SL Paper 2

An ideal monatomic gas is kept in a container of volume 2.1×10^{-4} m^3, temperature 310 K and pressure 5.3×10^5 Pa.

The volume of the gas in (a) is increased to 6.8×10^{-4} m^3 at constant temperature.

a.i. State what is meant by an ideal gas. [1]

a.ii. Calculate the number of atoms in the gas. [1]

a.iii. Calculate, in J, the internal energy of the gas. [2]

b.i. Calculate, in Pa, the new pressure of the gas. [1]

b.ii. Explain, in terms of molecular motion, this change in pressure. [2]

A closed box of fixed volume 0.15 m^3 contains 3.0 mol of an ideal monatomic gas. The temperature of the gas is 290 K.

When the gas is supplied with 0.86 kJ of energy, its temperature increases by 23 K. The specific heat capacity of the gas is 3.1 kJ kg^{-1} K^{-1}.

a. Calculate the pressure of the gas. [1]

b.i. Calculate, in kg, the mass of the gas. [1]

b.ii. Calculate the average kinetic energy of the particles of the gas. [1]

c. Explain, with reference to the kinetic model of an ideal gas, how an increase in temperature of the gas leads to an increase in pressure. [3]

This question is about thermal properties of matter.

a. Explain, in terms of the energy of its molecules, why the temperature of a pure substance does not change during melting. [3]

b. Three ice cubes at a temperature of 0°C are dropped into a container of water at a temperature of 22°C. The mass of each ice cube is 25 g and the mass of the water is 330 g. The ice melts, so that the temperature of the water decreases. The thermal capacity of the container is negligible. [4]

The following data are available.

Specific latent heat of fusion of ice $= 3.3 \times 10^5 \text{J kg}^{-1}$

Specific heat capacity of water $= 4.2 \times 10^3 \text{ J kg}^{-1} \text{ K}^{-1}$

Calculate the final temperature of the water when all of the ice has melted. Assume that no thermal energy is exchanged between the water and the surroundings.

This question is about internal energy.

(i) Mathilde raises the temperature of water in an electric kettle to boiling point. Once the water is boiling steadily, she measures the change in the mass of the kettle and its contents over a period of time.

The following data are available.

Initial mass of kettle and water = 1.880 kg
Final mass of kettle and water = 1.580 kg
Time between mass measurements = 300 s
Power dissipation in the kettle = 2.5 kW

Determine the specific latent heat of vaporization of water.

(ii) Outline why your answer to (b)(i) is an overestimate of the specific latent heat of vaporization of water.

This question is about energy.

At its melting temperature, molten zinc is poured into an iron mould. The molten zinc becomes a solid without changing temperature.

a. Outline why a given mass of molten zinc has a greater internal energy than the same mass of solid zinc at the same temperature. [3]

b. Molten zinc cools in an iron mould. [4]

The temperature of the iron mould was 20° C before the molten zinc, at its melting temperature, was poured into it. The final temperature of the iron mould and the solidified zinc is 89° C.

The following data are available.

Mass of iron mould $= 12 \text{ kg}$

Mass of zinc $= 1.5 \text{ kg}$

Specific heat capacity of iron $= 440 \text{ J kg}^{-1}\text{K}^{-1}$

Specific latent heat of fusion of zinc $= 113 \text{ kJ kg}^{-1}$

Melting temperature of zinc $= 420\ ^\circ\text{C}$

Using the data, determine the specific heat capacity of zinc.

This question is in **two** parts. **Part 1** is about energy resources. **Part 2** is about thermal physics.

Part 1 Energy resources

Electricity can be generated using nuclear fission, by burning fossil fuels or using pump storage hydroelectric schemes.

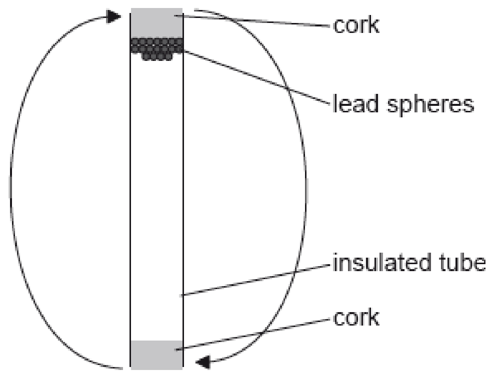
In a nuclear reactor, outline the purpose of the

Fission of one uranium-235 nucleus releases 203 MeV.

This question is in **two** parts. **Part 1** is about energy resources. **Part 2** is about thermal physics.

Part 2 Thermal physics

A mass of 0.22 kg of lead spheres is placed in a well-insulated tube. The tube is turned upside down several times so that the spheres fall through an average height of 0.45 m each time the tube is turned. The temperature of the spheres is found to increase by 8 °C.



a. Outline which of the three generation methods above is renewable. [2]

b.i. heat exchanger. [1]

b.ii. moderator. [2]

c.i. Determine the maximum amount of energy, in joule, released by 1.0 g of uranium-235 as a result of fission. [3]

d.i. Describe the main principles of the operation of a pump storage hydroelectric scheme. [3]

d.ii. A hydroelectric scheme has an efficiency of 92%. Water stored in the dam falls through an average height of 57 m. Determine the rate of flow of water, in $\mathrm{kg\,s^{-1}}$, required to generate an electrical output power of 4.5 MW. [3]

e. Distinguish between specific heat capacity and specific latent heat. [2]

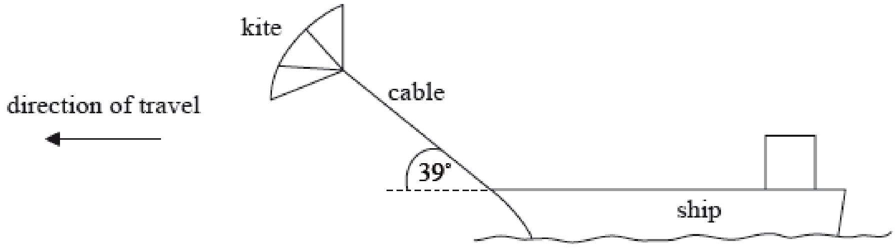
f.i. Discuss the changes to the energy of the lead spheres. [2]

f.ii. The specific heat capacity of lead is $1.3 \times 10^2\ \mathrm{J\,kg^{-1}K^{-1}}$. Deduce the number of times that the tube is turned upside down. [4]

This question is in **two** parts. **Part 1** is about the motion of a ship. **Part 2** is about melting ice.

