ATAR Year 11

Physics Unit 1 & 2 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, $V_t = V_1 + V_2 + V_3 \ldots.$
  $R_t = R_1 + R_2 + R_3 \ldots.$

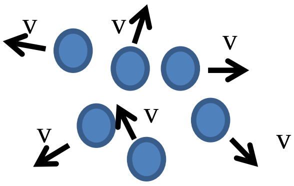
  parallel components, V = constant, $I_t = I_1 + I_2 + I_3 \ldots.$
  $$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots$$

- 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

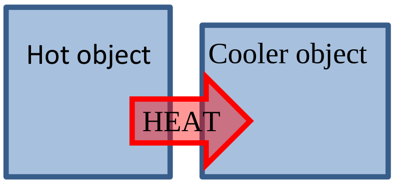
Heating Processes

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)



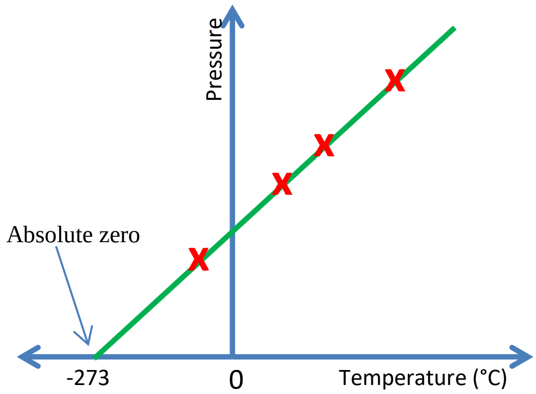
Internal Energy of a body is a measure of the total kinetic and potential energy stored in that body. Measured in Joules.

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.

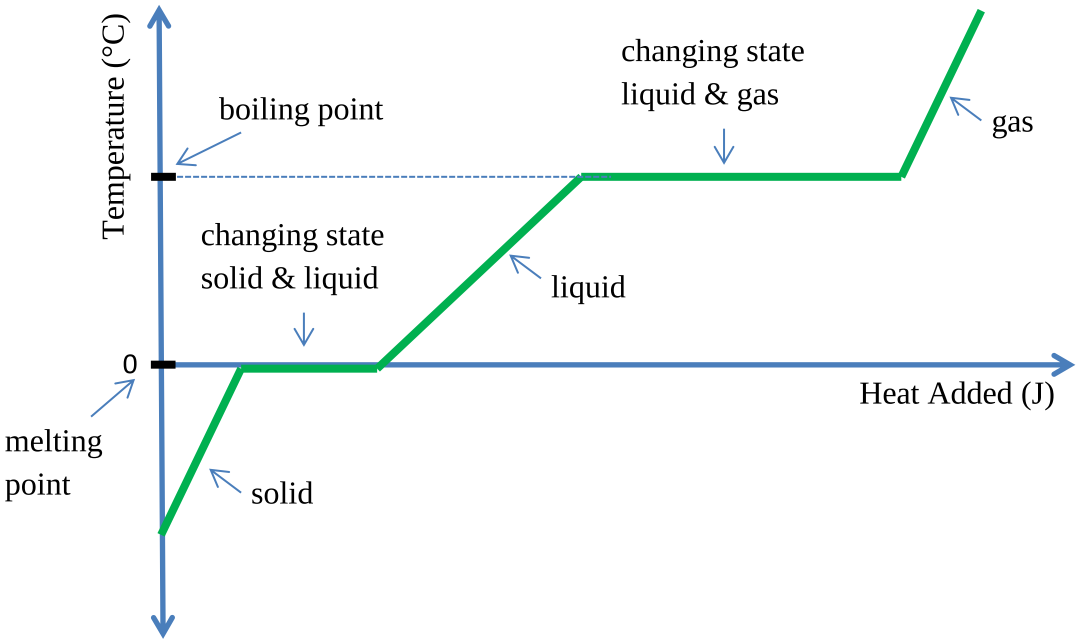
Q = mL

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)

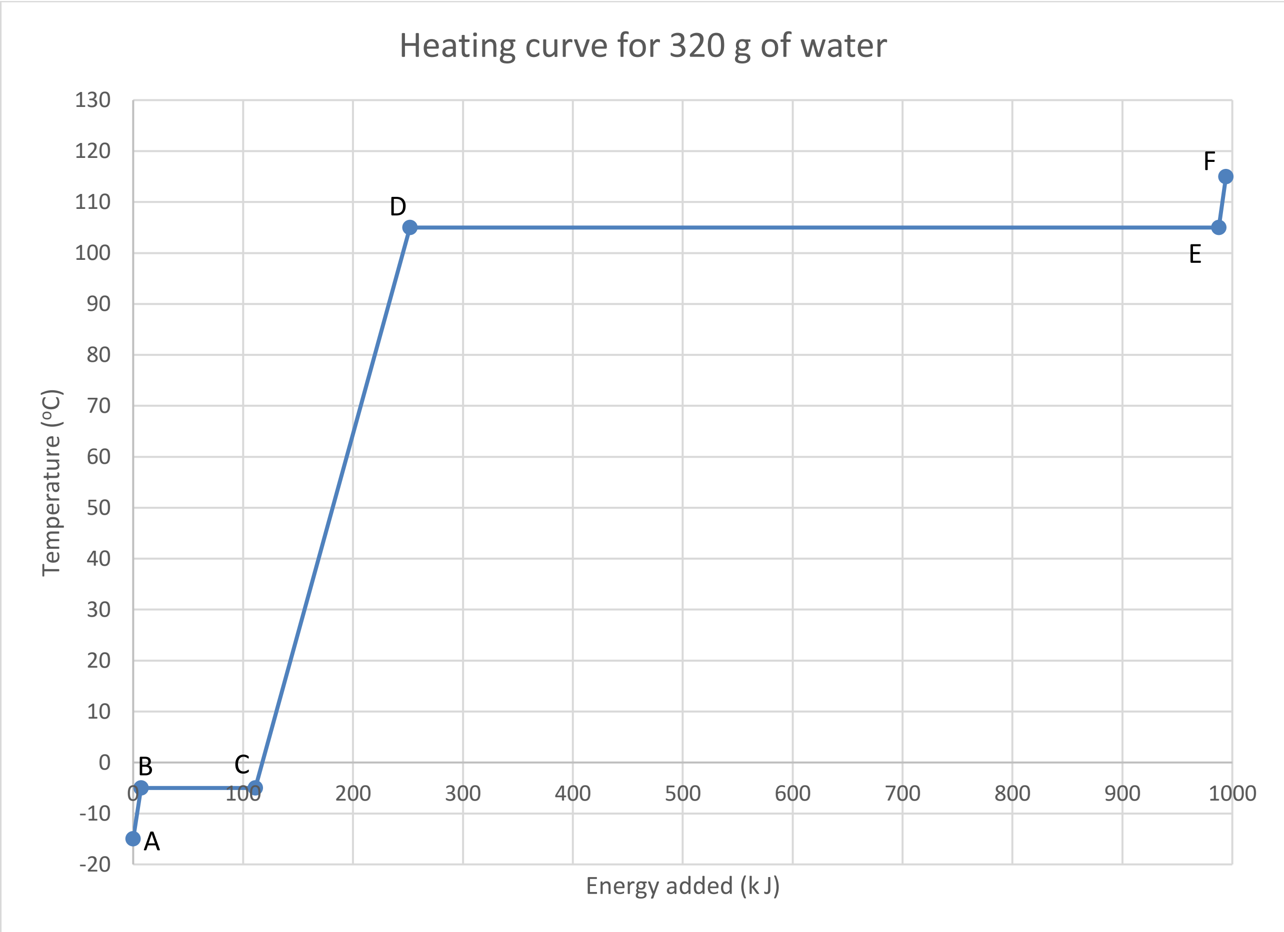
(d) If the hot water system holds 3.00×10^{2} L of water, calculate the increase in temperature of the water in one hour if the system absorbs 3.45 kW of solar energy (assuming all efficiency losses have been taken into account).

(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)

Question 4 **(12 marks)**

To investigate the properties of salt water Lia heated 320 g of frozen salt water at -15°C to a temperature of 115°C in an insulated container. Her results are shown in the heating curve below.



(a) Explain why the temperature of the salt water is constant between points D and E. You must refer to the kinetic particle model and the internal energy of the salt water.

(4 marks)

(b) Calculate the latent heat of vaporisation of the salt water from the graph. (4 marks)

(c) Calculate the specific heat of salt water from the graph. (4 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 1.40×10^5 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 4.00×10^2 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

4. (a) Description	**Marks**
Between Points D and E the salt water is changing phase (boiling).	1
As the energy is added to the salt water the particles separate which increases the potential energy and total internal energy of the of the salt water.	1
Temperature is a measure of the average kinetic energy of the particles.	1
As there is no change in temperature the average kinetic energy of the particles remains constant.	1
Total	**4**

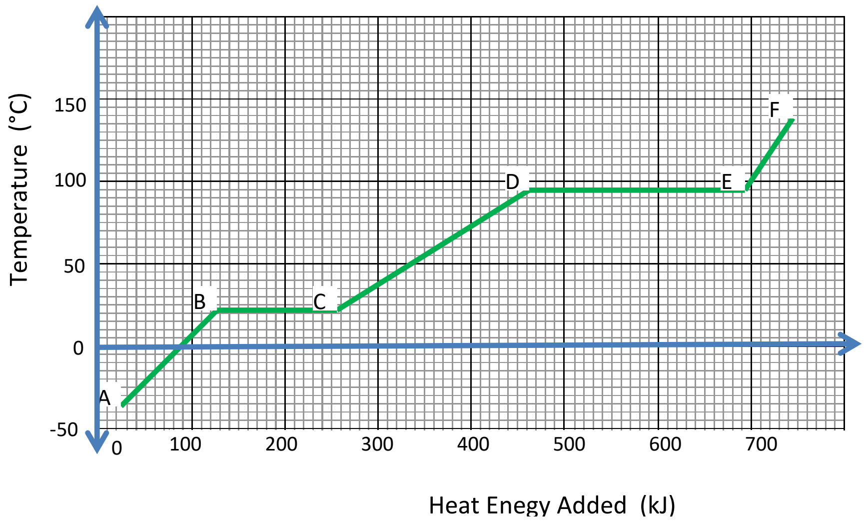
(b) Description	**Marks**
From the graph $Q_v = 990 - 250$	1
$= 740\ kJ$ (accept between 730 and 750 kJ)	1
$Q_v = mL_v$ $L_v = \frac{Q_v}{m} = \frac{740\times10^3}{0.320}$	1
$L_v = 2.31 \times 10^6\ J\ kg^{-1}$	1
Note: L_v will be between $2.28 \times 10^6\ J\ kg^{-1}$ and $2.34 \times 10^6\ J\ kg^{-1}$ for acceptable values of Q_v.	
Total	**4**

(c) Description	Marks
From the graph $\Delta T = 102 - -2 = 104^oC$	1
$Q_w = 250 \times 10^3 - 110 \times 10^3 = 1.40 \times 10^5\ J$	1
$Q_w = mc_w\Delta T$ $c_w = \frac{Q_w}{m\Delta T} = \frac{1{,}40\times10^5}{0.320\times104}$	1
$= 4.21 \times 10^3\ J\ kg^{-1}\ {}^oC^{-1}$	1
Tolerance on temperature values $\pm 2^oC$ Tolerance on Q_w $\pm 1 \times 10^4\ J$	
Total	**4**

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.

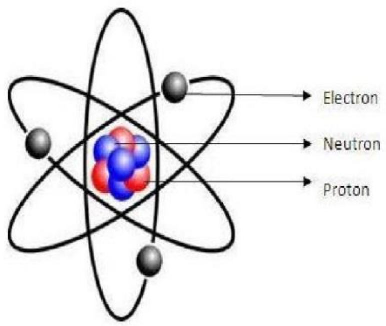
Nuclear Radiation – Produced by changes that occur in the nucleus of some atoms. Includes Alpha particles, Beta particles and Gamma rays.

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%).

