would otherwise occur of the rods were not present. Lowering more of the control rods into the reactor core will absorb more neutrons and slow the reaction down. Lifting the control rods further out of the core will reduce the amount of neutron absorption, allowing more to be absorbed by the fissile material, effectively speeding the reaction up.

Question 4

(a)Total energy given off = 15.0 x 10^3 x 4.18 x 10^9 = 6.27 x 10^{13} J
From $\Delta E = \Delta mc^2$ => $\Delta m = \Delta E / c^2$ = 6.27 x 10^{13} / $(3.0 \times 10^8)^2$ = 6.97 x 10^{-4} kg = 0.697 g

(b) % = mass converted / total mass x 100% = 0.697 x 10^{-3} / 64.1 x 100% = 0.00109%

(c) The two separate masses of U-235 are sub-critical – i.e., their mass and/or shape are such that an uncontrolled chain reaction will not occur as a result of neutrons being produced by the fission of U-235 atoms. When the masses combine, they reach a critical mass at which neutrons produced by fission are absorbed by other U-235 atoms, which in turn produce neutrons and a cascading fission reaction occurs, releasing enormous amounts of energy in a fraction of a second.

(d) More energy is released per nucleon in nuclear fusion than in nuclear fission. This is due to a larger percentage of the mass being transformed into energy in fusion reactions.

Ionising Radiation and Nuclear Reactions Questions

1. Write the name of the element and determine the number of protons and neutrons in the nucleus of each of the following;

   a) $^{4}_{2}He$ b) $^{234}_{92}U$ c) $^{23}_{11}Na$ d) $^{206}_{82}Pb$ e) $^{234}_{90}Th$

2. Write decay equations to show the alpha decay of each of the following:
   a) radon-222 (Rn) b) uranium-238 c) bismuth-214 (Bi)

3. Write decay equations to show beta decay of the following;
   a) Thorium-234 (Th) b) phosphorus-32 (P) c) lead-214 (Pb)

4. Write an equation to show the gamma decay of an excited iodine-131 atom.

5. Write an equation to show the fusion of deuterium and tritium into an alpha particle and another particle.

6. A smoke detector, which we should all have in the house, contains a small radioactive source, an air gap and a detector. When particles of smoke go into the air gap, they block some of the radiation and the detector registers a lower count. This sets off the alarm. What type of radiation is the radioactive source emitting? Explain your answer.

7. How can we protect ourselves from;
   a) alpha radiation b) beta radiation c) gamma radiation

8. Patients suffering from cancer can be treated using a source of radiation to kill the cancer cells. What type of radiation would be used in the following situations(explain your choice);
   a) Cancer deep under the skin which is treated by a source outside the body.
   b) Case in which the source can be injected directly to the site of cancer cells.

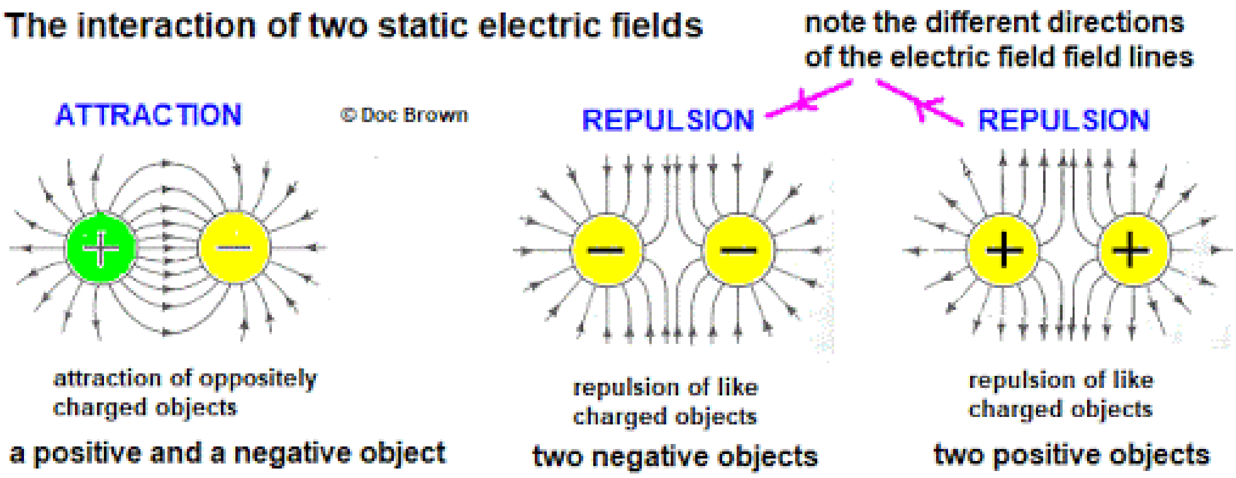
9. During radiation treatments where the source is outside the patient's body, the radiographer will rotate the source around the patient's body. Explain.

10. The activity of a sample of carbon-14 is measured to be 8 decays per second. How long will it take for the activity to drop to 1 Bq if the half-life is 5 730 years?

11. A radioactive sample is found to have an activity of 4.5×10^{8} Bq. The radioisotope has a half-life of three hours. Find its activity after two days.