Part 1 Motion of a ship

Some cargo ships use kites working together with the ship's engines to move the vessel.



The tension in the cable that connects the kite to the ship is 250 kN. The kite is pulling the ship at an angle of 39° to the horizontal. The ship travels at a steady speed of $8.5\ \mathrm{m\,s^{-1}}$ when the ship's engines operate with a power output of 2.7 MW.

The ship's engines are switched off and the ship comes to rest from a speed of $7\ \mathrm{m\,s^{-1}}$ in a time of 650 s.

Part 2 Melting ice

A container of negligible mass, isolated from its surroundings, contains 0.150 kg of ice at a temperature of –18.7 °C. An electric heater supplies energy at a rate of 125 W.

a. Outline the meaning of work. [2]

b.i. Calculate the work done on the ship by the kite when the ship travels a distance of 1.0 km. [2]

b.ii. Show that, when the ship is travelling at a speed of $8.5\ \mathrm{m\,s^{-1}}$, the kite provides about 40% of the total power required by the ship. [4]

c. The kite is taken down and no longer produces a force on the ship. The resistive force F that opposes the motion of the ship is related to the speed v of the ship by [3]

$$F = kv^2$$

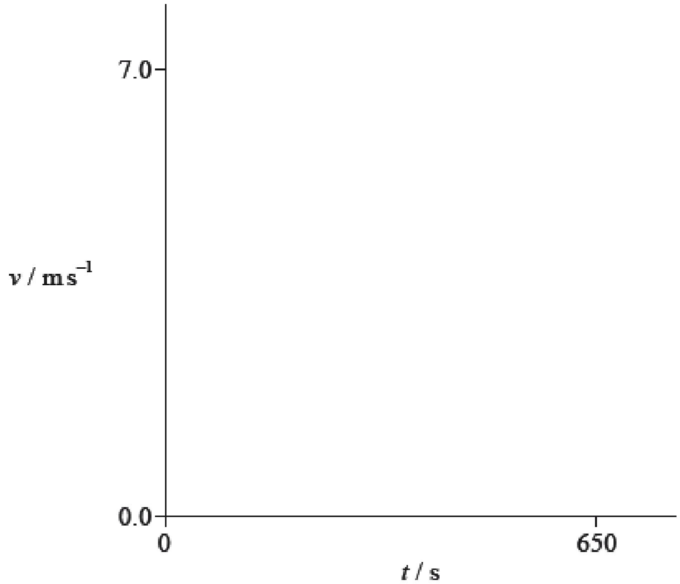
where k is a constant.

Show that, if the power output of the engines remains at 2.7 MW, the speed of the ship will decrease to about $7\ \mathrm{m\,s^{-1}}$. Assume that k is independent of whether the kite is in use or not.

d.i. Estimate the distance that the ship takes to stop. Assume that the acceleration is uniform. [2]

d.ii. It is unlikely that the acceleration of the ship will be uniform given that the resistive force acting on the ship depends on the speed of the ship. [2]

Using the axes, sketch a graph to show how the speed v varies with time t after the ship's engines are switched off.



e. Describe, with reference to molecular behaviour, the process of melting ice. [2]

f.i. After a time interval of 45.0 s all of the ice has reached a temperature of 0 °C without any melting. Calculate the specific heat capacity of ice. [2]

f.ii. The following data are available. [3]

Specific heat capacity of water $= 4200 \text{ J kg}^{-1}\text{K}^{-1}$

Specific latent heat of fusion of ice $= 3.30 \times 10^5 \text{ J kg}^{-1}$

Determine the final temperature of the water when the heater supplies energy for a further 600 s.

g. The whole of the experiment in (f)(i) and (f)(ii) is repeated with a container of negligible mass that is not isolated from the surroundings. The temperature of the surroundings is 18 °C. Comment on the final temperature of the water in (f)(ii). [3]

This question is about the use of energy resources.

Electrical energy is obtained from tidal energy at La Rance in France.

Water flows into a river basin from the sea for six hours and then flows from the basin back to the sea for another six hours. The water flows through turbines and generates energy during both flows.

The following data are available.

Area of river basin $= 22 \text{ km}^2$

Change in water level of basin over six hours $= 6.0 \text{ m}$

Density of water $= 1000 \text{ kg m}^{-3}$

Nuclear reactors are used to generate energy. In a particular nuclear reactor, neutrons collide elastically with carbon-12 nuclei $\left({}^{12}_{6}\text{C}\right)$ that act as the moderator of the reactor. A neutron with an initial speed of $9.8 \times 10^6 \text{ m s}^{-1}$ collides head-on with a stationary carbon-12 nucleus. Immediately after the collision the carbon-12 nucleus has a speed of $1.5 \times 10^6 \text{ m s}^{-1}$.

a. State the difference between renewable and non-renewable energy sources. [1]

b. (i) The basin empties over a six hour period. Show that about $6000\ \mathrm{m}^3$ of water flows through the turbines every second. [10]

(ii) Show that the average power that the water can supply over the six hour period is about 0.2 GW.