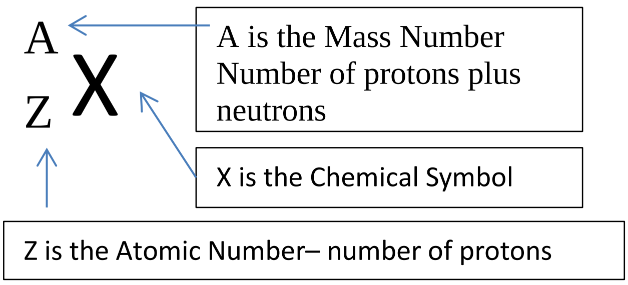
Model of Atom



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
n = number of half-lives = $t \div t_{\frac{1}{2}}$
t = time passed
$A = A_0(\frac{1}{2})^n$
$t_{\frac{1}{2}}$ = 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

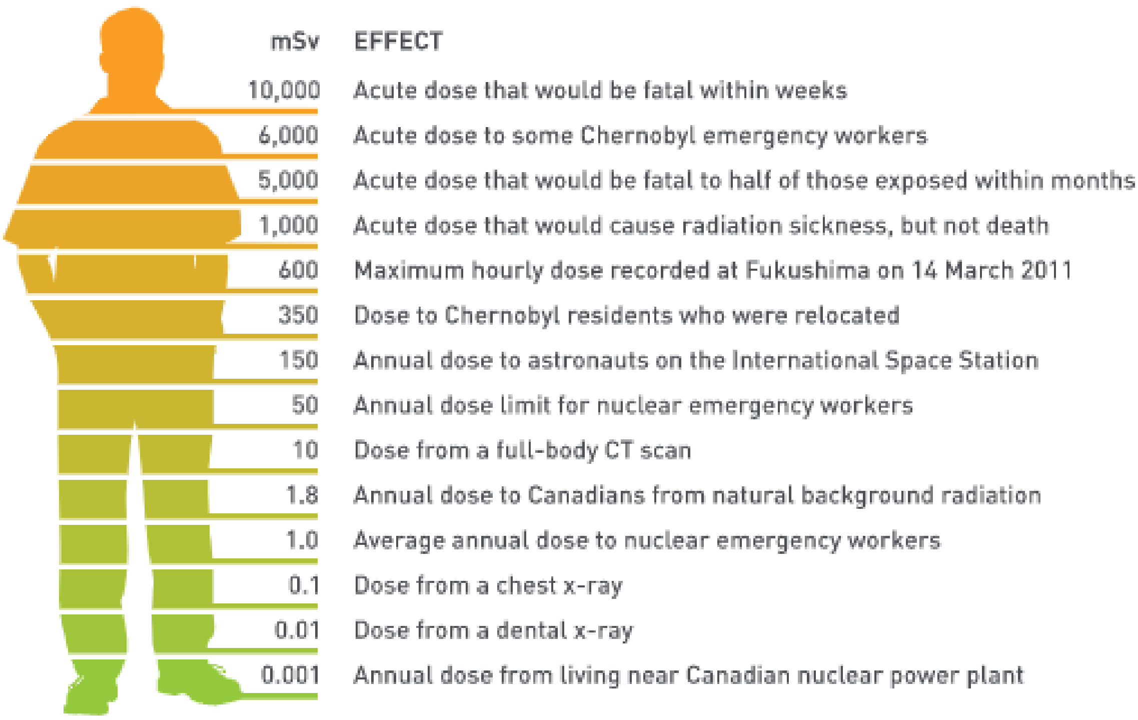
Biological Effects Of Radiation

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

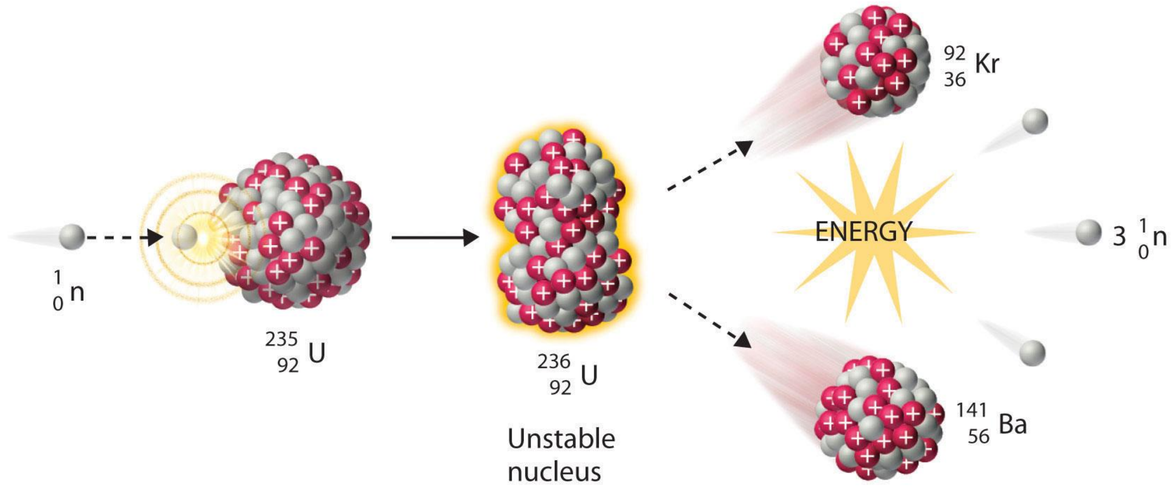
Dose Equivalent = Absorbed Dose X Quality Factor   units – sievert(Sv)

Effects of radiation on people

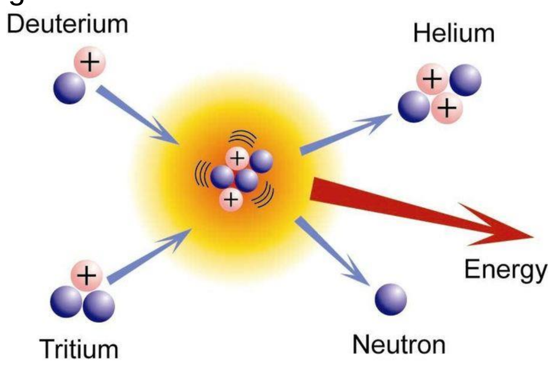


Nuclear Energy

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 x 10^{-27} kg
mass of U-233 = 3.869716824 x 10^{-25} kg
mass of Zr-93 = 1.542749382 x 10^{-25} kg
mass of Te-138 = 2.290370146 x 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)

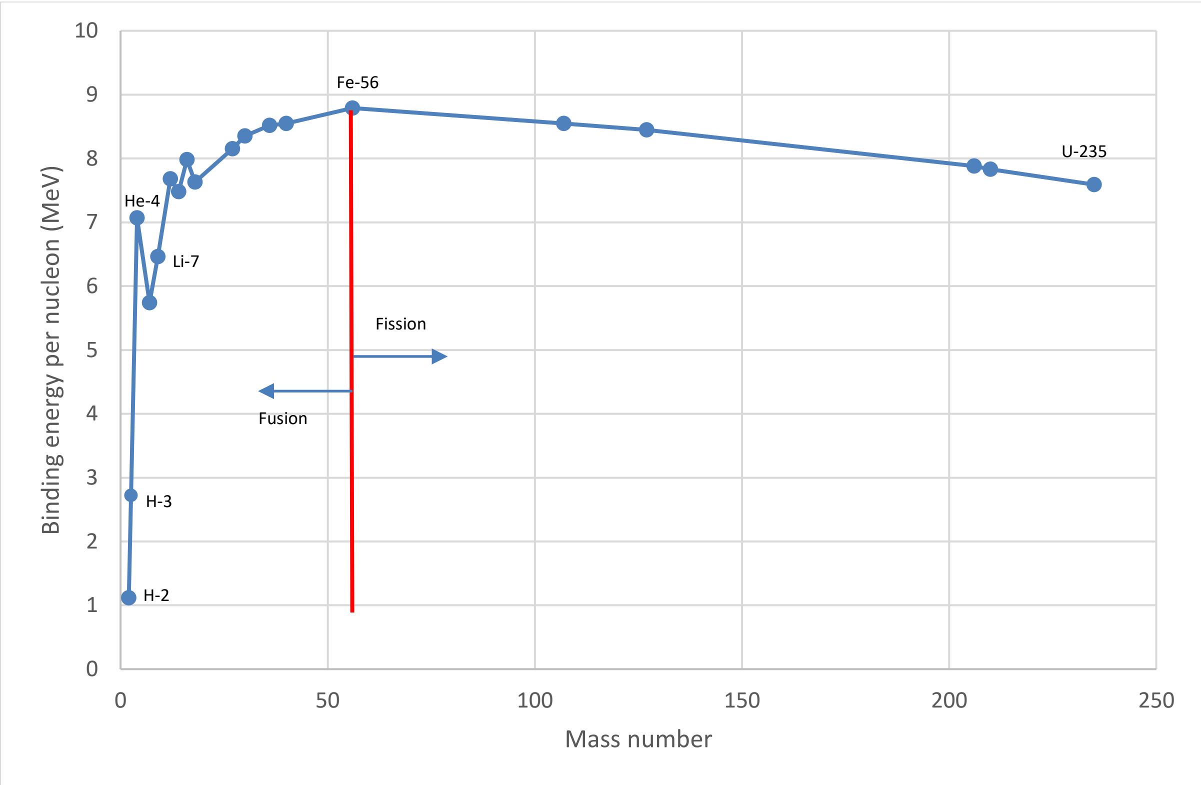
The Little Boy atomic bomb was a 'gun-type' fission weapon. When the bomb was detonated, a 38.5 kg 'bullet' of uranium-235 was fired towards a 25.6 kg 'target' of uranium-235. The combined uranium-235 then began nuclear fission and energy equivalent to 15.0 kT of TNT was released.

(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)

Question 5 **(11 marks)**

The figure below plots the binding energy per nucleon for elements of different mass numbers.



(a) Consider the Helium-4 and Lithium-7 nuclei. Which atom has the greater binding energy? Explain your answer (3 marks)

(b) Use the graph to explain why the fusion of two H-2 atoms to form He-4 will release energy. (3 marks)

(c) Calculate the binding energy for ${}^{56}_{26}Fe$ in MeV where: (5 marks)

$m({}^{56}_{26}Fe)$ =55.92069 u

$m(p^{+}) = 1.007276$ u

$m(n) = 1.008664$ u

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 = 4.80×10^2 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 = $48.9 \times 10^{-3} \times 20 = 0.978$ 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)
$= 1.674929445 \times 10^{-27} + 3.869716824 \times 10^{-25} – (1.542749382 \times 10^{-25} + 2.290370146 \times 10^{-25}$
$+ (3 \times 1.674929445 \times 10^{-27})$
$= 3.886466118 \times 10^{-25} – (3.883367411 \times 10^{-25})$
$= 3.098707 \times 10^{-28}$ kg

From $E = mc^2$ => $E = 3.098707 \times 10^{-28} \times (3.00 \times 10^8)^2 = 2.7888363 \times 10^{-11}$ J
Convert to eV: $2.7888363 \times 10^{-11} / 1.6 \times 10^{-19}$ = 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 = $15.0 \times 10^3 \times 4.18 \times 10^9 = 6.27 \times 10^{13}$ J
From $\Delta E = \Delta mc^2$ => $\Delta m = \Delta E / c^2 = 6.27 \times 10^{13} / (3.0 \times 10^8)^2 = 6.97 \times 10^{-4}$ kg = 0.697 g

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

(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.

Question 5 (a) **Description**	**Marks**
Lithium-7	1
binding energy He-4 = 4 x 7 = 28 MeV binding energy Li-7 = 7 x 6.4 =44.8 MeV Therefore total binding energy Li-7 > total binding energy He-4	1-2
Total	**3**

(b) **Description**	**Marks**
The H-2 atoms have a lower binding energy per nucleon than He-4 and therefore a greater mass per nucleon.	1
As the two H-2 atoms and the He-4 atom have the same number of nucleons the He-4 atom has less mass than the two H-2 atoms.	1
The lost mass is converted to energy through $E=mc^2$.	1
Total	**3**

(c) **Description**	**Marks**
mass of separated protons and neutrons $m(p^+ \; and \; n) = 26 \times 1.007276 + 30 \times 1.008664$	1
$= 56.449096 \; u$	1
Mass difference $\Delta m = m(^{56}_{26}Fe) \; - m(p^+ \; and \; n)$ $= 55.92069 - 56.449096$	1
$= 0.528406 \; u$	1
$BE = 0.528406 \times 931 = 492 \; MeV$	1
Total	**5**

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.

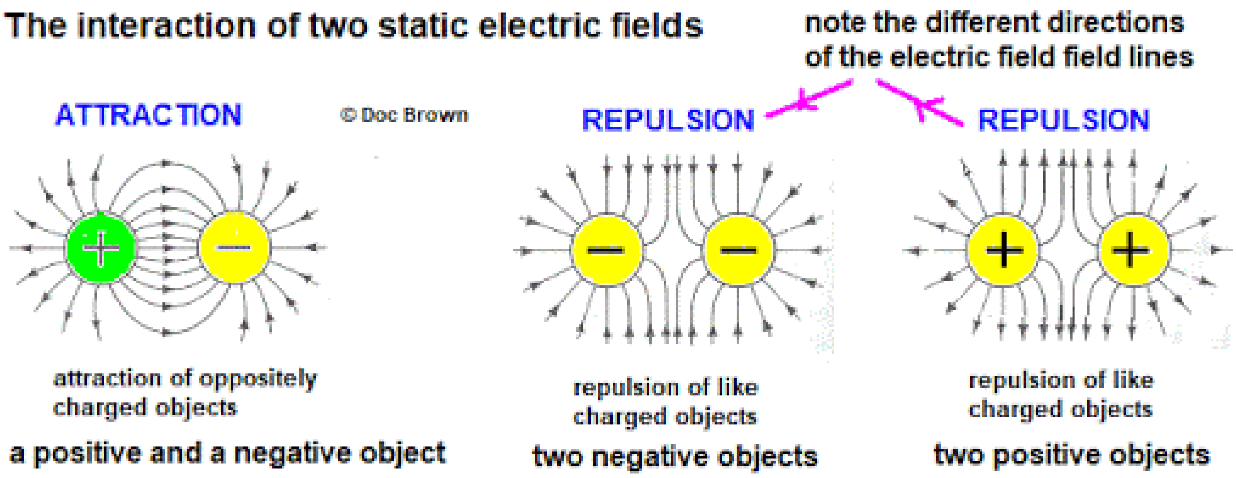
9. During radiation treatments where the source is outside the patient's body, the radiographer will rotate the source around the patient's body. Explain.

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.