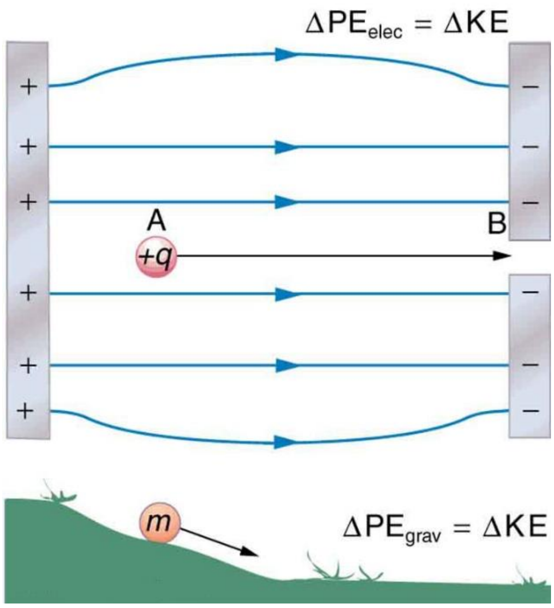
Electrical Circuits

Static Electricity is produced by rubbing two materials together. Electrons are transferred from one material to the other making one positively charged and the other negatively charged.
Like charges repel, and unlike charges attract.
Positive and negative charges attract neutral objects.



Electric Potential Difference (Voltage)
This is the energy per unit of charge and is required to make a charged particle move.

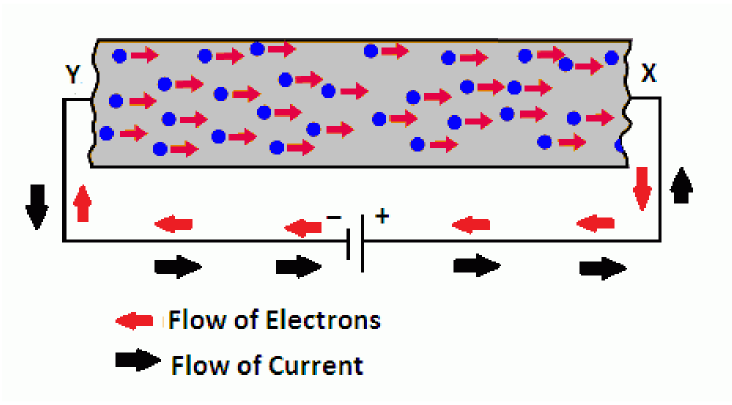
$V = \frac{W}{q}$ V = electric potential energy, or voltage (volts – V)
W = work done on charge (J)
$W = Vq$ q = charge (C)



Electric Current (I)
This is the rate of flow of electric charges.

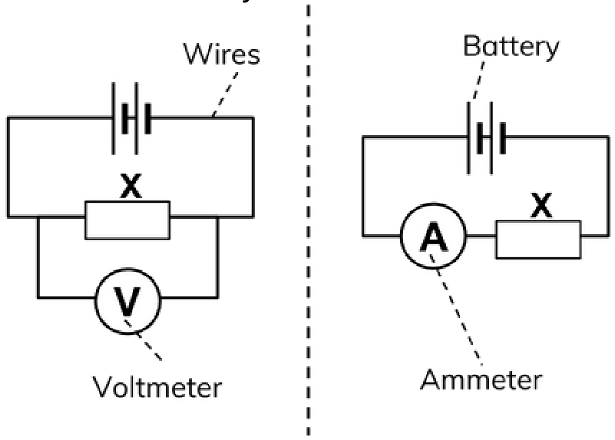
$I = \frac{q}{t}$ I = Current (Amperes – A)
q = charge (C)
t = time (s)

Conventional Current is in the direction of **positive** charge flow.
It is in the opposite direction to the flow of electrons.



Measuring Potential Difference (Voltage) and Current

A voltmeter must always be connected in parallel to find the voltage across X.
An ammeter must always be connected in series to find the current through X.



Direct Current (DC) charge flow is in one direction, eg battery.

Alternating Current (AC) flow of charge alternates back and forth, eg power point.

Electrical Power (P)

The rate of doing work or releasing energy.

P = VI   P = Power (Watts – W)
V = Voltage (V)
I = Current (A)

Electrical Energy Used

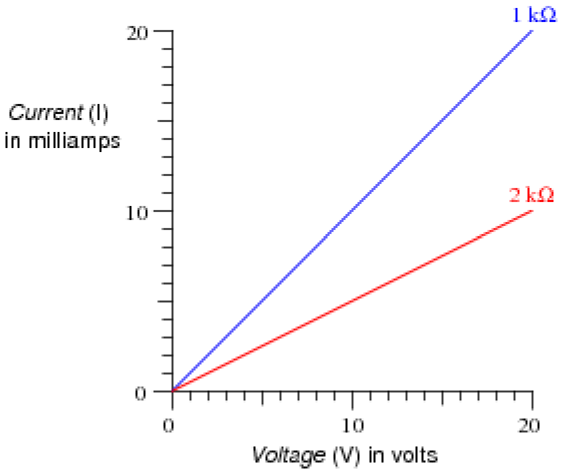
E = Pt   E = Energy used or work done (J)
E = VIt   P = Power (W)
V = Voltage (V)
I = Current (A)
t = time (s)

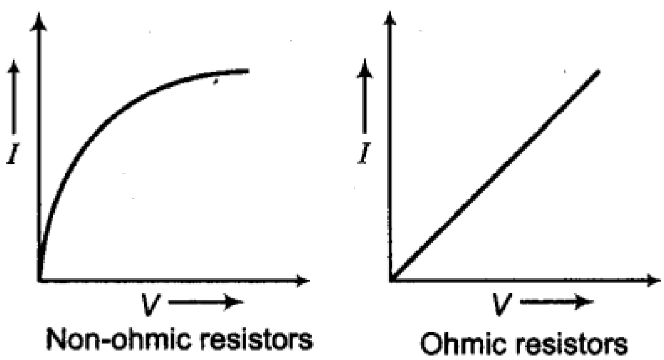
Western Power measure energy use by households in kilowatt-hours(kWh) because a Joule is too small a unit.   1 kWh = 3600000 Joules.