(iii) La Rance tidal power station has an energy output of $5.4 \times 10^8\ \mathrm{kW\,h}$ per year. Calculate the overall efficiency of the power station. Assume that the water can supply 0.2 GW at all times.

Energy resources such as La Rance tidal power station could replace the use of

fossil fuels. This may result in an increase in the average albedo of Earth.

(iv) State **two** reasons why the albedo of Earth must be given as an average value.

d. (i) State the principle of conservation of momentum. [10]

(ii) Show that the speed of the neutron immediately after the collision is about $8.0 \times 10^6\ \mathrm{m\,s^{-1}}$.

(iii) Show that the fractional change in energy of the neutron as a result of the collision

is about 0.3.

(iv) Estimate the minimum number of collisions required for the neutron to reduce its initial energy by a factor of 10^6.

(v) Outline why the reduction in energy is necessary for this type of reactor to function.

This question is in **two** parts. **Part 1** is about a lightning discharge. **Part 2** is about fuel for heating.

Part 1 Lightning discharge

The magnitude of the electric field strength E between two infinite charged parallel plates is given by the expression

$$E = \frac{\sigma}{\varepsilon_0}$$

where σ is the charge per unit area on one of the plates.

A thundercloud carries a charge of magnitude 35 C spread over its base. The area of the base is $1.2 \times 10^7\ \mathrm{m}^2$.

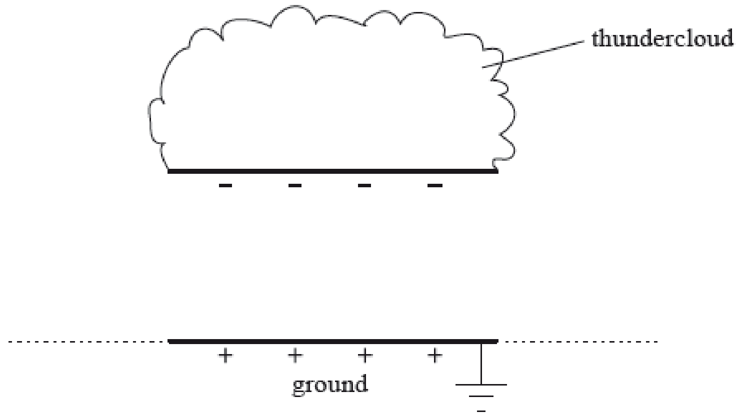
Part 2 Fuel for heating

A room heater burns liquid fuel and the following data are available.

$$\begin{array}{ll}
\text{Density of liquid fuel} & = 8.0 \times 10^2\ \mathrm{kg\,m^{-3}} \\
\text{Energy produced by 1 m}^3\text{ of liquid fuel} & = 2.7 \times 10^{10}\ \mathrm{J} \\
\text{Rate at which fuel is consumed} & = 0.13\ \mathrm{g\,s^{-1}} \\
\text{Latent heat of vaporization of the fuel} & = 290\ \mathrm{kJ\,kg^{-1}}
\end{array}$$

Part 1a. Define *electric field strength*. [2]

Part 1b. A thundercloud can be modelled as a negatively charged plate that is parallel to the ground. [3]



The magnitude of the charge on the plate increases due to processes in the atmosphere. Eventually a current discharges from the thundercloud to the ground.

On the diagram, draw the electric field pattern between the thundercloud base and the ground.

Part 1.c. (i) Determine the magnitude of the electric field between the base of the thundercloud and the ground. [12]

(ii) State **two** assumptions made in (c)(i).

1.

2.

(iii) When the thundercloud discharges, the average discharge current is 1.8 kA. Estimate the discharge time.

(iv) The potential difference between the thundercloud and the ground before discharge is $2.5 \times 10^{8}\ \mathrm{V}$. Determine the energy released in the discharge.

Part 2.a. Define the *energy density* of a fuel. [1]

Part 2.b. (i) Use the data to calculate the power output of the room heater, ignoring the power required to convert the liquid fuel into a gas. [5]

(ii) Show why, in your calculation in (b)(i), the power required to convert the liquid fuel into a gas at its boiling point can be ignored.

Part 2.c. State, in terms of molecular structure and their motion, **two** differences between a liquid and a gas. [2]

1.

2.

Part 2 Melting of the Pobeda ice island

a. The Pobeda ice island forms regularly when icebergs run aground near the Antarctic ice shelf. The "island", which consists of a slab of pure ice, breaks apart and melts over a period of decades. The following data are available. [8]

Typical dimensions of surface of island = 70 km × 35 km
Typical height of island = 240 m
Average temperature of the island = –35°C
Density of sea ice = 920 kg m^{-3}
Specific latent heat of fusion of ice = 3.3×10^{5} J kg^{-1}
Specific heat capacity of ice = 2.1×10^{3} J $kg^{-1}K^{-1}$

(i) Distinguish, with reference to molecular motion and energy, between solid ice and liquid water.

(ii) Show that the energy required to melt the island to form water at 0°C is about 2×10^{20} J. Assume that the top and bottom surfaces of the island are flat and that it has vertical sides.

(iii) The Sun supplies thermal energy at an average rate of 450 W m^{-2} to the surface of the island. The albedo of melting ice is 0.80. Determine an estimate of the time taken to melt the island assuming that the melted water is removed immediately and that no heat is lost to the surroundings.

b. Suggest the likely effect on the average albedo of the region in which the island was floating as a result of the melting of the Pobeda ice island. [2]

In an experiment to determine the specific latent heat of fusion of ice, an ice cube is dropped into water that is contained in a well-insulated calorimeter of negligible specific heat capacity. The following data are available.