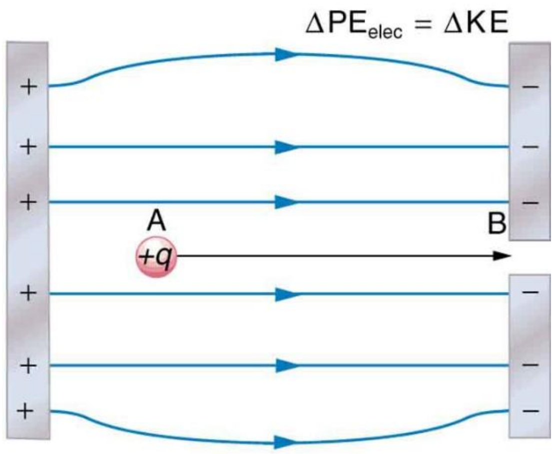


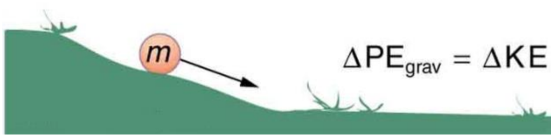
Electric Potential Difference (Voltage)
This is the energy per unit of charge and is required to make a charged particle move.

$V = \frac{W}{q}$ — V = electric potential energy, or voltage (volts – V)

W = work done on charge (J)

$W = Vq$ — q = charge (C)





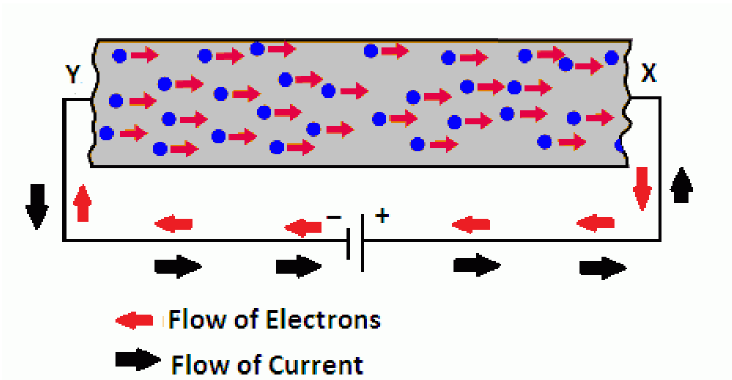
Electric Current (I)
This is the rate of flow of electric charges.

$I = \frac{q}{t}$ — I = Current (Amperes – A)

q = charge (C)

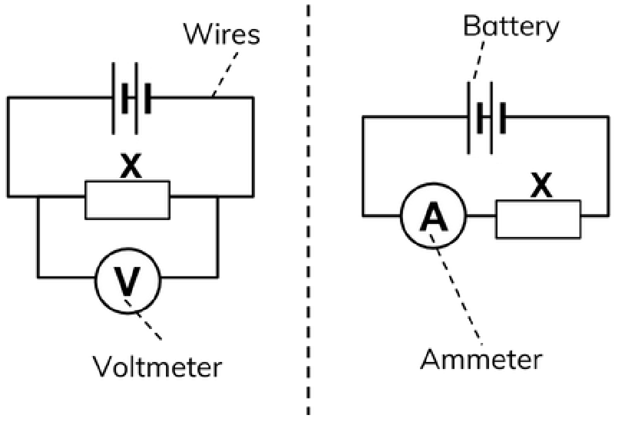
t = time (s)

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

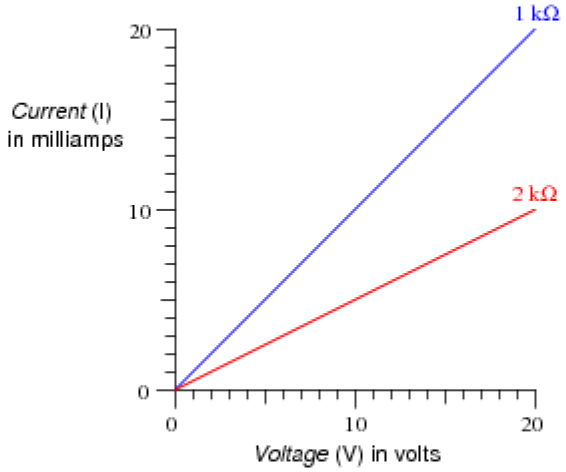
$E = Pt$ E = Energy used or work done (J)
$E = VIt$ P = Power (W)
V = Voltage (V)
I = Current (A)
t = time (s)

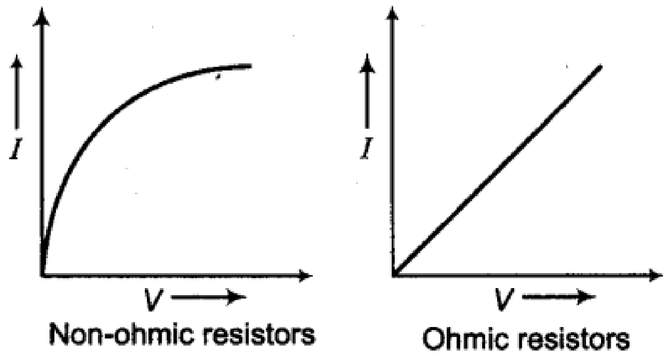
Western Power measure energy use by households in kilowatt-hours(kWh) because a Joule is too small a unit.   1 kWh = 3600000 Joules.

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)

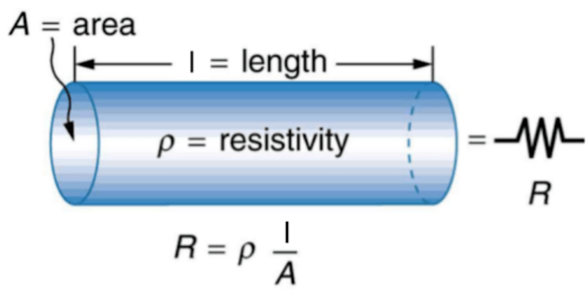




Factors affecting Resistance

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

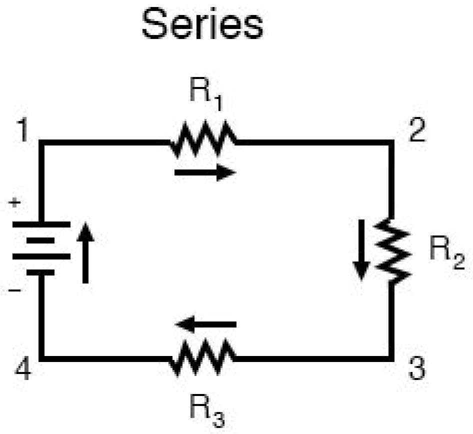
R = resistance (Ω)
ρ = resistivity (Ωm)
l = length (m)
A = cross-sectional area (m^2)

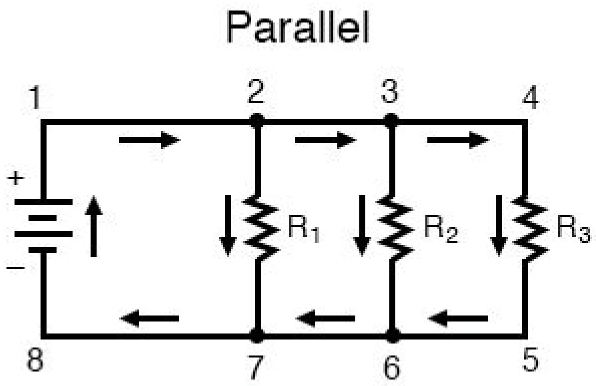


Note that this formula is not in the course, but it helps us to understand resistance.

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, $R_T = R_1 + R_2 + R_3 + ...$





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.

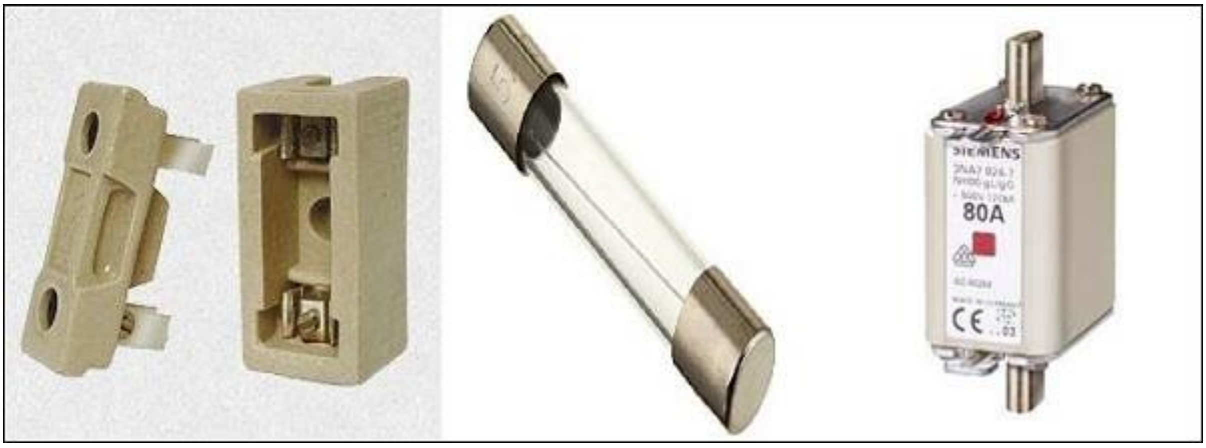
$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

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 x 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)**

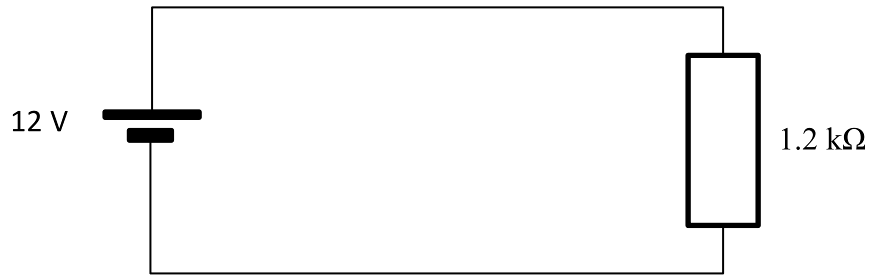
(a) Describe the purpose of a residual current device (RCD) and explain how it functions.

(2 marks)

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

Question 5 **(14 marks)**

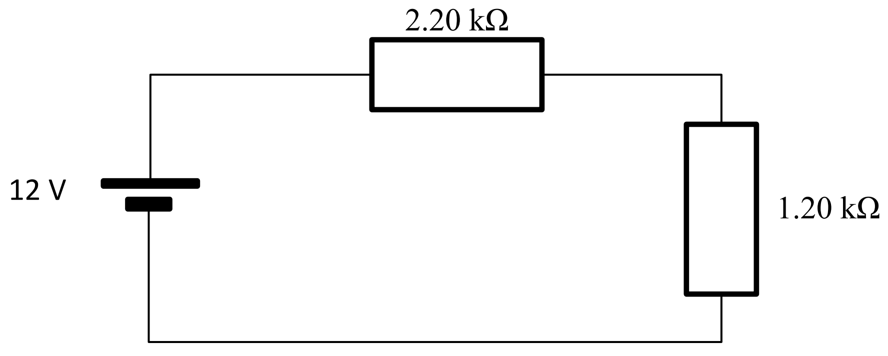
A resistor is connected to a 12.0 V battery via conductive wires as shown in the following circuit diagram. The resistor has a value of 1.20 kΩ.



(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?

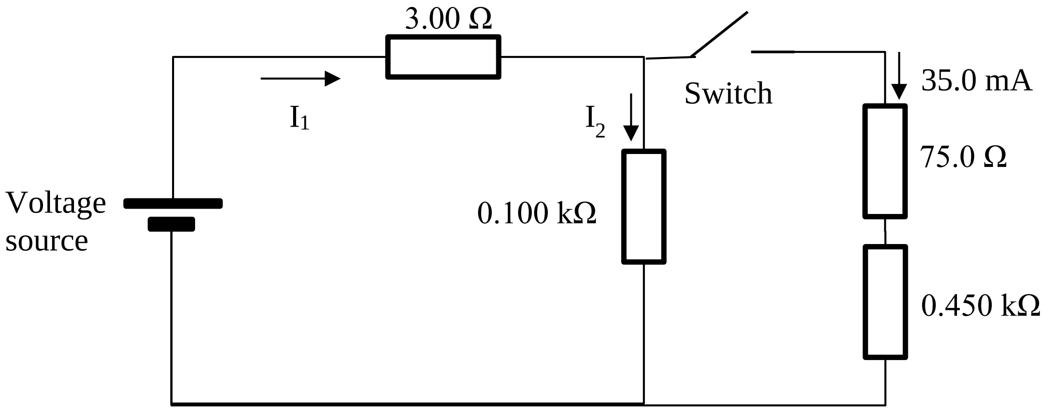
(i) longer wires were used (1 mark)

(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) $R_T = 1.2\text{ k} + 2.2\text{ k} = 3.4\text{ k}\Omega$

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;

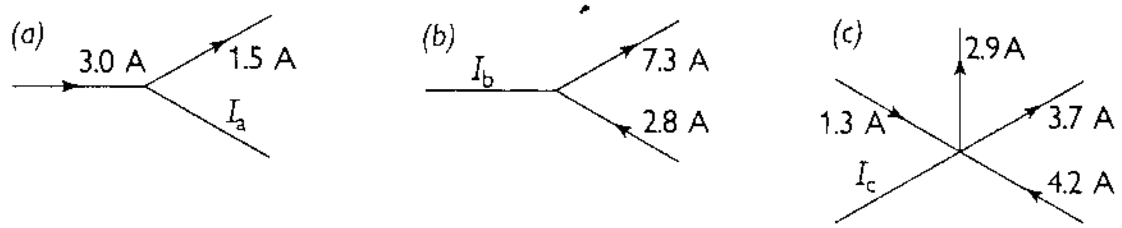
Voltage	**Current**	**Resistance**
	2 A	6 Ω
12 V		45 Ω
6 V	55 mA	
	5.5 A	3.2 kΩ
50 kV		250 kΩ
1.5 V	20 mA	

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.