Ohm's Law

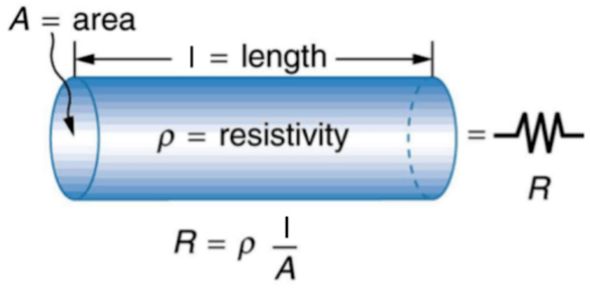
The current through a resistor is proportional to the potential difference applied to it.

V = IR   V = potential difference (V)
I = current (A)
R = resistance (Ω)





Factors affecting Resistance



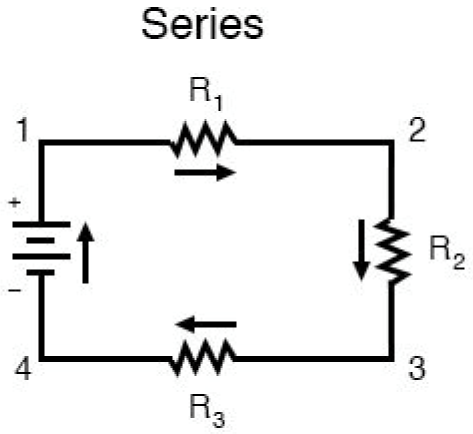
$$R = \frac{\rho l}{A}$$

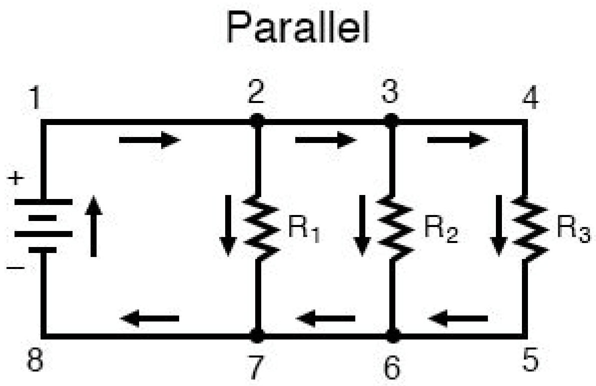
R = resistance (Ω)
ρ = resistivity (Ωm)
l = length (m)
A = cross-sectional area (m^2)

Note that this formula is not in the course, but it helps us to understand resistance.

Series Circuits have only one path for the current to flow through.

All appliances must be on or off at the same time.
One appliance 'blows' then they all go off.
Appliances share the total voltage so more appliances means each gets less voltage.
Total Resistance, $R_T = R_1 + R_2 + R_3 + \dots$.





Parallel Circuits have more than one path for current to flow.

Appliances can be independently switched on and off.
One appliance 'blows' and others stay on.
Appliances all receive supply voltage and don't have to share.
Total Resistance is always lower than the lowest individual resistance.

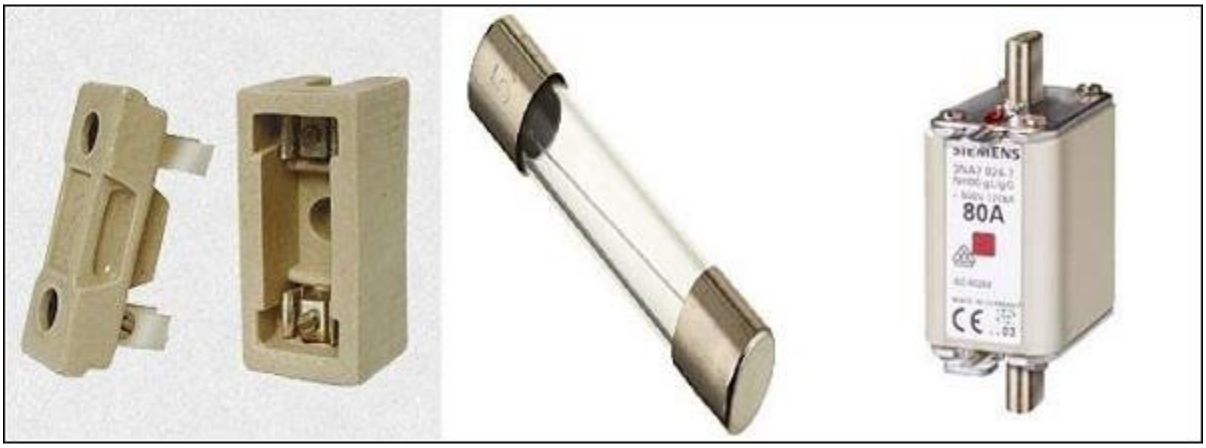
$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$

AC Power is used by industry and in our homes because it has many advantages over DC power.
AC power is more easily generated, can easily be transformed to higher or lower voltages, can be transmitted at high voltage to reduce energy loses, is cheaper to produce, and its frequency can be used to run timing devices.

Electrical Safety

Electricity can produce severe shock or death and many fires are started due to electrical faults. We must be extremely careful with electricity and make sure that only licenced electricians do electrical work.

Electrical safety devices include earth wires, fuses, circuit breakers, and double insulation.