Mass of ice cube = 25g
Mass of water = 350g
Initial temperature of ice cube = 0˚C
Initial temperature of water = 18˚C
Final temperature of water = 12˚C
Specific heat capacity of water = 4200$Jkg^{-1}K^{-1}$

a. Using the data, estimate the specific latent heat of fusion of ice. [4]

b. The experiment is repeated using the same mass of crushed ice. [2]

Suggest the effect, if any, of crushing the ice on

(i) the final temperature of the water.

(ii) the time it takes the water to reach its final temperature.

Part 2 Internal energy

Humans generate internal energy when moving, while their core temperature remains approximately constant.

a. Distinguish between the concepts of internal energy and temperature. [3]

c. An athlete loses 1.8 kg of water from her body through sweating during a training session that lasts one hour. [2]

Estimate the rate of energy loss by the athlete due to sweating. The specific latent heat of evaporation of water is 2.3×10^{6} J kg^{-1}.

This question is in **two** parts. **Part 1** is about ideal gases and specific heat capacity. **Part 2** is about simple harmonic motion and waves.

Part 1 Ideal gases and specific heat capacity

a. State **two** assumptions of the kinetic model of an ideal gas. [2]

b. Argon behaves as an ideal gas for a large range of temperatures and pressures. One mole of argon is confined in a cylinder by a freely moving piston. [4]

(i) Define what is meant by the term *one mole of argon*.

(ii) The temperature of the argon is 300 K. The piston is fixed and the argon is heated at constant volume such that its internal energy increases by 620 J. The temperature of the argon is now 350 K.

Determine the specific heat capacity of argon in J kg^{-1} K^{-1} under the condition of constant volume. (The molecular weight of argon is 40)

c. At the temperature of 350 K, the piston in (b) is now freed and the argon expands until its temperature reaches 300 K. [3]

Explain, in terms of the molecular model of an ideal gas, why the temperature of argon decreases on expansion.

This question is about thermal energy transfer.

A hot piece of iron is placed into a container of cold water. After a time the iron and water reach thermal equilibrium. The heat capacity of the container is negligible.

a. Define *specific heat capacity.* [2]

b. The following data are available. [5]

Mass of water = 0.35 kg
Mass of iron = 0.58 kg
Specific heat capacity of water = 4200 J $kg^{-1}K^{-1}$
Initial temperature of water = 20°C
Final temperature of water = 44°C
Initial temperature of iron = 180°C

(i) Determine the specific heat capacity of iron.

(ii) Explain why the value calculated in (b)(i) is likely to be different from the accepted value.

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a. Define *internal energy.* [2]

b. 0.46 mole of an ideal monatomic gas is trapped in a cylinder. The gas has a volume of 21 m^3 and a pressure of 1.4 Pa. [4]

(i) State how the internal energy of an ideal gas differs from that of a real gas.

(ii) Determine, in kelvin, the temperature of the gas in the cylinder.

(iii) The kinetic theory of ideal gases is one example of a scientific model. Identify **one** reason why scientists find such models useful.

This question is about internal energy and thermal energy (heat).

a. Distinguish between internal energy and thermal energy. [3]

b. Describe, with reference to the energy of the molecules, the difference in internal energy of a piece of iron and the internal energy of an ideal gas. [2]

c. A piece of iron is placed in a kiln until it reaches the temperature θ of the kiln. The iron is then quickly transferred to water held in a thermally insulated container. The water is stirred until it reaches a steady temperature. The following data are available. [4]

Thermal capacity of the piece of iron = $60 JK^{-1}$
Thermal capacity of the water = $2.0\times10^3 JK^{-1}$
Initial temperature of the water = 16°C
Final temperature of the water = 45°C

The thermal capacity of the container and insulation is negligible.

(i) State an expression, in terms of θ and the above data, for the energy transfer of the iron in cooling from the temperature of the kiln to the final temperature of the water.

(ii) Calculate the increase in internal energy of the water as the iron cools in the water.

(iii) Use your answers to (c)(i) and (c)(ii) to determine θ.

Part 2 Thermal concepts

a. Distinguish between internal energy and thermal energy (heat). [2]

Internal energy:

Thermal energy:

b. A 300 W immersion heater is placed in a beaker containing 0.25 kg of water at a temperature of 18°C. The heater is switched on for 120 s, after which time the temperature of the water is 45°C. The thermal capacity of the beaker is negligible and the specific heat capacity of water is $4.2\times10^3 J\ kg^{-1}K^{-1}$. [4]

(i) Estimate the change in internal energy of the water.

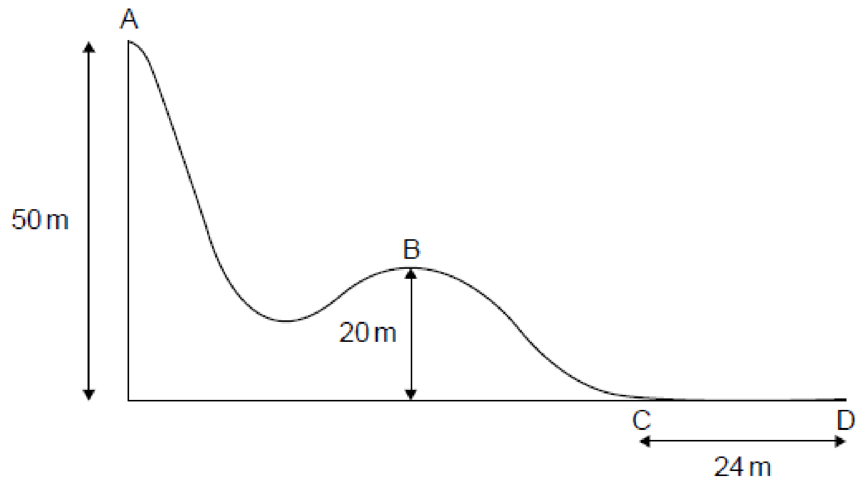
(ii) Determine the rate at which thermal energy is transferred from the water to the surroundings during the time that the heater is switched on.

c. The water in (b) is further heated until it starts to boil at constant temperature. It is boiled for 500s measured from the time that it first starts to boil. The mass of water remaining after this time is 0.20kg. [5]

(i) Estimate, using the answer to (b)(ii), the specific latent heat of vaporization of the water.