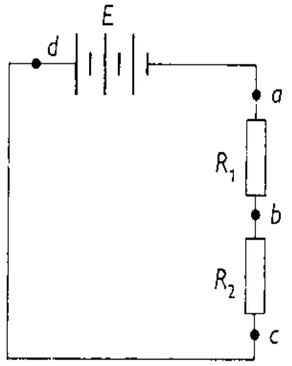
9. You are given 3 resistors with values 2Ω, 5Ω and 10Ω.
   a) What will be their total resistance if connected in series?

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.

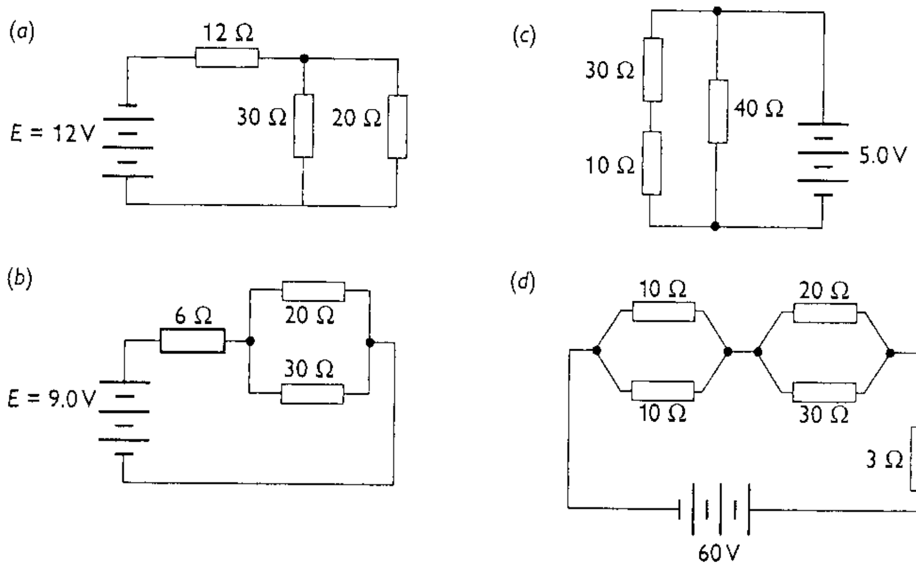
10. Find the unknown current at each of the junctions in the figure below. State the direction of the current in each case



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



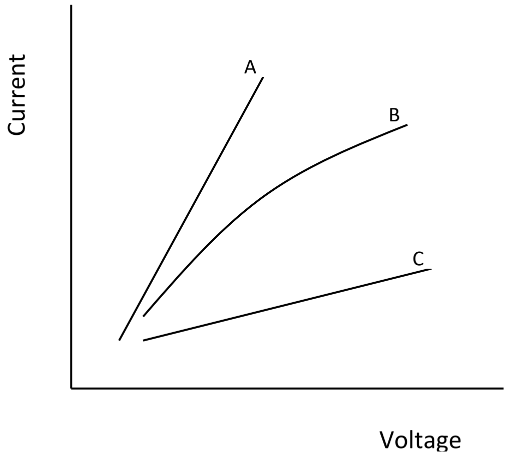
12. For each of the circuits (a), (b), (c) and (d), shown below, find;
(i) the effective resistance of each circuit
(ii) the total current in each circuit
(iii) the voltage drop across each resistor
(iv) the current through each resistor.



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?



Linear Motion & Force

Scalars and Vectors
A scalar has magnitude(size) only, where as a vector has size and direction.
Examples;

Scalars		**Vectors**	
distance	mass	displacement	force
speed		velocity	momentum
time		acceleration	

Measuring Motion
We must measure distance from a reference point over time.

Average Speed = $\frac{\text{total distance covered}}{\text{time taken}}$ units are m/s or ms^{-1}

Convert from km/h to m/s m/s = $\frac{\text{km/h}}{3.6}$

Instantaneous speed can be found by finding the gradient of a distance/time graph at a particular point in time.

Acceleration is the change in velocity over time.

Acceleration = $\frac{\text{final velocity – initial velocity}}{\text{Time}} = \frac{v - u}{t}$

Equations of Motion

$v = u + at$	v = final velocity (ms^{-1})
$s = ut + ½at^2$	u = initial velocity (ms^{-1})
$v^2 = u^2 + 2as$	t = time (s)
	a = acceleration (ms^{-2})
	s = displacement (m)

Gravity – When motion is caused by gravity, then acceleration is equal to gravity.
a = 9.8 ms^{-2} on the way down,
and a = - 9.8 ms^{-2} on the way up.

Graphing Motion
Displacement/time graphs
- slope(gradient) is the velocity

Velocity/time graphs
- slope is the acceleration
- area under graph is the displacement

Acceleration/time graphs can be used, but are not common.

Note : Look carefully at the axes of all graphs to identify which type it is.
Graphs of any motion will look different depending on what type of graph you are using.

Adding Vectors
Vectors are represented by arrows, with the length being the magnitude and the arrowhead showing the direction.
Two vectors can be added by putting the tail of the second vector at the head of the first. The resultant vector then goes from the tail of the first vector to the head of the second.
Vector diagrams can be drawn to scale and solved by measurement, or you can use pythagorus, or SOHCAHTOA to solve mathematically.

Newton's 1st Law Of Motion
A body will remain at rest or in uniform motion unless acted on by an external, unbalanced force.

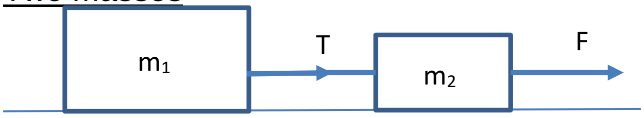
Newton's 2nd Law
The acceleration of a body is proportional to the net force applied and inversely proportional to its mass.

$F = ma$ or $F = \frac{m(v - u)}{t}$

F = Force(Newtons)
m = mass(kg)
a = acceleration(ms^{-2})
v = final velocity(ms^{-1})
u = initial velocity(ms^{-1})
t = time(s)

Newton's 3rd Law
For every action there is an equal and opposite reaction.

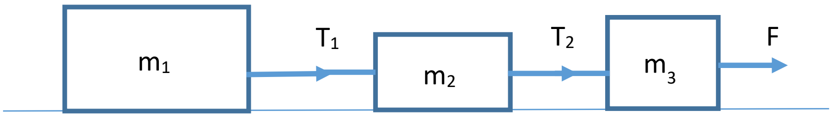
Connected Masses
Two masses



Both masses are accelerated at the same rate because they are joined together.

$a = \frac{\text{Net Force}}{(m_1 + m_2)}$ then $F - T = m_2a$ → $T = F - m_2a$

Three masses



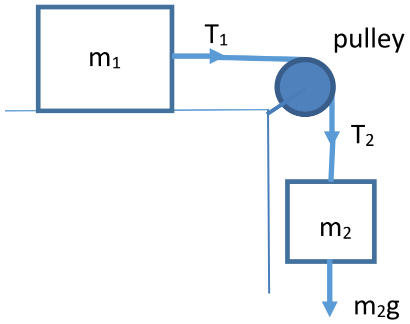
All 3 masses are accelerated at the same rate because they are joined together.

$a = \frac{\text{Net Force}}{(m_1 + m_2 + m3)}$ then $F - T_2 = m_3a$ → $T_2 = F - m_3a$

$T_1 = m_1a$

$T_2 - T_1 = m_2a$

Two masses with one hanging over pulley



$T_1 = T_2$

$a = \dfrac{m_2 g}{(m_1 + m_2)}$

$T_1 = T_2 = m_2 g - m_2 a$

Momentum(ρ) is the product of mass and velocity of a body.

$\rho = mv$ units are $kgms^{-1}$

Conservation of Momentum - momentum before collision = momentum after

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

Impulse

$$I = Ft = \frac{m(v-u)t}{t} = m(v-u) = \text{change in momentum} = \Delta\rho$$

Work, $W = Fs$

W = Work (joules)
F = Force (N)
s = displacement(m)

Power $P = \dfrac{W}{t} = \dfrac{Fs}{t} = Fv$ P = Power(Watts)

Kinetic Energy, $E_K = \frac{1}{2}mv^2$

Potential Energy, $E_P = mgh$

Conservation Of Energy

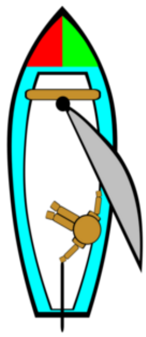
Potential energy is converted to kinetic energy on the way down.
Kinetic energy is converted to potential energy on the way up.

$$\Delta E_K = \Delta E_P$$

Linear Motion & Force Exam Questions

Question 1 (5 marks)

Conall is sailing a boat North at 5.50 m s^{-1} when he enters a current travelling East at 1.50 m s^{-1}. Calculate Conall's resultant velocity once he enters the current. You must state the magnitude and direction of his resultant velocity.



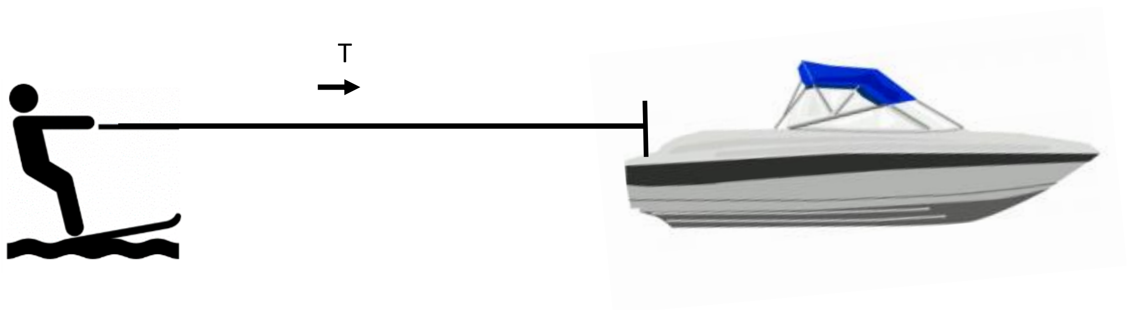
Question 2 (4 marks)

As shown in the diagram Car 1 is moving to the right at an initial speed u. The car then impacts the rear end of Car 2 which is initially stationary. Both Car 1 and Car 2 have the same mass m. After the collision both cars are effectively joined and move to the right at half of the initial speed of Car 1.

Determine if the collision is elastic or inelastic.

Question 3 (15 marks)

The figure below shows a water skier being pulled to the right by a speed boat. The water skier and the boat are travelling in a straight line and the water skier is directly behind the boat. The mass of the person is 80.0 kg and the frictional force between the water skies and the water is 100 N. *T* is the tension in the rope.



The water skier has an initial speed of 12.8 m s^{-1} and is accelerated by the boat at 5.20 m s^{-2}.

(a) Calculate the time that it takes for the water skier to reach a final speed of 64.0 m s^{-1}. (2 marks)

(b) Calculate the distance that the skier travels while being accelerated. (3 marks)

(c) Calculate the work done by the boat while pulling the water skier a distance of 3.00 km at a constant speed of 64.0 m s^{-1}. (2 marks)

(d) Calculate the power required to overcome friction when pulling the water skier at a constant speed of 64.0 m s^{-1}. (2 marks)

(e) Calculate the tension in the rope if the rope is horizontal and the water skier is accelerated at 5.20 m s^{-2}. (3 marks)

(f) The angle of the ski rope is changed such that it now makes an angle of 15.0 º to the horizontal. Calculate the tension in the rope if the friction force is 100 N and the boat travels at a constant speed. (3 marks)

Question 4 **(13 marks)**

Jack drops a small rubber ball from a height of 1.50 m above flat ground. The mass of the ball is 0.120 kg. Air resistance can be neglected for each of the following questions.

(a) Which of the following statements correctly describes the applied forces as the ball impacts the ground? Circle the correct answer and provide an explanation below.

(i) The force that the ball applies to the ground is **greater than** the force that the ground applies to the ball.

(ii) The force that the ball applies to the ground is **less than** the force that the ground applies to the ball.

(iii) The force that the ball applies to the ground is **equal to** the force that the ground applies to the ball.

Explanation (3 marks)

(b) Calculate the velocity of the ball as it impacts the ground. (3 marks)

(c) The ball is dropped again from a different height and impacts the ground with a speed of 5.00 m s^{-1}. If the collision that the ball makes with the ground is elastic and the impact time is 0.01 s, calculate the magnitude of the average force that the ball applies to the ground.
(3 marks)

(d) A 46.0 g golf ball is dropped and impacts the ground with a velocity of 7.00 m s^{-1}. The golf ball then bounces to a height of 1.75 m above the ground. Calculate the efficiency of the impact.