Exam Questions

Question 1 **(4 marks)**

In a Van de Graaff generator a rubber belt rubs against an acrylic plate transferring electrons from the plate to the belt. Calculate the electric current generated when 2.70×10^{18} electrons are transferred to the rubber belt over a period of 5 minutes and 30.0 seconds.

Question 2 **(4 marks)**

Capacitors store electrical energy by keeping opposite charges separated on parallel metal plates. An insulator between the plates maintains the charge separation.

(a) Briefly explain why charge separation would result in energy being stored. (2 marks)

(b) A battery has some similarities with a capacitor in that there is a separation of charges. The charge separation is achieved by a chemical reaction. If the chemical reaction does 4.50 J of work for each 3.13×10^{18} electrons, what is the voltage of the battery?(2 marks)

Question 3 **(6 marks)**

Electricity supplied to your home will typically be single phase and consist of two wires – a neutral wire and an active wire. The active wire will be connected to your house via an electricity meter and a main switch. The neutral wire will be connected to earth.

(a) Explain why the active wire, rather than the neutral wire, is connected to the main switch. (2 marks)

(b) Some electrical appliances in the home do not have an earth pin on their electrical plug. Suggest a reason as to why an electrical appliance, for example a hair dryer, may not have an earth pin. (2 marks)

(c) What is the purpose of the earth wire? (2 marks)

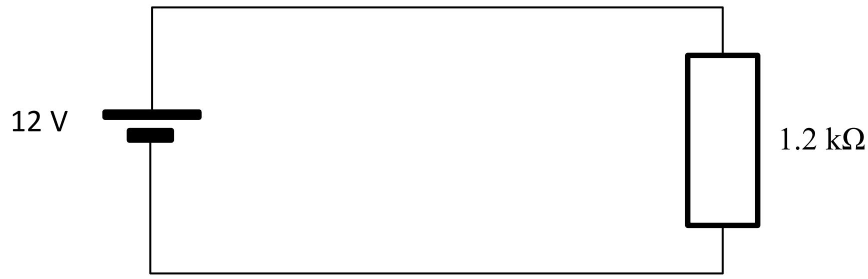
Question 4 **(4 marks)**

(a) Describe the purpose of a residual current device (RCD) and explain how it functions. (2 marks)

(b) Explain the difference between a fuse and a circuit breaker. (2 marks)

Question 5 **(14 marks)**

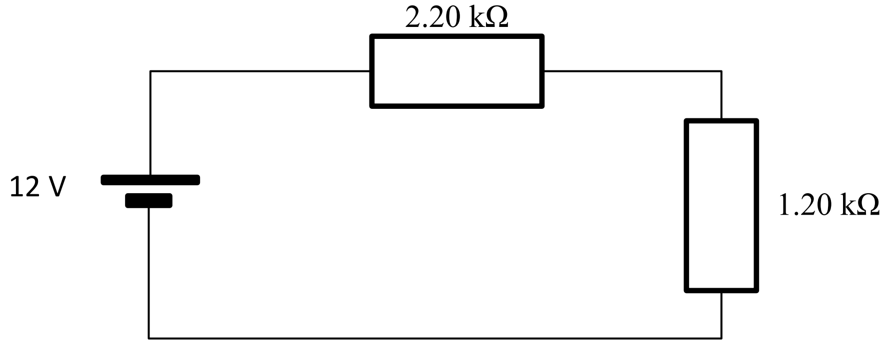
A resistor is connected to a 12.0 V battery via conductive wires as shown in the following circuit diagram. The resistor has a value of 1.20 kΩ.



(a) Draw a voltmeter and ammeter on the circuit diagram to show how they would be connected to measure the current and voltage in the circuit. (2 marks)

(b) Calculate the current flowing through the 1.20 kΩ resistor. (1 mark)

A 2.20 kΩ resistor is placed in series with the 1.20 kΩ resistor as shown below.



(c) Calculate the current flowing through the 2.20 kΩ resistor. (2 marks)

(d) Calculate the current flowing through the 1.20 kΩ resistor. (1 mark)

(e) Calculate the power that is consumed by the 2.20 kΩ resistor. (2 marks)

(f) Calculate the power that is consumed by the 1.20 kΩ resistor. (2 marks)

In the above calculations we have ignored any resistance that the electrical conductors may have.

(g) If the resistance of the electrical conductors was high enough that it had an effect on the circuit, would more or less power be consumed by the 2.20 kΩ resistor? (1 mark)

(h) If the electrical conductors were all made of the same conductive material, what would be the effect of the following changes on the overall resistance of the circuit?

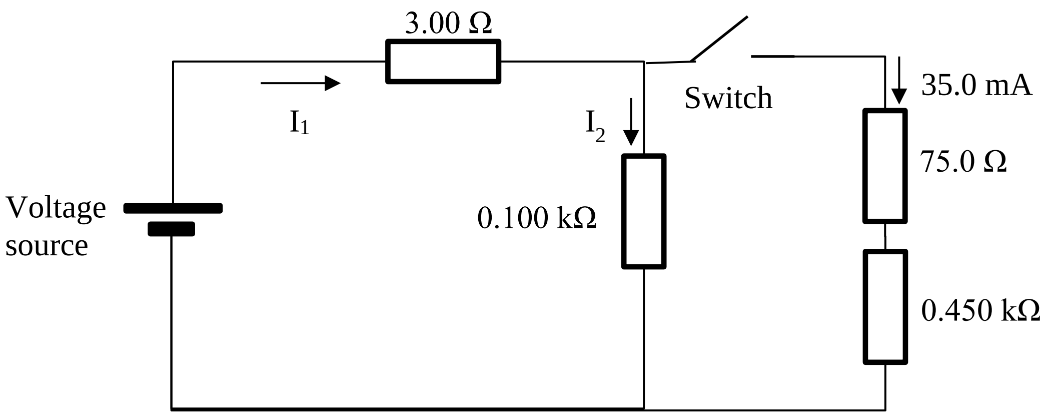
(i) longer wires were used (1 mark)