(ii) Explain, in terms of the energy of the molecules of the water, why the water boils at constant temperature.

The diagram below shows part of a downhill ski course which starts at point A, 50 m above level ground. Point B is 20 m above level ground.



A skier of mass 65 kg starts from rest at point A and during the ski course some of the gravitational potential energy transferred to kinetic energy.

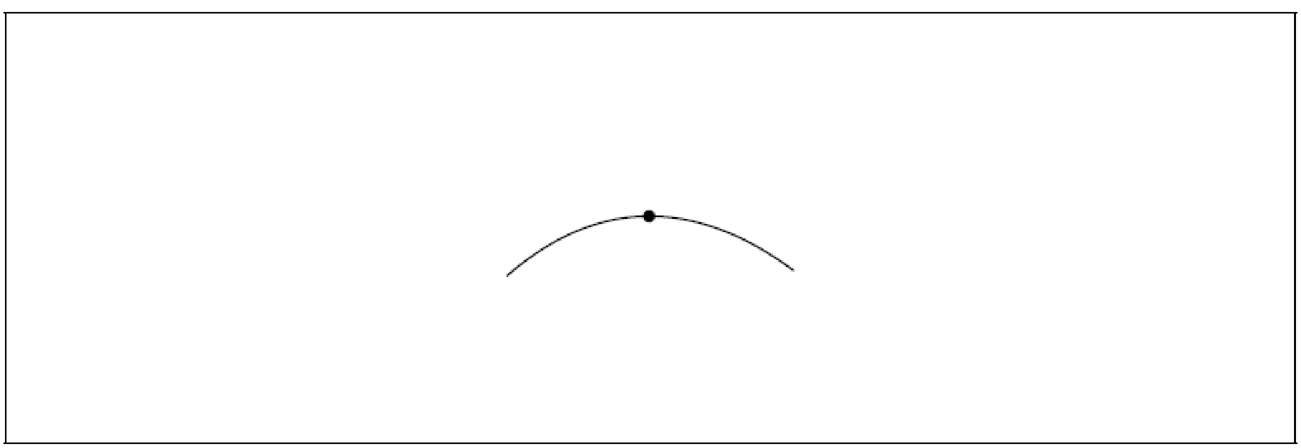
At the side of the course flexible safety nets are used. Another skier of mass 76 kg falls normally into the safety net with speed 9.6 m s^{-1}.

a.i. From A to B, 24 % of the gravitational potential energy transferred to kinetic energy. Show that the velocity at B is 12 m s^{-1}. [2]

a.ii. Some of the gravitational potential energy transferred into internal energy of the skis, slightly increasing their temperature. Distinguish between internal energy and temperature. [2]

b.i. The dot on the following diagram represents the skier as she passes point B. [2]

Draw and label the vertical forces acting on the skier.



b.ii. The hill at point B has a circular shape with a radius of 20 m. Determine whether the skier will lose contact with the ground at point B. [3]

c. The skier reaches point C with a speed of 8.2 m s^{-1}. She stops after a distance of 24 m at point D. [3]

Determine the coefficient of dynamic friction between the base of the skis and the snow. Assume that the frictional force is constant and that air resistance can be neglected.

d.i. Calculate the impulse required from the net to stop the skier and state an appropriate unit for your answer. [2]

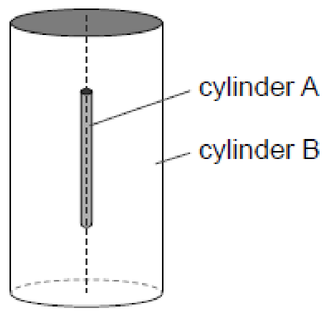
d.ii. Explain, with reference to change in momentum, why a flexible safety net is less likely to harm the skier than a rigid barrier. [2]

The first scientists to identify alpha particles by a direct method were Rutherford and Royds. They knew that radium-226 ($^{226}_{86}\mathrm{Ra}$) decays by alpha emission to form a nuclide known as radon (Rn).

a. Write down the missing values in the nuclear equation for this decay. [1]

$$^{226}_{88}\mathrm{Ra} \rightarrow {}^{\cdots\cdots}_{86}\mathrm{Rn} + {}^{\cdots\cdots}_{2}\alpha$$

b. Rutherford and Royds put some pure radium-226 in a small closed cylinder A. Cylinder A is fixed in the centre of a larger closed cylinder B. [1]



At the start of the experiment all the air was removed from cylinder B. The alpha particles combined with electrons as they moved through the wall of cylinder A to form helium gas in cylinder B.