Answers to Exam Questions

Question 1 Description	Marks
$\sum v = \sqrt{v_{boat}^2 + v_{current}^2}$ $= \sqrt{5.50^2 + 1.50^2}$	1
$\sum v = 5.70\ m\ s^{-1}$	1
$tan\theta = \frac{v_{current}}{v_{boat}}$ $\theta = \tan^{-1}\left(\frac{1.50}{5.50}\right)$	1
$\theta = 15.3^o$	1
$\sum v = 5.70\ m\ s^{-1}, N15.3^o E$ (or similar)	1
Total	**5**

Question 2 Description	Marks
Before the collision $KE_{before} = \frac{1}{2}mu^2$ After the collision $KE_{after} = \frac{1}{2}(m+m)v^2$	1
Substituting v=u/2 $KE_{after} = \frac{1}{2}(2m) \times \left(\frac{u}{2}\right)^2$ $= m \times \left(\frac{u^2}{4}\right)$ $= \frac{1}{4}mu^2$	1-2
As $KE_{before} \neq KE_{after}$ collision is inelastic.	1
Total	**4**

Question 3 (a) Description	Marks
$a = \frac{v-u}{t}$ $t = \frac{v-u}{a}$ $= \frac{64.0-12.80}{5.20}$	1
$t = 9.85\ s$	1
Total	**2**

(b) Description	Marks
$v^2 = u^2 + 2as$ $s = \frac{v^2-u^2}{2a}$	1
$s = \frac{64^2-12.8^2}{2\times5.2\ m0}$	1
$s = 378\ m$	1
Total	**3**

(c) Description	Marks
$W = F \times s$ $= 100 \times 3000$	1
$W = 3.00 \times 10^5\ J$	1
Total	**2**

(d) Description	Marks
$P = Fv$ $= 100 \times 64.0$	1
$P = 6.40\ kW$	1
Total	**2**

(e) Description	Marks
$\Sigma F = ma$ $T - F_f = ma$	1
$T = ma + F_f$ $= 80.0 \times 5.20 + 100$	1
$T = 516\ N$	1
Total	**3**

(f) Description	**Marks**
$cos\theta = \frac{F_f}{F_r}$	1
$cos15 = \frac{100}{F_r}$ $F_r = \frac{100}{\cos 15}$	1
$F_r = 104\ N$	1
Total	**3**

Question 4 (a) Description	**Marks**
(iii) The force that the ball applies to the ground is **equal to** the force that the ground applies to the ball.	1
Newtons Third Law states that for every action there is an equal and opposite reaction	1
Therefore the force that the ball applies to the ground is equal to the force applied to the ball.	1
Total	**3**

(b) Description	**Marks**
$v^2 = u^2 + 2as$ $v^2 = 0^2 + 2 \times -9.8 \times -1.50$	1
$v = -\sqrt{2 \times -9.8 \times -1.50}$	1
$v = -\ 5.42\ m/s\ \ or\ \ 5.42\ m/s\ \ down$	1
Total	**3**

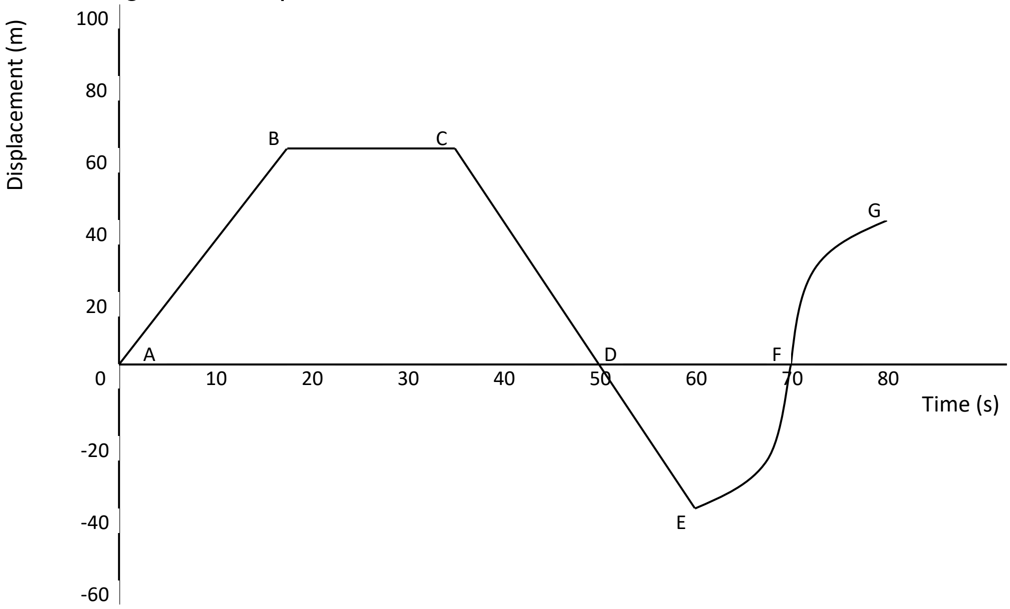
(c) Description	**Marks**
$F\Delta t = mv - mu$ $F = \frac{mv-mu}{\Delta t}$ $F = \frac{0.120\times5-0.120\times-5}{0.01}$	1-2
$F = 120\ N$	1
Total	**3**

(d) Description	**Marks**
At impact $TME_1 = \frac{1}{2} \times m \times v_1^2 + m \times g \times h_1$ $= \frac{1}{2} \times 0.046 \times 7.00^2$ $= 1.127\ J$	1
At max height $TME_2 = \frac{1}{2} \times m \times v_2^2 + m \times g \times h_2$ $= 0 + 0.046 \times 9.8 \times 1.75$ $= 0.7889\ J$	1
$efficiency = \frac{TME_2}{TME_1} \times 100$ $= \frac{0.7889}{1.127} \times 100$	1
$efficiency = 70.0\ \%$	1
Total	**4**

Linear Motion & Force Questions

1. Sort the following into vector and scalar quantities;
mass, weight, distance, speed, velocity, time, energy, displacement, acceleration, force, temperature, momentum.

2. The following graph shows the straight line motion of a model car. The car starts off travelling east from point zero.



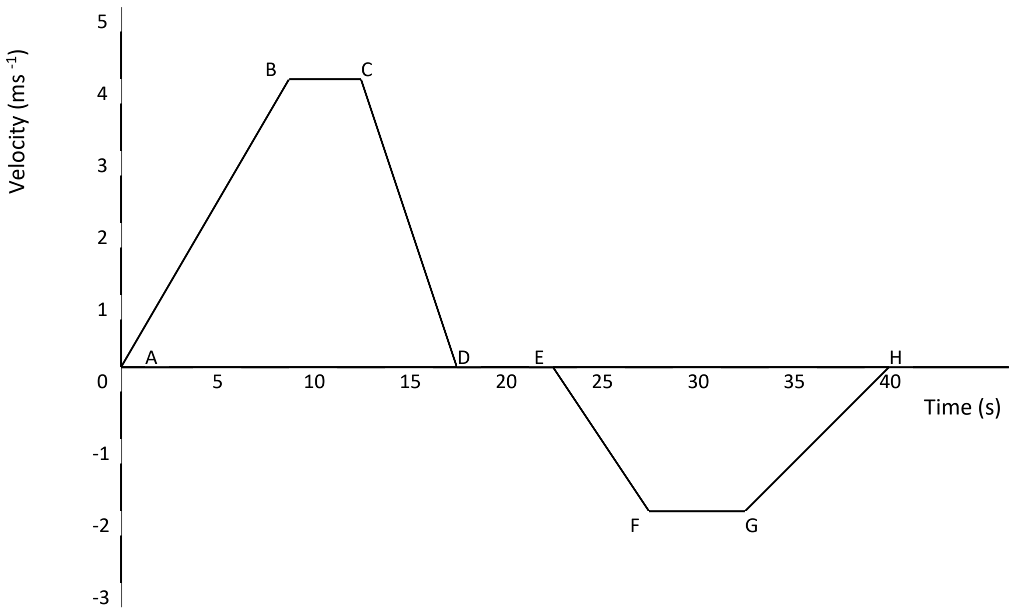
a) Which segments of the graph show the car travelling east?
b) Which segments of the graph show the car not moving?
c) Calculate the velocity over segment AB.
d) What was the total distance that the car travelled from A to G?
e) What was the total displacement from A to E?
f) Calculate the average speed of the car.
g) Calculate the average velocity of the car.
h) Describe the car's motion from E to F.
i) Describe the car's motion from F to G.

3. A boy rides his bike to a friends' house. He rides west for 800 m, then north for 1.30 km, then east for 300 m. The journey takes 10 minutes.
a) What distance did he travel?
b) What was his displacement?
c) Calculate his average speed.
d) Calculate his average velocity.

4. In 1995, a cyclist, set a world record of 3 min, 36.081 s for the 3000 m pursuit.
(a) What was her average speed?
(b) How long would it take her to cycle a distance of 151 km, if she could maintain her average speed for the 3000 in pursuit for the whole distance?
(c) How long does it take a car to travel the 151 km if its average speed is 80 km h^{-1}?
(d) A car travels 151 km South and then back to the starting point in 4.0 hrs.
(i) What is its average speed? (ii) What is its average velocity?

5. A boat sets off perpendicular to the bank, to cross a river of width 250 m. The speed of the boat in still water is 3.20 ms^{-1}, however, there is a current downstream at 1.20 ms^{-1}, which pushes the boat sideways.
   a) Find the resultant velocity of the boat (include direction as an angle to the bank)
   b) Find the total distance the boat travels in crossing the river.
   c) How long does the crossing take?
   d) How far downstream from the starting point does the boat travel?

6. The following graph shows the velocity of a girl on her bike, riding up and down the street.



   a) Calculate the acceleration for sections AB and CD.
   b) Which section/s had zero acceleration?
   c) Calculate the acceleration for sections EF and GH.
   d) Find the total distance travelled.
   e) Calculate the average speed.
   f) Find the total displacement after the 40 seconds.
   g) Calculate the average velocity.

7. A car accelerates from rest at 3.00 ms^{-2} for 7.0 seconds, then maintains this speed for the next 2.0 minutes. It then slows to a stop for a traffic light, taking 10.0 seconds to stop.
   a) Calculate the maximum velocity of the car (in ms^{-1} and kmh^{-1}).
   b) Calculate the average deceleration of the car as it came to a stop.
   c) How far did the car travel.

8. How long does it take for:
   (a) a car to accelerate on a straight road at a constant 6.0 ms^{-2} from an initial speed of 60 km h^{-1} (17 m s^{-1}) to a final speed of 100 kmh^{-1} (28 ms^{-1})?
   (b) a downhill skier to accelerate from rest at a constant 2.0 ms $^{-2}$ to a speed of 10 m s^{-1}.

9. A car is speeding at a constant velocity of 30.0 ms^{-1} in an 80 kmh^{-1} zone as it passes a stationary police motorcycle hiding behind a bush. The motorcycle starts to accelerate at 5.00 ms^{-2} at the same instant that the car passes it and continues to accelerate for 8.0 seconds. It then stops accelerating and maintains its speed until it catches the car.

a) How long does it take the police motorcycle to catch the car?
b) How far did the motorcycle travel before catching the car?

10. A ball is thrown straight up into the air from a height of 1.20 m above the ground at a velocity of 5.00 ms^{-1}.

a) Find the maximum height the ball reached above ground level.
b) How long was the ball in the air if it was allowed to hit the ground?

11. A skateboard rider travelling down a hill notices the busy road ahead and comes to a stop in 2.0 s over a distance of 12 m. Assume a constant negative acceleration.

(a) What was the initial speed of the skateboard?
(b) What was the acceleration of the skateboard as it came to a stop?

12. Draw vector diagrams to find the resultant for the following pairs of vectors; (Be sure to find magnitude and direction)

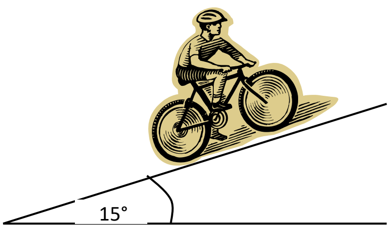
a) 8.0 km North and 6.0 km East
b) 35.0 N South and 45.0 N East
c) 68.0 kmh^{-1} West and 23.0 kmh^{-1} South
d) 9.80 ms^{-2} down and 3.20 ms^{-2} left

13. A tennis ball of mass 80.0 g hits the ground at an angle of 45° with a speed of 25.0 ms^{-1}. It bounces off at 45° with a reduced speed of 22.0 ms^{-1}. Calculate the change in momentum of the ball.

14. A 60 g tennis ball is bounced vertically onto the ground. After reaching the ground with a downwards velocity of 8.0 ms^{-1}, the ball rebounds with a velocity of 6.0 ms^{-1} vertically upwards.

(a) What is the change in momentum of the tennis ball?
(b) What is the impulse applied by the tennis ball to the ground?
Explain how you obtained your answer without any information about the change in momentum of the ground.
(c) Does the ground actually move as a result of the impulse applied by the tennis ball? Explain your answer.
(d) If the tennis ball is in contact with the ground for 2.0×10^{-3} s, what is the average net force on the tennis ball during this interval?
(e) What is the average normal reaction force during this time interval?

15. A cyclist of mass 70.0 kg is riding up an incline of 15°.



a) If the bike has a mass of 18 kg, find the force due to gravity down the slope that the cyclist must work against.

b) The cyclist must also work against a force due to air resistance and friction of 20.0 N. If he is travelling at a constant velocity, what is the driving force being applied up the slop

16. A cannon of mass 550 kg fires a cannon ball of mass 30.0 kg with a velocity of 45.0 ms^{-1}. With what speed does the cannon begin to move backwards.