(ii) thicker wires were used (1 mark)

(iii) the temperature of the wires was increased (1 mark)

Question 6 **(15 marks)**

Consider the circuit shown below. For parts (a) through to (f) assume that the switch is closed:



(a)

(i) Calculate the voltage drop across the 75.0 Ω resistor. (1 mark)

(ii) Calculate the voltage drop across the 0.450 kΩ resistor (1 mark)

(b) Hence determine the voltage drop across the 0.100 kΩ resistor (1 mark)

(c) (i) Calculate the current flowing through the 0.100 kΩ resistor (i.e., I_2) (1 mark)

(ii) Calculate the current flowing through the 3.00 Ω resistor (i.e., I_1) (1 mark)

(d) Calculate the voltage drop across the 3.00 Ω resistor (1 mark)

(e) Hence determine the voltage that the voltage source is outputting (1 mark)

(f) Determine the combined resistance of the resistors as connected in the diagram (3 marks)

(g) The 0.100 kΩ resistor is rated to handle a power of 4.00 W. If the power provided to the 0.100 kΩ resistor exceeds 4.00 W it will fail.

(i) What is the power provided to the 0.100 kΩ resistor when the switch is closed?

(2 marks)

(ii) Will the 0.100 kΩ resistor fail if the switch is opened? Justify your answer with a calculation. (3 marks)

Answers to Exam Questions

Question 1

$I = q / t$

$q = 2.70 \times 10^{18} \times 1.6 \times 10^{-19}$ (charge on 1 e^-) = 0.432 C

$t = 5.5 \times 60 = 330$

$I = 0.432 / 330 = 1.31 \times 10^{-3}$ A or 1.31 mA

Question 2

(a) Work is done in separating the opposite charges – the work that is done is stored as potential energy, which can be released when the charges are allowed to flow towards one another again and convert the potential energy into work.

(b) $V = W / q$

W = 4.5 J

$q = 3.13 \times 10^{18} \times 1.6 \times 10^{-19} = 0.5008$

V = 4.5 / 0.5008 = 8.99 V

Question 3

(a) Power is supplied via the active wire and returned via the neutral. Connecting the active wire to the house via the main switch will allow the house to be isolated from the 'live' wire (for example if work is to be carried out), which will prevent the risk of electric shock.

(b) The earth pin allows the electrical appliance to be connected to the earth wire. This is necessary for a device if it has a conductive outer body as insulation on the active wire may become worn or otherwise come into contact with the body, making it live. Many devices have outer bodies that are made of insulators (e.g., the plastic body of a hairdryer), and so it will not become live while being touched by a user.

(c) The earth wire provides a pathway for electricity to flow through to ground in preference to flowing through a person touching a live device/wire etc.

Question 4

(a) The purpose of an RCD is to trip a circuit breaker and switch off the mains electricity if a fault or an accident occurs that results in the grounding of a 'live' wire. It functions by detecting differences between current flowing through the active wire and current flowing through the neutral wire. If there is a difference between the two, this is an indication that current is 'leaking' and not passing through the switch. This 'leakage' current could cause an electrical fire, or could be passing through a person. If a difference is detected (as little as 30 mA difference), the RCD triggers a circuit breaker (within only milliseconds), thereby potentially preventing a fire or electric shock (or electrocution).

(b) A fuse is formed from a wire that has a relatively low melting point. If a large current flows through it, the wire will melt and, if the fuse is connected in series with the circuit, it will break the circuit. A circuit breaker is arranged to detect current flowing through the circuit breaker – if it exceeds a predetermined limit, the circuit breaker will trigger an electromagnetic switch which disconnects the circuit. A circuit breaker can be reset, but a fuse has to be replaced.

Question 5

(a) Connect the ammeter in series with the resistor, and the voltmeter in parallel with the resistor.

(b) $I = V / R = 12 / 1.2 \times 10^3 = 1.00 \times 10^{-2}$ A or 10.0 mA

(c) R_T = 1.2 k + 2.2 k = 3.4 kΩ

Same current flows through each of the 1.2 and 2.2 kΩ resistors.

Therefore:

$I = V / R_T = 12 / 3.4 \times 10^3 = 3.53 \times 10^{-3}$ A or 3.53 mA

(d) The same current flows through each resistor as they are in series – i.e., 3.53 mA

(e) Can calculate the voltage drop across the 2.2 kΩ resistor:
$V = IR = 3.53 \times 10^{-3} \times 2.2 \times 10^{3} = 7.766$ V
Then $P = VI = 7.766 \times 3.53 \times 10^{-3} = 2.74 \times 10^{-2}$ W or 27.4 mW
Or can calculate directly from $V = I^2R = (3.53 \times 10^{-3})^2 \times 2.2 \times 10^{3} = 27.4$ mW
(f) Can calculate the voltage drop across the 1.2 kΩ resistor:
$V = IR = 3.53 \times 10^{-3} \times 1.2 \times 10^{3} = 4.236$ V
Then $P = VI = 4.236 \times 3.53 \times 10^{-3} = 1.50 \times 10^{-2}$ W or 15.0 mW
Or can calculate directly from $V = I^2R = (3.53 \times 10^{-3})^2 \times 1.2 \times 10^{3} = 15.0$ mW
(g) Less power would be consumed – the additional resistance of the conductors would increase the overall resistance of the circuit, thereby reducing the current flowing through each of the circuit elements. The resistance of the 2.2 kΩ resistor remains the same, so the $P = I^2R$ value would be reduced.
(h) (i) R would increase as there is more 'material' in the way of the electron flow.
(ii) R would decrease as there are more 'pathways' for the electrons to flow along.
(iii) R would increase as the particles in the conductor are vibrating faster, increasing the number of 'interactions' with electrons flowing therethrough, thereby providing greater resistance