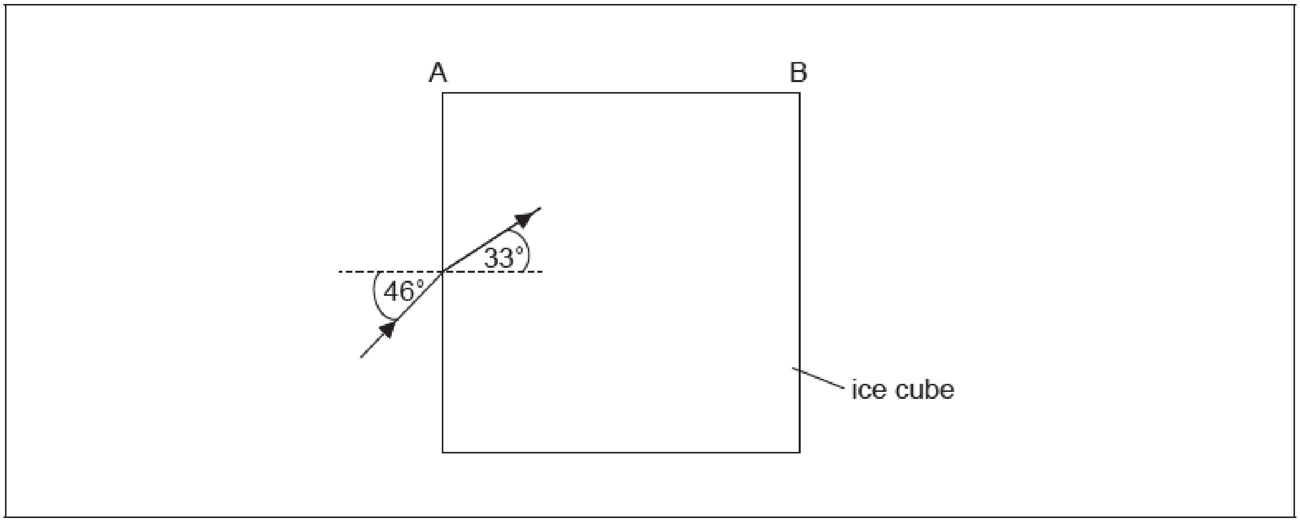
The wall of cylinder A is made from glass. Outline why this glass wall had to be very thin.

c. Rutherford and Royds expected 2.7 x 10^{15} alpha particles to be emitted during the experiment. The experiment was carried out at a temperature of 18 °C. The volume of cylinder B was 1.3 x 10^{-5} m^3 and the volume of cylinder A was negligible. Calculate the pressure of the helium gas that was collected in cylinder B. [3]

d. Rutherford and Royds identified the helium gas in cylinder B by observing its emission spectrum. Outline, with reference to atomic energy levels, how an emission spectrum is formed. [3]

e. The work was first reported in a peer-reviewed scientific journal. Outline why Rutherford and Royds chose to publish their work in this way. [1]

A large cube is formed from ice. A light ray is incident from a vacuum at an angle of 46˚ to the normal on one surface of the cube. The light ray is parallel to the plane of one of the sides of the cube. The angle of refraction inside the cube is 33˚.



Each side of the ice cube is 0.75 m in length. The initial temperature of the ice cube is –20 °C.

a.i. Calculate the speed of light inside the ice cube. [2]

a.ii. Show that no light emerges from side AB. [3]

a.iii. Sketch, on the diagram, the subsequent path of the light ray. [2]

b.i. Determine the energy required to melt all of the ice from –20 °C to water at a temperature of 0 °C. [4]

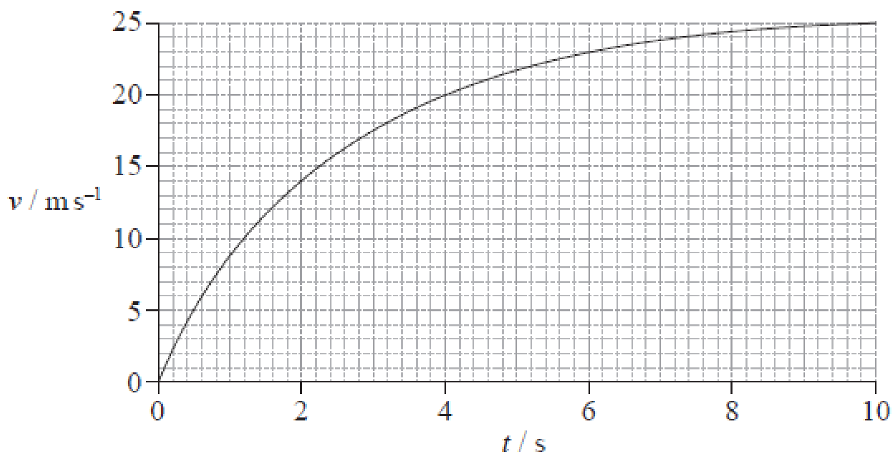
Specific latent heat of fusion of ice = 330 kJ kg^{-1}
Specific heat capacity of ice = 2.1 kJ kg^{-1} k^{-1}
Density of ice = 920 kg m^{-3}

b.ii. Outline the difference between the molecular structure of a solid and a liquid. [1]

This question is in **two** parts. **Part 1** is about mechanics and thermal physics. **Part 2** is about nuclear physics.

Part 1 Mechanics and thermal physics

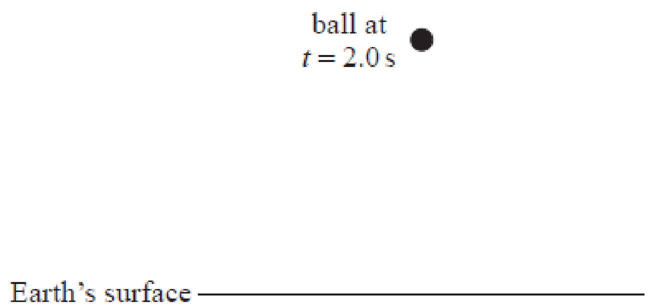
The graph shows the variation with time t of the speed v of a ball of mass 0.50 kg, that has been released from rest above the Earth's surface.