17. Use Newton's 1st Law to explain why seat belts are fitted to cars.

18. Use Newton's 2nd Law to explain how air bags, crumple zones, collapsible steering wheels, and padded dash boards can help save peoples' lives in a car accident.

19. Explain how we use Newton's 3rd Law to walk or run.

20. A 850 g basketball is dropped from a height of 2.00 m. Calculate the;
a) Initial potential energy of the ball
b) Kinetic energy of the ball as it strikes the ground
c) The stored elastic potential energy in the ball if 35% of its kinetic energy is lost in the collision as heat and noise.
d) The height the ball bounces.

21. A downhill skier of mass 60 kg accelerates down a slope inclined at an angle of 30° to the horizontal. Her acceleration is a constant 2.0 ms^{-2}. What is the magnitude of the friction force resisting her motion?

22. A car with a total mass of 1400 kg (including occupants) travelling at 60 km h^{-1} hits a large tree and stops in 0.080 s.
(a) What impulse is applied to the car by the tree?
(b) What force is exerted by the tree on the car?
(c) What is the magnitude of the deceleration of the 70 kg driver of the car if he is wearing a properly fitted seat belt?

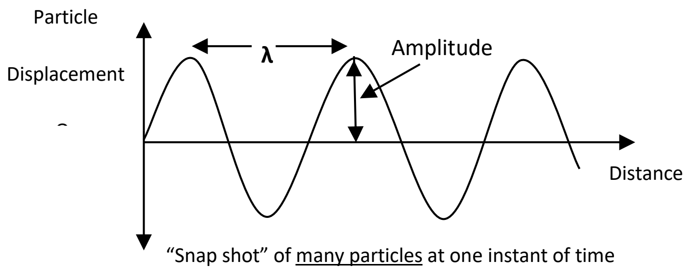
23. Nick and his brother Luke are keen roller-bladers. Nick approaches his stationary brother at a speed of 2.0 ms^{-1} and bumps into him. As a result of the collision Nick, who has a mass of 60 kg, stops moving, and Luke, who has a mass of 70 kg, moves off in a straight line. The surface on which they are `blading' is smooth enough so that friction can be ignored.
(a) With what speed does Luke move off?
(b) What is the magnitude of the impulse on Nick as a result of the bump?
(c) What is the magnitude of Nick's change in momentum?
(d) What is the magnitude of Luke's change in momentum?
(e) How would the motion of each of the brothers after their interaction be different if they pushed each other instead of just bumping?
(f) If Nick held onto Luke so that they moved off together, what would be their final velocity?

Waves

Transverse Waves – particle movement is perpendicular to wave velocity.
eg. Water waves, waves in stretched strings, etc.
Longitudinal Waves – particle movement is parallel to wave velocity.
eg. Sound.
Amplitude – the maximum displacement of a particle from it mean position.
Frequency(f) – the number of wavelengths produced in one second. Units Hertz(Hz).
Wavelength(λ) – the length of a wave. Units Metres(m).

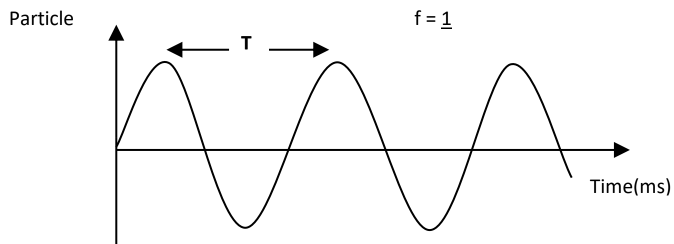
Graphing Waves (look at axes carefully)

Particle Displacement Vs Distance
- Snap shot which shows **many particles** at one instant in time.
- Can find wavelength, λ.
- Pressure Vs Distance gives the same information.



"Snap shot" of many particles at one instant of time

Particle Displacement Vs Time
- Shows the movement of **one particle** only.
- Can find Period, T, then Frequency, f = 1/T

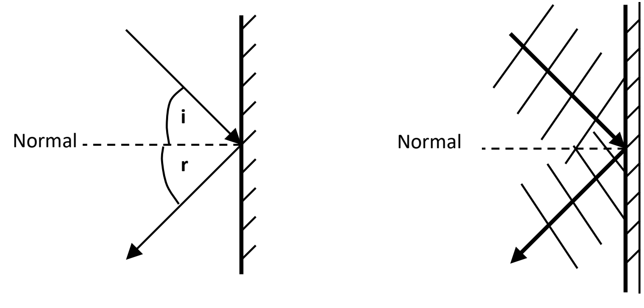


The movement of one particle only over time

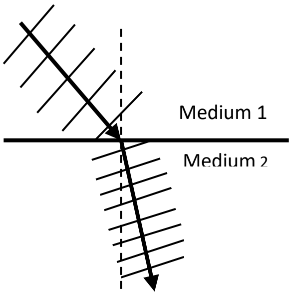
Wave Equation $v = f.\lambda$

The Law of Reflection states that the angle of incidence is equal to the angle of reflection (i = r).

All angles are measured to the **normal**.



Refraction is the bending of a wave due to a change in speed as it travels from one medium to another due to the wave velocity being different in the two media.

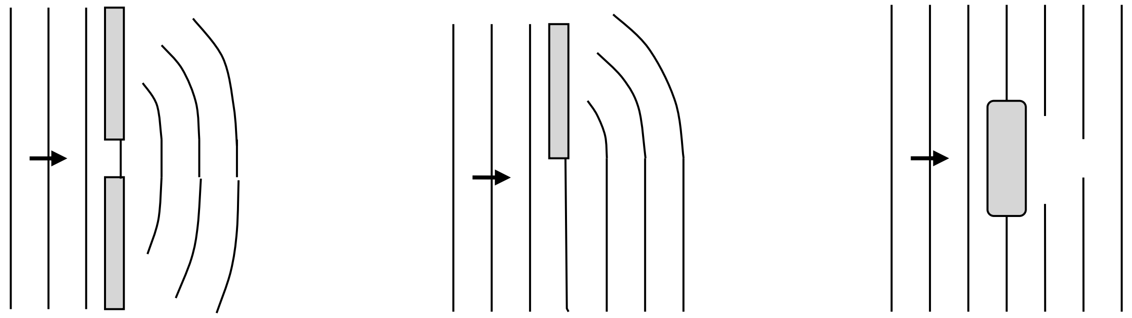


Note that the wave fronts are closer together when the wave is traveling slower.
Waves bend towards the normal when going from a faster medium to a slower medium.
They bend away from the normal when speeding up.

Diffraction is the spreading of a wave as it goes through a gap, past a corner, or around an obstacle

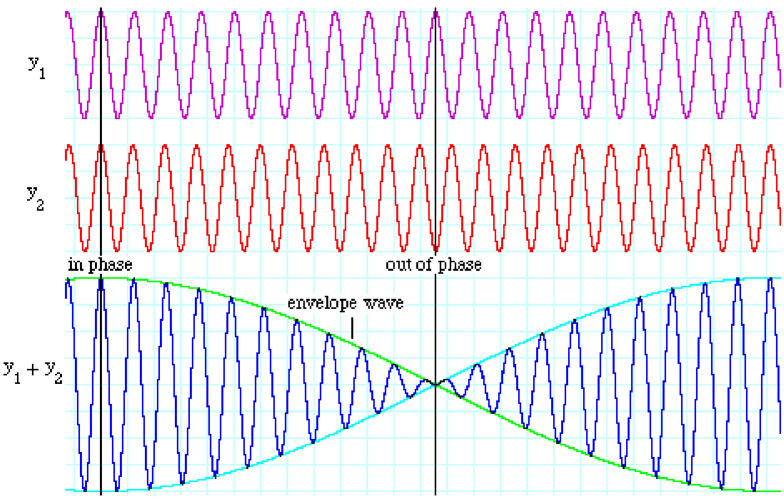
Diffraction occurs **best** when the **gap or obstacle is about the same size as the wavelength** of the wave.

In general, larger wavelengths are more easily diffracted.

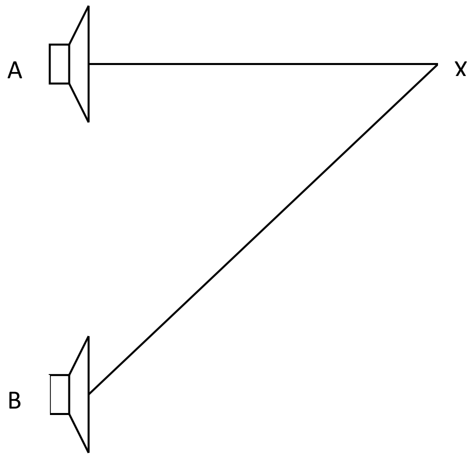


Forced Vibrations occur when an object is forced to vibrate by something else.
eg. Bench top is forced to vibrate at same frequency as tuning fork.
Natural Vibrations occur when an object is hit and left to vibrate at its natural frequency. eg. Tuning fork, guitar string, etc
Resonance occurs when the forcing vibrations match the natural frequency. The amplitude will increase while the forcing vibrations continue.
eg. Person pushing child on swing, opera singer holding a note to break wine glass, resonating air columns, and vibrating strings

Interference between two sound sources with **slightly different frequencies** will produce
Beats. $f_b = |f_2 - f_1|$
Beat frequency must be less than 10 Hz or our ears will not hear it as a beat because the loud parts are too close together.



Interference between two sources of sound of **same frequency**(i.e. 2 speakers).

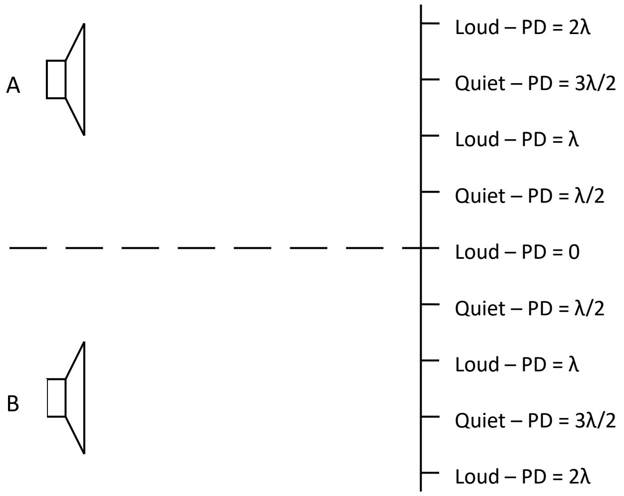


Path Difference(PD) = BX – AX

If **PD = 0, λ, 2λ, 3λ, . . .**

Then X is a point of constructive interference(Loud).

If **PD = λ/2, 3λ/2, 5λ/2, . . .**

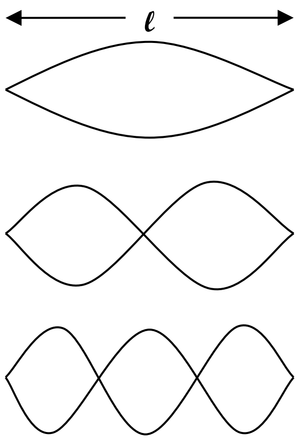


Constructive and destructive interference is symmetrical about the line that is midway between the two speakers.

This can be used in calculations where the

Vibrations in Strings and Air Columns (open and closed pipes).

Stretched Strings



First Harmonic

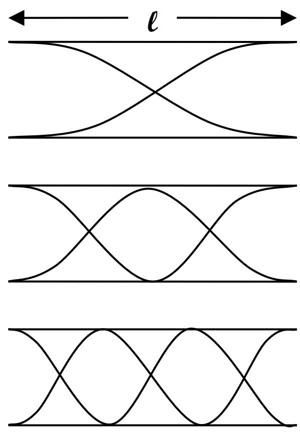
← **λ= 2ℓ** →

f = f$_o$

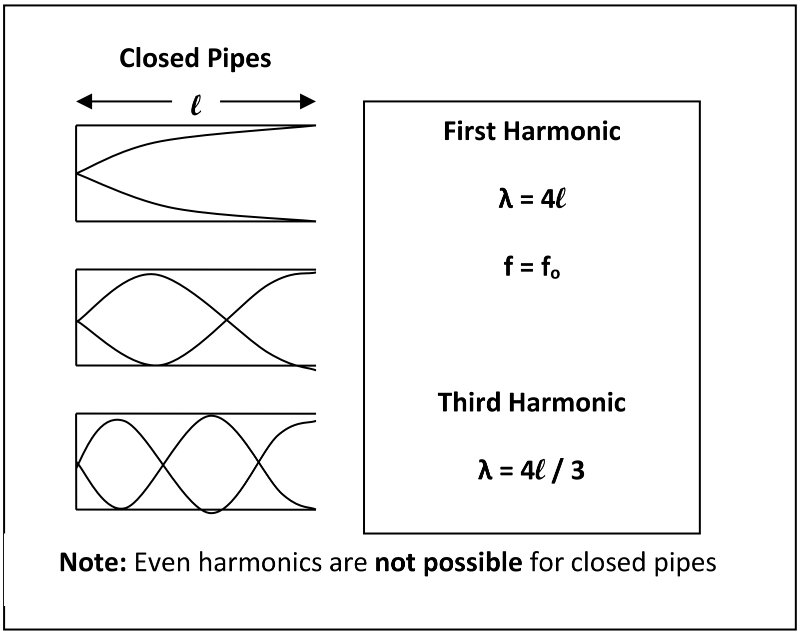
Second Harmonic

← **λ= ℓ** →

Open Pipes



Note ; All diagrams show particle displacement nodes and antinodes

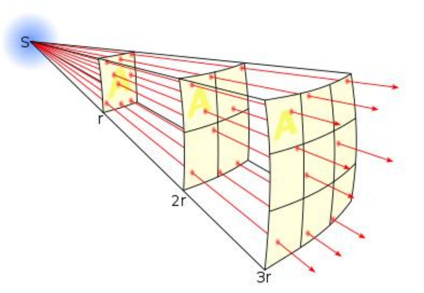


Pressure nodes and antinodes are in the opposite positions to the particle displacement nodes and antinodes in the diagrams shown above.