Question 6
(a) (i) $V = IR = (35.0 \times 10^{-3}) \times (75) = 2.625$ V = 2.63 V
(ii) $V = IR = (35.0 \times 10^{-3}) \times (450) = 15.75$ V = 15.8 V
(b) V across 100 Ω resistor = V drop across both 75 and 450 Ω resistors
V = 2.625 + 15.75 = 18.375 = 18.4 V
(c) (i) $I_2 = V / R = 18.375 / 100 = 183.75$ mA = 184 mA
(ii) $I_1 = I_2 + 35.0$ mA = 183.75 mA + 35.0 mA = 218.75 mA = 219 mA
(d) $V = IR = 218.75 \times 10^{-3} \times 3 = 0.656$ V
(e) $V = V_{3\Omega} + V_{100\Omega} = 0.65625 + 18.375 = 19.0$ V
(f) $R_T = R_{3\Omega}$ in series with ($R_{100\Omega}$ in parallel with ($R_{75\Omega}$ in series with $R_{450\Omega}$)
$R_T = 3 + (1 / (1/100 + 1/(75+450)))$
$R_T = 3 + (1/1/84))$
$R_T = 3 + 84$
$R_T = 87.0\ \Omega$
(g) (i) $P = VI = (18.375)(183.75 \times 10^{-3}) = 3.38$ W
(ii) If the switch is opened, no current will flow through the 75 and 450 Ω resistors.
The current flowing through the circuit will be:
$I = V / (R_{3\Omega} + R_{100\Omega}) = 19.03 / (3 + 100) = 0.18475$ A
The power through the 100 Ω resistor can now be calculated from:
$P = I^2R = (0.18475)^2 \times 100 = 3.41$ W => the resistor will not fail as the power is less than 4 W

Electrical Circuits Questions

1. Many people who have jumped on a trampoline have experienced a small electric shock as they touch the metal frame as they get off the trampoline. Explain why this happens.

2. A current of 125 mA flows through a wire for 20.0 minutes.
   a) Calculate the total charge that flowed through the wire.
   b) If an electron carries a charge of -1.60×10^{-19} C, how many electrons moved through the wire.

3. Explain the difference between conventional current and electron flow.

4. Calculate the energy given to 0.55 C of charge by a 1.5 Volt cell.

5. Calculate the current that should flow through the following;
   a) A 2 200 W kettle connected to 240 V.
   b) A 100 W light bulb connected to the mains.
   c) A 200 W car CD tuner connected to 12 V.

6. In one day the following appliances were used;
   The 350 W fridge motor was on for a total of 3.00 hours.
   The 120 W TV was on for 6.00 hours.
   The 75 W DVD player was on for 3.00 hours
   Five 60 W light bulbs were on for 4.00 hours each.
   The 2 200 W kettle was on for 10.0 minutes.
   The 3000 W stove was on for 1.50 hours.
   a) Calculate the total energy used in kWh
   b) If Western Power charges 15 cents a kWh, how much did it cost to run these appliances?

7. Complete the following table;

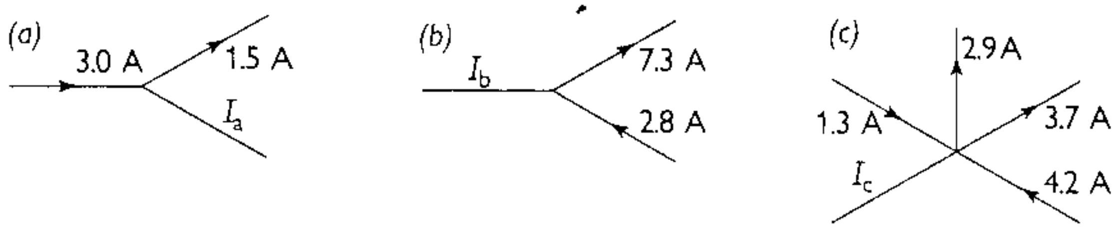
Voltage	**Current**	**Resistance**
	2 A	6 Ω
12 V		45 Ω
6 V	55 mA	
	5.5 A	3.2 kΩ
50 kV		250 kΩ
1.5 V	20 mA	

8. A 100 W light globe in your house receives 240 V.
   a) Calculate the current flowing through the globe.
   b) Calculate its resistance
   c) Light bulbs are very inefficient and only convert about 10% of the electrical energy into light energy. Most of the other electrical energy is converted into heat. Find the total light energy produced in 10 minutes.

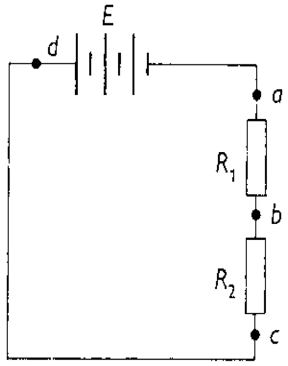
9. You are given 3 resistors with values 2Ω, 5Ω and 10Ω.
   a) What will be their total resistance if connected in series?

b) A 6 V battery is now connected in series. Calculate the current flowing through each resistor.
c) Find the voltage drop across each resistor.
d) The resistors are now connected in parallel. What is the total resistance?
e) The 6 V battery is connected to these resistors in parallel. What will be the total current flowing in the circuit?
f) Calculate the current flowing through each resistor.
g) Find the voltage drop across each resistor.