The force of air resistance is **not** negligible. Assume that the acceleration of free fall is g = 9.81ms^{-2}.

a. State, without any calculations, how the graph could be used to determine the distance fallen. [1]

b. (i) In the space below, draw and label arrows to represent the forces on the ball at 2.0 s. [7]



(ii) Use the graph opposite to show that the acceleration of the ball at 2.0 s is approximately 4 ms^{-2}.

(iii) Calculate the magnitude of the force of air resistance on the ball at 2.0 s.

(iv) State and explain whether the air resistance on the ball at *t* = 5.0 s is smaller than, equal to **or** greater than the air resistance at *t* = 2.0 s.

c. After 10 s the ball has fallen 190 m. [6]

(i) Show that the sum of the potential and kinetic energies of the ball has decreased by 780 J.

(ii) The specific heat capacity of the ball is 480 J kg^{-1} K^{-1}. Estimate the increase in the temperature of the ball.

(iii) State an assumption made in the estimate in (c)(ii).

This question is in **two** parts. **Part 1** is about electric fields and radioactive decay. **Part 2** is about change of phase.

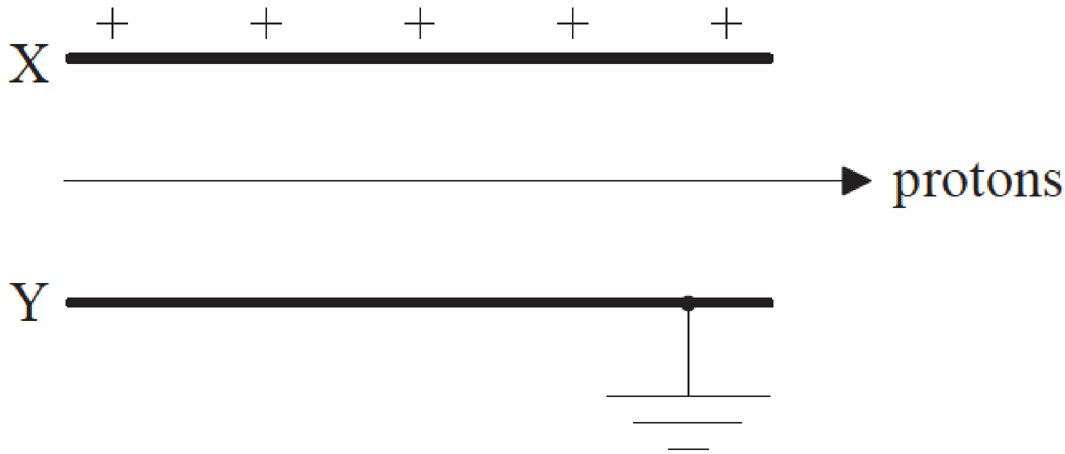
Part 1 Electric fields and radioactive decay

Part 2 Change of phase

a. Define *electric field strength*. [2]

b. A simple model of the proton is that of a sphere of radius 1.0×10^{-15}m with charge concentrated at the centre of the sphere. Estimate the magnitude of the field strength at the surface of the proton. [2]

c. Protons travelling with a speed of $3.9\times10^{6}ms^{-1}$ enter the region between two charged parallel plates X and Y. Plate X is positively charged and plate Y is connected to earth. [4]



A uniform magnetic field also exists in the region between the plates. The direction of the field is such that the protons pass between the plates without deflection.

(i) State the direction of the magnetic field.

(ii) The magnitude of the magnetic field strength is 2.3×10^{-4}T. Determine the magnitude of the electric field strength between the plates, stating an appropriate unit for your answer.

d. Protons can be produced by the bombardment of nitrogen-14 nuclei with alpha particles. The nuclear reaction equation for this process is given [1]

below.

$$^{14}_{7}\mathrm{N} + {}^{4}_{2}\mathrm{He} \rightarrow \mathrm{X} + {}^{1}_{1}\mathrm{H}$$

Identify the proton number and nucleon number for the nucleus X.

e. The following data are available for the reaction in (d). [3]

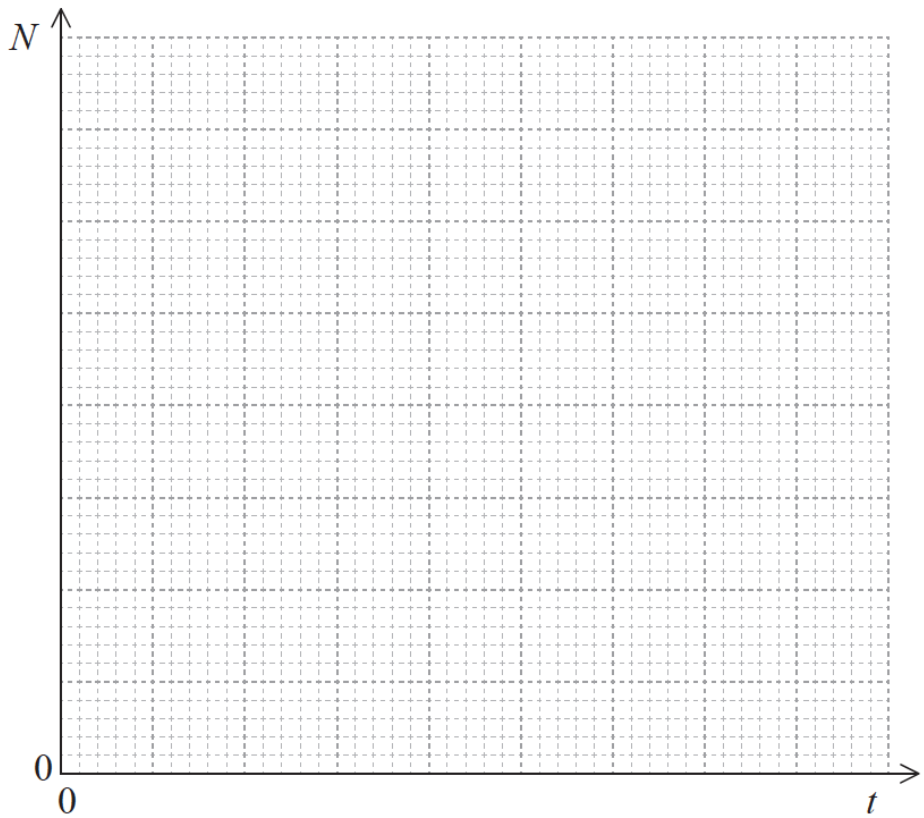
Rest mass of nitrogen-14 nucleus =14.0031 u
Rest mass of alpha particle =4.0026 u
Rest mass of X nucleus =16.9991 u
Rest mass of proton =1.0073 u