Intensity of Sound and The Inverse Square Law

The loudness of a sound is often referred to as sound intensity.
The intensity of a sound is the amount of sound energy (measured in Joules, J) passing through a unit area (a square metre) in one second.
Intensity has the unit of Joules per second per square metre. As 1 Joule per second is also the unit for power, watts (W), we get the unit for intensity being Watts per square metre, W m^{-2}.

The energy from a light or sound wave will spread out as it moves away from its source. As it moves away the energy will spread across an increasingly larger area and the intensity of the sound or light will decrease. The intensity of the sound or light will decrease in proportion to the inverse of the square of the distance from the source. We assume that the source of the sound or light acts as a point source and the relationship between intensity and distance is known as the inverse square law.



Mathematically, the inverse square law is: $I \propto 1/r^2$

To compare the intensity of sound or light at two points: $I_1 r_1^2 = I_2 r_2^2$

Where:

I_1= intensity at position 1
r_1= distance between the source and position 1
I_2= intensity at position 2
r_2= distance between the source and position 2

Waves Exam Questions

Question 5 **(5 marks)**

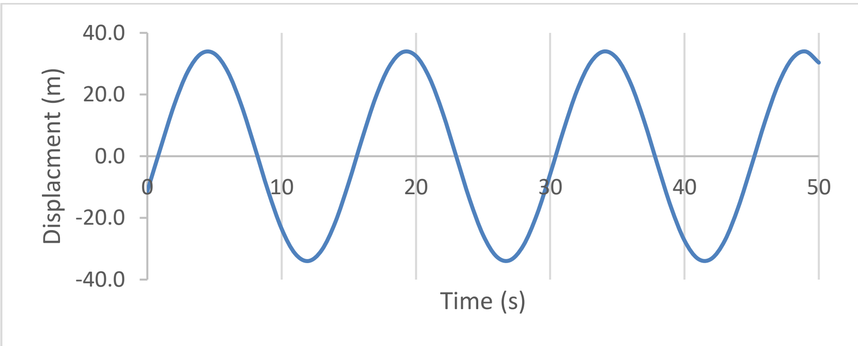
Dolphins use high frequency clicks in the range of 40.0 kHz to 150 kHz for echolocation.

(a) If the speed of sound in water is 1480 m s^{-1}, calculate the wavelength of a 150 kHz click. (2 marks)

(b) If a stationary dolphin emits a click and it takes 150 ms for the click to return to the dolphin from the sea floor, calculate the distance from the dolphin to the sea floor. (3 marks)

Question 8 **(5 marks)**

In February, 1933, the USS Ramapo, a 146 metre navy vessel found itself in an extraordinary storm on its way from Manila to San Diego. The storm lasted 7 days and stretched from the coast of Asia to New York, producing strong winds over thousands of miles of unobstructed ocean. During the storm the crew had time to carefully observe the nearly sinusoidal ocean waves. The plot shows a displacement-time graph of waves similar to that recorded by the USS Ramapo.



(a) Use the graph to determine the amplitude of the waves. (1 mark)

(b) Use the graph to determine the period of the wave. (1 mark)

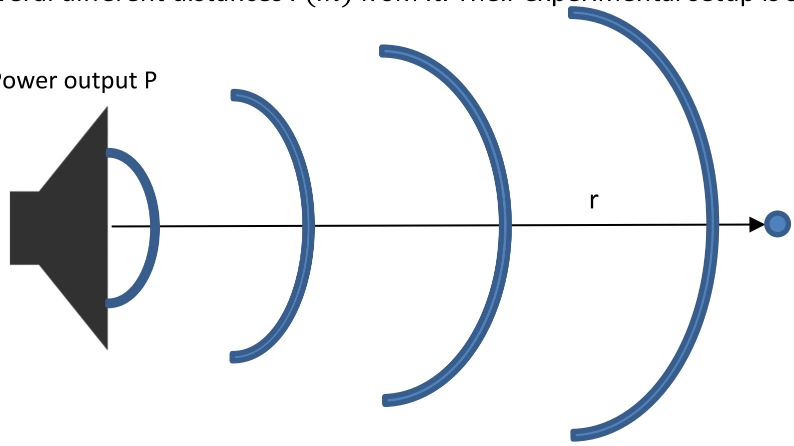
(c) If the period of a wave is 15.0 s and its speed is 23.0 m s^{-1}, calculate its wavelength. (3 marks)

Question 10 **(3 marks)**

Explain how resonance occurs when a person is pushed on the swing.

Question 17 **(17 marks)**

Jacqueline and Kieran set up an experiment to determine the power output of a loudspeaker. In this investigation they measured the sound intensity I $(W\ m^{-2})$ produced by the loudspeaker at several different distances $r(m)$ from it. Their experimental setup is shown below.



The equation which relates the power output of the speaker, the sound intensity and the distance from the speaker is $I = \frac{P}{4\pi r^2}$

where

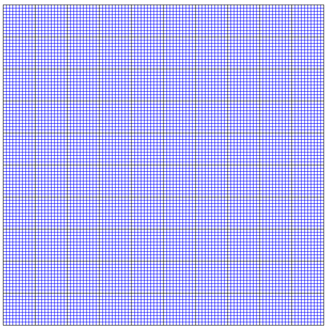
- $I = sound\ intensity\ (W\ m^{-2})$
- $P = power\ output\ of\ the\ speaker\ (W)$
- $r = distance\ from\ the\ speaker\ (m)$

A table of results for this investigation is shown below:

r (m)	I (W m^{-2})	1/r^2 (m^{-2})
0.500	39.7	
0.750	16.8	
1.50	4.20	
3.00	1.10	

(a) Complete the last column in the table above. Give your answers to three significant figures. (4 marks)

(b) On the graph paper provided plot $1/r^2$ versus sound intensity I. Plot $1/r^2$ on the *x*-axis and sound intensity on the *y*-axis. You must label your axes. (5 marks)



(c) Add a line of best fit to your graph. (1 mark)

(d) Using your line of best fit, determine the sound intensity 0.9 m from the speaker. (2 marks)

(e) Determine the gradient of your line of best fit. You must show your rise and run on the graph. (3 marks)

(f) The sound intensity equation can be written as $I = \frac{P}{4\pi} \times \frac{1}{r^2}$

The term $\frac{P}{4\pi}$ in the above equation is equal to the gradient of the line of best fit which you calculated in Part (e). Using $gradient = \frac{P}{4\pi}$ calculate the power of the source P. If you did not calculate the gradient use a value of 9.90 W. (2 marks)

Answers to Waves Exam Questions

Question 5(a) Description	Marks
$v = f\lambda$ $\lambda = \frac{v}{f}$ $= \frac{1480}{150\times10^3}$	1
$\lambda = 9.87\ mm\ or\ 9.87\ \times 10^{-3} m$	1
Total	**2**

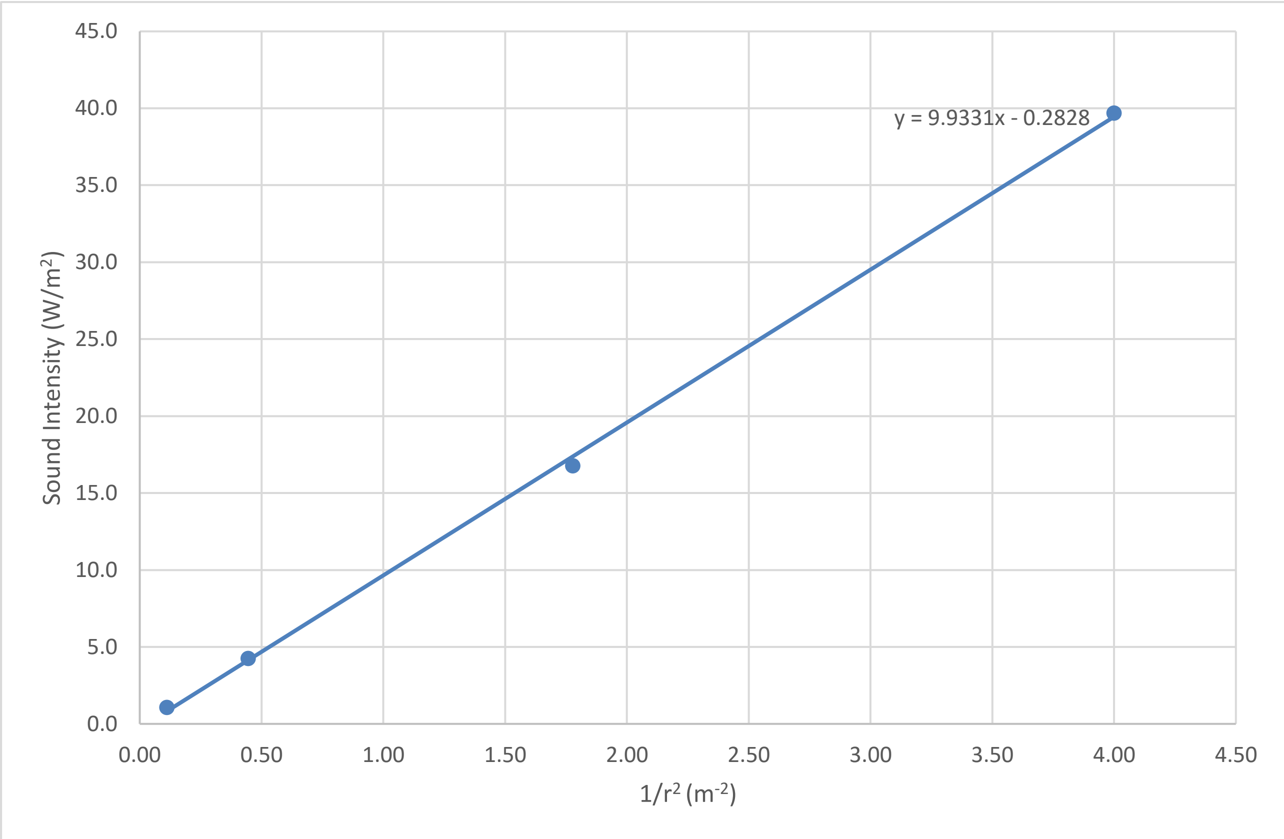
5(b) Description	Marks
$v = \frac{s}{t}$ $s = v \times t$ $= 1480 \times 0.15$	1
$d = 222\ m$	1
Distance to sea floor is half of the total distance that the sound travels. $d_{floor} = \frac{222}{2} = 111\ m$	1

Question 8 Description	Marks
(a) $34\ m \pm 1\ m$	1
(b) $15\ s \pm 1\ s$	1
(c) $v = f\lambda = \frac{\lambda}{T}$	1
$\lambda = v \times T$ $= 23.0 \times 15$ $= 345\ m$	1-2
Alternatively for (c) $f = \frac{1}{T} = \frac{1}{15} = 0.0667\ Hz$ (1 mark) $\lambda = \frac{v}{f} = \frac{345}{0.0667} = 345\ m$ (2 marks)	
Total	**5**

Question 10. Description	Marks
To produce resonance the person pushes the swing • in the direction of motion of the swing • at the natural frequency.	1-2
As the forcing frequency is equal to the natural frequency the swing begins to resonate.	1
Several descriptions will be valid here. Accept any reasonable answer.	
Total	**3**

Question 17

r (m)	I (W m^{-2})	1/r^2 (m^{-2})
0.500	39.7	4.00
0.750	16.8	1.78
1.50	4.20	0.444
3.00	1.10	0.111



Description	Marks
(b)	
Correct axes labels	1-2
Correct scale on axes	1
Correct plotting of points	1-2
Total	**5**
(c)	
Line of best fit is a straight line running through the middle of the points.	1
Total	**1**

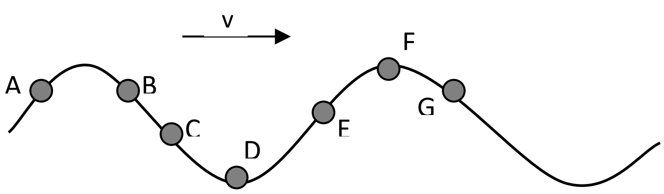
(d) **Description**	**Marks**
When r = 0.9 m, $1/r^2 = 1/0.9^2 = 1.23\ m^{-2}$	1
From the line of best fit $I = 12\ W\ m^{-2}$ Accept values for intensity between 11 and 13 $W\ m^{-2}$	1
Total	**2**

(e) **Description**	**Marks**
Rise and run shown on the graph.	1
$gradient = \frac{rise}{run} = \frac{39.5-4.7}{4-0.5}$	1
$gradient = 9.94\ W$	1
No unit for gradient is necessary.	
Total	**3**

(f) **Description**	**Marks**
$gradient = \frac{P}{4\pi}$ $P = gradient \times 4\pi$ $= 9.94 \times 4 \times \pi$	1
$P = 125\ W$	1
Total	**2**

Waves Questions

1. The figure below illustrates a water wave traveling in the direction shown. Show the motion of the tennis balls floating at A, B, C, D, E, F, and G at this instant in time.