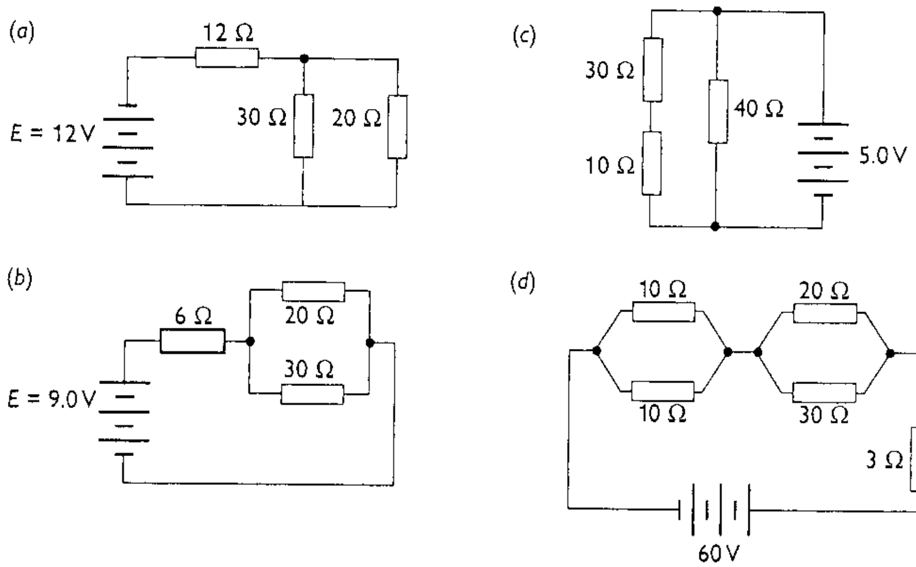
10. Find the unknown current at each of the junctions in the figure below. State the direction of the current in each case



11. In the series circuit shown below, V_{ab} = 20 V, R_2 = 30 Ω, and I_a = 2.0 A. Find values for the following: (a) I_b (b) V_{bc} (c) R_1 (d) R_{eff} (e) E



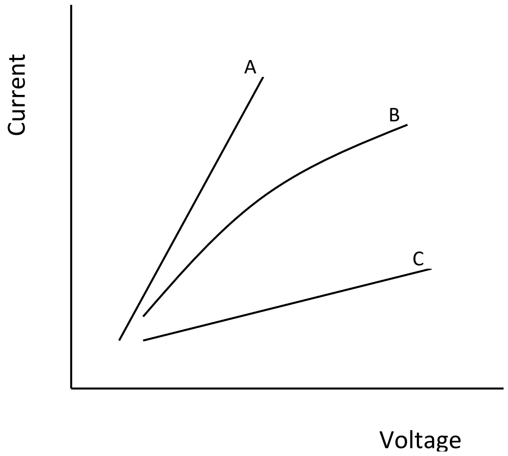
12. For each of the circuits (a), (b), (c) and (d), shown below, find;
(i) the effective resistance of each circuit
(ii) the total current in each circuit
(iii) the voltage drop across each resistor
(iv) the current through each resistor.



13. A bar radiator has a `hot' resistance of 24 Ω and runs off a 240 V supply.
(a) At what rate is electrical energy transferred into heat?
(b) What current does the radiator draw?
(c) If electricity costs 12 cents per kilowatt hour, what does it cost to run the radiator for 5.0 h?

14. Three materials were connected to a power pack in turn, the voltage was varied and the current was measured. The results are graphed below;

a) Which substance has the greatest resistance?
b) Which substance/s are ohmic resistors?
c) Can you suggest a reason why the graph for B is curved?
d) This experiment can be done easily in the lab. Can you suggest what B might be?



Answers

Heating Processes Questions

1. (a) The metal atoms vibrate faster and faster as they gain heat energy.
   (b) The metal atoms lose a lot of heat energy as it is transferred to the water. As a result the metal atoms vibrate much slower. The water molecules move much faster, with some moving so fast that they change phase to a gas and leave the surface of the water.
2. (a) approx. 22°C and 94°C,
   (b) Heat energy is being used to break bonds between the particles so the substance can change state.
   (c) Greater gradient means that less heat is needed to increase the temperature, which means a lower specific heat capacity. Therefore the specific heat capacity of the liquid is greater than the solid in this case.
   (d) Latent heat of vaporisation is greater, L_f= 2.17 x 10^5 Jkg^{-1} and L_v= 3.83 x 10^5 Jkg^{-1}.
3. 6.69 x 10^5 J
4. 5.26 x 106 J
5. 3.03 x 10^5 J.
6. 23.3°C.
7. 1021 $Jkg^{-1}K^{-1}$.
8. Kalgoorlie is inland and is surrounded by dirt, which has a relatively low specific heat capacity. In the hot weather, the dirt cannot absorb much heat energy without its temperature rising dramatically → high temperatures. In cool weather, the dirt has little heat stored to give to its surroundings so the temperature drops. Rottnest is surrounded by water, which has a high specific heat capacity. In hot weather, the water can absorb a lot of heat without its temperature rising too high. It can also absorb heat from the land, keeping things cooler. In cold weather, the water has a lot of stored heat energy, which it gives to its surroundings so the temperature does not drop so low.
9. When you get out of the water, you are covered by a thin layer of water which starts to evaporate. A large amount of heat is needed for this evaporation, so this heat is absorbed from your body, making you feel cold.
10. Sweating reduces the temperature of the body. Sweat on the skin is basically water. The water evaporates by gaining energy from the skin to change state. Taking energy from the surface of [he skin results in a reduction in the energy of the skin molecules, and a reduction in the temperature of the skin
11. The wool or material the jumper is made from is a poor conductor of heat. It also traps air, which is a poor conductor, so the jumper reduces conduction of heat away. The trapped air means that convection is significantly reduced. The jumper also absorbs radiated heat and reradiates it back to us, so heat loss by radiation is reduced.
12. Plastic, ceramics and wood are poor conductors of heat so they transfer little heat energy from the saucepan to your hand. Metal is a good conductor of heat and could cause you to burn your hand.