Show that the minimum kinetic energy that the alpha particle must have in order for the reaction to take place is about 0.7 Me V.

f. A nucleus of another isotope of the element X in (d) decays with a half-life $T_{\frac{1}{2}}$ to a nucleus of an isotope of fluorine-19 (F-19). [5]

(i) Define the terms *isotope* and *half-life*.

(ii) Using the axes below, sketch a graph to show how the number of atoms *N* in a sample of X varies with time *t*, from *t*=0 to $t = 3T_{\frac{1}{2}}$. There are N_0 atoms in the sample at *t*=0.



g. Water at constant pressure boils at constant temperature. Outline, in terms of the energy of the molecules, the reason for this. [2]

h. In an experiment to measure the specific latent heat of vaporization of water, steam at 100°C was passed into water in an insulated container. [4]

The following data are available.

Initial mass of water in container = 0.300kg
Final mass of water in container = 0.312kg
Initial temperature of water in container = 15.2°C
Final temperature of water in container = 34.6°C
Specific heat capacity of water = $4.18\times10^{3}\,\text{Jkg}^{-1}\text{K}^{-1}$

Show that the data give a value of about $1.8\times10^{6}\,\text{Jkg}^{-1}$ for the specific latent heat of vaporization *L* of water.

i. Explain why, other than measurement or calculation error, the accepted value of *L* is greater than that given in (h). [2]

This question is in **two** parts. **Part 1** is about nuclear reactions. **Part 2** is about thermal energy transfer.

Part 1 Nuclear reactions

Part 2 Thermal energy transfer

a. (i) Define the term *unified atomic mass unit.* [2]

(ii) The mass of a nucleus of einsteinium-255 is 255.09 u. Calculate the mass in MeVc^{-2}.

c. When particle X collides with a stationary nucleus of calcium-40 (Ca-40), a nucleus of potassium (K-40) and a proton are produced. [6]

$$^{40}_{20}\mathrm{Ca} + \mathrm{X} \rightarrow {}^{40}_{19}\mathrm{K} + {}^{1}_{1}\mathrm{p}$$

The following data are available for the reaction.

Particle	Rest mass / MeV c^{-2}
calcium-40	37214.694
X	939.565
potassium-40	37216.560
proton	938.272

(i) Identify particle X.

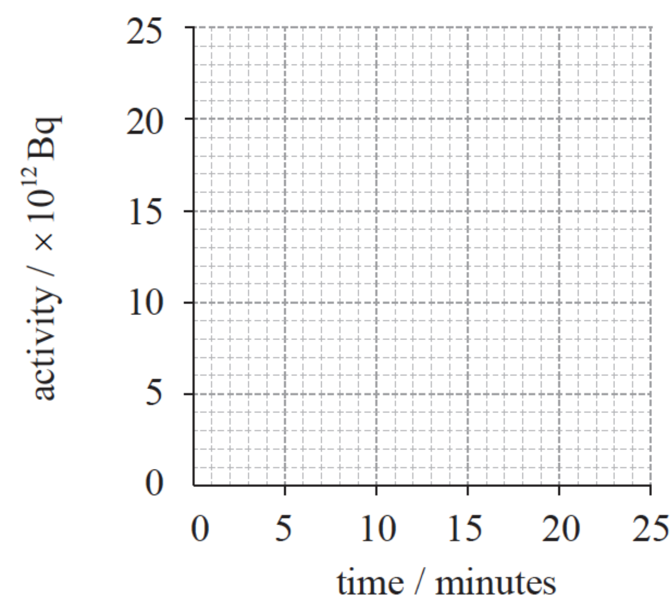
(ii) Suggest why this reaction can only occur if the initial kinetic energy of particle X is greater than a minimum value.

(iii) Before the reaction occurs, particle X has kinetic energy 8.326 MeV. Determine the total combined kinetic energy of the potassium nucleus and the proton.

d. Potassium-38 decays with a half-life of eight minutes. [5]

(i) Define the term *radioactive half-life*.

(ii) A sample of potassium-38 has an initial activity of 24×10^{12}Bq. On the axes below, draw a graph to show the variation with time of the activity of the sample.



(iii) Determine the activity of the sample after 2 hours.

e. (i) Define the *specific latent heat* of fusion of a substance. [5]

(ii) Explain, in terms of the molecular model of matter, the relative magnitudes of the specific latent heat of vaporization of water and the specific latent heat of fusion of water.

f. A piece of ice is placed into a beaker of water and melts completely. [5]

The following data are available.

Initial mass of ice = 0.020 kg
Initial mass of water = 0.25 kg
Initial temperature of ice = 0°C
Initial temperature of water = 80°C
Specific latent heat of fusion of ice = 3.3×10^{5}J kg^{-1}
Specific heat capacity of water = 4200 J $kg^{-1}K^{-1}$

(i) Determine the final temperature of the water.

(ii) State **two** assumptions that you made in your answer to part (f)(i).