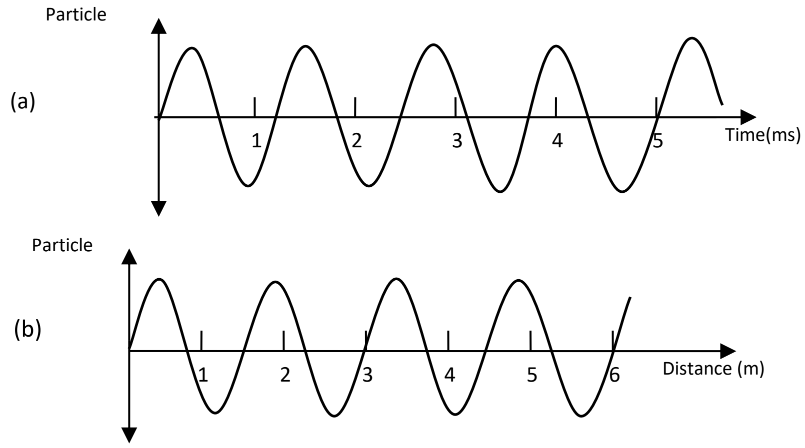


2. What type of wave(s) does a violin require to produce the note we hear? Explain.

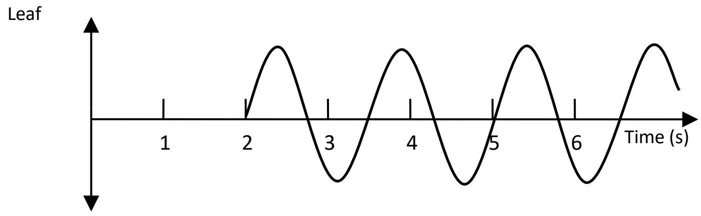
3. A sound wave in air has a period of 0.4 seconds. (a) Find its frequency and (b) wavelength.

4. A wave of wavelength 1.0 m has a frequency of 8 Hz.
Calculate the (a) speed, and (b) period of the wave.

5. Find the wavelength and frequency for the following sound waves:



6. A stone is thrown into a pond. The following graph shows the displacement of a leaf over time, a short distance away from the spot the stone dropped.



a) If the wave speed is 4 ms^{-1}, how far away from the leaf did the stone drop.
b) Find the wavelength of the wave.
c) Assuming the water at the spot the stone dropped continued to move up and down, draw a particle displacement Vs distance graph at time = 4.0 s for the water molecules on the surface from the drop point to 20 m away.

7. Two waves, each of wavelength 1.0 m are traveling along a stretched cord in opposite directions.
   a) What will be the distance between their nodes?

b) If the cord is 5.0 m long and is fixed at both ends, how many nodal points will there be along the cord?

8. Two identical waves are traveling at 5.0 m s^{-1} in opposite directions along a rope that is fixed at both ends. If the period of the wave is 0.4 s and it takes 4.0 s to travel along the rope from end to end, calculate,
a) the length of the rope;
b) the frequency of the waves;
c) the wavelength of the waves
d) the distance between successive nodal points
e) the number of antinodal points in that rope; and,
f) the maximum displacement of the rope if each wave has an amplitude of 0.1 m.

9. Explain why water waves slow down as they approach the beach?

10. The watchman riding at the top of the mast of a ship can easily locate shallow regions in the sea even though they are invisible. How is he able to do this?

11. Will there be appreciable diffraction if a wave of wavelength 5.0 cm approaches a slit of width,
a) 10.0 cm? b) 5.0 cm? c) 2.0 cm? Explain your answer.

12. (a) If the speed of sound in water is 1.32 x 10^3ms^{-1} what are the frequency and the wavelength of a 256Hz sound wave produced in air that travels from air into the water ?
(b) Why are small fish (approx. 10cm) not be picked up by sonar of frequency below about 15kHz?

13. When a tuning fork is used to tune a piano the tuner listens for beats.
(a) What are beats and, using a diagram, explain how are they produced ?
(b) How does this help the piano tuner ?

14. In some concert halls. "dead spots" to sounds can occur. What can cause this problem?

15. a) Two speakers, A and B are 3.00 m apart and emit exactly the same frequency of sound. Ted stands 4.00 m directly in front of speaker A and hears a loud sound. He walks 3.00 m slowly in a straight line across to be 4.00 m in front of speaker B. Ted hears 8 quiet spots during this walk with the finishing point being loud. What frequency sound is being emitted by the speakers? Speed of sound = 340 ms^{-1}.
b) The frequency is now changed to 680 Hz and Ted walks slowly back to his original position. How many quiet spots will he hear on the way back?

16. How is it possible that we cannot see around the corners, but we are able to hear around the corners?

17. A standing wave pattern is formed in a long corridor when the speed of sound in air is 340 m s^{-1} . If the frequency of note of that wave is 60 Hz, then what is distance between,
a) two successive loud spots?
b) two successive soft spots? and
c) a soft spot and the next loud spot?
d) How many loud spots and soft spots are formed in the corridor is 100.0 m long?

18. Would a sound wave of wavelength 6.l x 10^{-4} m be heard by an average person? Why or why not?

19. A healthy ear responds to sound waves in the range 0.02 m to about 10.0 m. Determine the upper and lower limits of frequency that the ear can hear if the velocity of sound in air is 330 m s^{-1}.

20. For a 100 m sprinting race, a timekeeper starts her stopwatch when she hears the sound of the starting gun. If the speed of sound is 340 m s^{-1}, what will be the error in the time measured for the run? Will this show the running time as greater than the actual time or less?

21. The speed of sound in a certain gas is 400 m s^{-1} at 0°C. By what increase in temperature, can the speed be increased to 500 m s^{-1}?

22. A gun is fired a certain distance from a vertical cliff and the echo is heard 10.0 s later. The gunner moved a certain distance and fired the gun again and heard the echo 8.0 s later.
a) How far was the cliff originally from the gunner?
b) In which direction in relation to the cliff did she move when she fired the second shot and by what distance?

23. A foghorn is sounded from a ship and the first echo from a cliff is registered 5.2 seconds later. If the speed of sound in the foggy air is 360 m s^{-1}, how far is the cliff?

24. If the tension in a particular string is doubled what effect does it have on its frequency?

25. A pipe closed at one end has a length of 0.50 m. Assuming the speed of sound in air is 340 m s^{-1},
a) What are the frequencies of the first three audible harmonics?
b) Draw wave patterns to show each of the above harmonics.

26. If the pipe from the above question was open at both ends,
a) What would be the frequencies of the first 3 harmonics?
b) Draw wave patterns to show each of the above harmonics.

27. A long tube is partially immersed in water. A 256 Hz tuning fork causes resonance when the lengths of the air columns are 0.332 m and 0.996 m. Determine the speed of sound using these data.

28. A closed tube of length 0.25 m resonates to a tuning fork. If the speed of sound in air is 350 m s^{-1}, what is the frequency of the fork? Suggest two other frequencies for which the tube may resonate?

29. A guitar string known to have a first harmonic frequency of 256 Hz is plucked simultaneously with another guitar and two beats are heard each second. When the second guitar string is tightened, four beats are heard each second. What are its original frequency and the final frequency?

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, $L_f = 2.17 \times 10^5$ Jkg^{-1} and $L_v = 3.83 \times 10^5$ Jkg^{-1}.
3. 6.69×10^5 J
4. 5.26 x 106 J
5. 3.03×10^5 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.

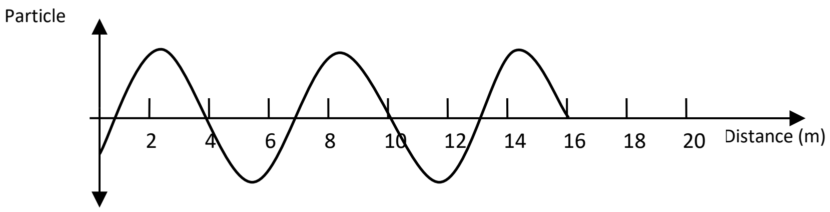
Linear Motion & Force

1. Scalars – mass, distance, speed, time, energy, temperature
Vectors – weight, velocity, displacement, acceleration, force, momentum.
2. a) AB, EF,& FG. b) BC c) 3.4 ms^{-1} d) 245 m e) 40 m West f) 3.06 ms^{-1}
g) 0.5 ms^{-1} West h) The car heads West from E, then accelerates. i) The car is going West at F at high speed, then it slows down.
3. a) 2.40 km b) 1.39 km c) 4.00 ms^{-1} d) 2.32 ms^{-1}
4. (a) 13.88 m s^{-1} (b) 3.0 h (c) 1.9 h (d) (i) 76 km h^{-1} (ii) 0 km h^{-1}
5. a) 3.42 ms^{-1}at 69.4° to the bank. b) 267 m c) 78.1 sec d) 93.7 m
6. a) 0.50 ms^{-2} b) BC, DE, & FG c) 0.40 ms^{-2}, 0.267 ms^{-2} d) 66.5 m e) 1.66 ms^{-1}
f) 21.5 m g) 0.538 ms^{-1}
7. a) 21.0 ms^{-1} b) 2.1 ms^{-2} c) 2.70 km
8. (a) 1.8 s (b) 5.0 s
9. a) 16 sec b) 480 m
10. a) 2.47 m b) 1.22 sec
11. (a) 12 ms^{-1} (b) -2.0 ms^{-1}
12. a) 10 km North 36.9° East b) 57.0 N South 52.1° East
c) 71.8 kmh^{-1} West 18.7° South d) 10.3 ms^{-2} Down 18.1° Left.
13. 2.66 $kgms^{-1}$(at angle of 3.65° to vertical)
14. (a) 0.84 kg ms^{-1} up (b) 0.84 N s down (c) No. The mass of the Earth is very large.
(d) 4.2×10^2 N up (e) 4.2×10^2 N up
15. a) 223 N b) 243 N **16.** 2.45 ms^{-1}
17. A body will continue in its state of motion unless acted on by an unbalanced force. The seatbelt provides that force to prevent a person continuing to travel towards the windscreen in an accident.
18. All these devices increase the time of the collision between the person and the inside of the car. This reduces the force of the collision.
19. For every action, there is an equal and opposite reaction. When walking we push off from the ground with a force in the opposite direction to which we wish to go. The ground provides an equal and opposite force in the direction we are going.
20. a) 16.7 J b) 16.7 J c) 10.8 J d) 1.30 m.
21. 180 N
22. (a) 2.3×10^4 N s opposite to the initial direction of motion of the car
(b) 2.9×10^5 N opposite to the initial direction of motion of the car
(c) $2.1 \times 10^2 ms^2$
23. (a) 1.7 ms^{-1} (b) 120 N s (c) 120 kg m s^{-1} (d) 120 N s
(e) They would have different speeds but the total momentum would still be conserved as there are no external horizontal forces acting on the boys. (f) 0.92 m s^{-1}

Waves

1. A down, B up, C up, D still, E down, F still, G up, H up
2. Transverse in strings, Longitudinal – sound in air
3. a) 2.5 Hz b) 138 m
4. a) 8.0 ms^{-1} b) 0.125 s
5. a) λ = 0.425 m f = 800 Hz b) λ = 1.5 m f = 227 Hz
6. a) 8 m b) λ = 6 m

c)



7. a) 0.5 m b) 11 nodes
8. a) 20 m b) 2.5 Hz c) 2 m d) 1 m e) 20 antinodes f) 0.2 m
9. Water getting shallow and crests push up
10. Wave crests slow in shallow water so they bunch up
11. Best diffraction with width of 5 cm
12. a) Frequency is the same 256Hz; wavelength is 5.16m
    b) Wavelength is 8.8cm therefore these fish do not reflect the waves. Diffraction occurs so that the wave goes around the fish.
13. a) Beats are a rapid rise and fall in the loudness of a tone that is heard when two very similar notes [frequencies] are sounded together. The two sounds interfere alternately reinforcing and cancelling as the waves become in phase and 180^o out of phase.
    b) The tuner listens for beats with his tuning fork and adjusts the tension of the string until the beats disappear at which time the notes are the same. When tuning other notes he can listen for beats between harmonics of different notes.
14. Destructive interference
15. a) 1360 Hz b) 4 quiet spots
16. Sound diffracts well because it has a relatively large wavelength. Light has a very short wavelength so no significant diffraction.
17. a) 2.835 m b) 2.835 m c) 1.418 m d) 71 loud & 71 soft spots
18. No. Frequency is 557000 Hz which is too high for us to hear
19. 16500 Hz and 33 Hz
20. Error of 0.29 s. Running time will be less than actual time.
21. 167˚ C - speed increases about 0.6 ms^{-1} for every 1˚ C increase.
22. a) 1.70 km b) 340 m closer to the cliff
23. 936 m away
24. If tension is doubled, frequency will increase by a factor of 1.414(square root of 2)
25. a) 170 Hz b) 510 Hz c) 850 Hz
26. a) 340 Hz b) 680 Hz c) 1020 Hz
27. Half λ between loud spots, ½ λ = 0.996 – 0.332 m wavelength = 1.328 m,
    c = f x λ = 256 x 1.328 = 340 ms^{-1}
28. 350 Hz, 1050 Hz, 1750 Hz
29. 258 Hz, 260 Hz