13. A simmering saucepan loses heat by convection and evaporation. By keeping the lid on, the water is prevented from evaporating because the air inside the pan is saturated. The evaporation of the water would cool the thing you are heating.
14. The carpet is a poor conductor of heat so it will conduct little heat from your foot, allowing your foot to stay warm. The tiles are a much better conductor than carpet so heat will be removed from your feet, making them feel cold.

Ionising Radiation and Nuclear Reactions

1. a) Helium 2 protons, 2 neutrons, e) Thorium 90 protons, 144 neutrons.
2. a) $^{222}_{86}Ra \rightarrow ^{218}_{84}Po + ^{4}_{2}He$ b) $^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He$ c) $^{214}_{83}Bi \rightarrow ^{210}_{81}Tl + ^{4}_{2}He$
3. a) $^{234}_{90}Th \rightarrow ^{234}_{91}Pa + ^{0}_{-1}e$ b) $^{32}_{15}P \rightarrow ^{32}_{16}S + ^{0}_{-1}e$ c) $^{214}_{82}Pb \rightarrow ^{214}_{83}Bi + ^{0}_{-1}\beta$
4. $^{131}_{53}I^* \rightarrow ^{131}_{53}I + \gamma$ **5.** $^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$
6. Alpha radiation, because it could be easily stopped by smoke particles, whereas beta and gamma would not be stopped so easily.
7.a) air, or cardboard, b) a little more air, or thin metal, c) thick lead or concrete
Note – you should do more research on this.
8. a) Gamma – It can penetrate the skin and tissues to make it to the site of the cancer cells. Unfortunately this will also cause damage to healthy cells on its way to the cancer.
b) Alpha – If delivered directly to the site, it will kill cancer cells and will be stopped so that it will not damage healthy cells around the site.
9. The cancer cells are being attacked from different angles making it more likely that they are killed, however the biggest advantage is that healthy cells are not receiving the dose of radiation for the whole time.
10. 17190 years. **11.** 6.87×10^3 Bq

Electrical Circuits

1. Your clothes rub on the trampoline mat causing electrons to be transferred from one material to another. You become charged, and since the mat cannot conduct the charge away, the charge builds up as you bounce. As you get off the mat you touch the metal frame, which is a conductor, transferring the charge from you, so you feel a shock.
2. a) 150 C b) 9.38×10^{20} electrons
3. Conventional current is the flow of positive charge, which goes from positive to negative. Electron flow is the flow of electrons(negative charge), which is in the opposite direction to conventional current.
4. 0.825 J **5.** a) 9.17 A b) 0.417 A c) 16.7 A **6.** a) 8.06 kWh b) $1.21
7. 12 V, 267mA, 109 Ω, 17600 V, 0.20 A, 75 Ω **8.** a) 0.417 A b) 576 Ω c) 6000 J
9. a) 17 Ω b) 0.353 A c) 2 Ω, 0.706 V; 5 Ω, 1.76 V; 10 Ω, 3.53 V d) 1.25 Ω
e) 4.80 A f) 2 Ω, 3.0 A; 5 Ω, 1.2 A; 10 Ω, 0.6 A g) All have 6 V.
10. (a) 1.5 A away from junction (b) 4.5 A into junction (c) 1.1 A into junction
11. (a) 2.0 A (b) 60 V (c) 10 Ω (d) 40 Ω (e) 80 V
12. (a)(i) 24 Ω (ii) 0.5 A (iii) all resistors, 6.0 V (iv) 12 Ω, 0.5 A ; 20 Ω, 0.3 A ; 30 Ω, 0.2 A
(b) (i) 18 Ω (ii) 0.5 A (iii) 6.0 Ω, 3.0 V ; 20 Ω and 30 Ω, 6.0 V
(iv) 6.0 Ω, 0.5 A ; 20 Ω, 0.3 A ; 30 Ω, 0.2 A
(c) (i) 20 Ω (ii) 0.25 A (iii) 40 Ω, 5.0 V ; 30 Ω, 3.75 V ; 10 Ω, 1.25 V
(iv) 40 Ω, 0.125 A ; 30 Ω, 0.125 A ; 10 Ω, 0.125 A
(d) (i) 20 Ω (ii) 3.0 A
(iii) 10 Ω resistors, 15 V; 20 Ω and 30 Ω resistors, 36 V ; 3 Ω, 9.0 V
(iv) 10 Ω resistors, 1.5 A ; 20 Ω, 1.8 A ; 30 Ω, 1.2 A ; 3 Ω, 3.0 A
13. (a) 2.4 kW (b) 10 A (c) $1.44
14. a) C b) A & C c) Resistance increases as the voltage increases. d) Light bulb.