1 A copper wire, diameter 1.63 mm and length 105 km, is to be melted down to sell for scrap.

(a) (i) Show that the mass of the wire is about 2000 kg.

density of copper 8960 kg m^{-3}

(3)

(ii) The wire is initially at a temperature of 25 °C and its melting point is 1085 °C. Calculate the energy required to raise the temperature of the wire to its melting point.

specific heat capacity of copper 385 J kg^{-1} K^{-1}

(2)

Energy .....

(b) Once the melting point is reached, there is no further increase in temperature until all of the copper has melted. Discuss what happens to the energy of the copper atoms before and during the melting process.

(2)

(Total for Question 7 marks)

2 It is suggested that before making tea in a teapot, the teapot should be warmed by pouring hot water into it. This allows more flavour to be extracted from the tea.

(a) Suggest why a pre-warmed teapot may allow more flavour to be extracted.

(1)

(b) (i) 0.26 kg of water at 95 °C is added to a stainless steel teapot. In a very short time the teapot and water both reach a temperature of 81 °C.

Show that the energy transferred from the water is about 15 kJ.

specific heat capacity of water = 4200 J kg^{-1} K^{-1}

(2)

(ii) Calculate the specific heat capacity of stainless steel, stating any assumption you make.

mass of teapot = 0.43 kg
initial temperature of teapot = 22 °C

(3)

Assumption

Specific heat capacity = J kg^{-1} K^{-1}

(iii) The accepted value for the specific heat capacity of stainless steel is 500 J kg^{-1} K^{-1}. Compare this with the value you have calculated and explain the difference.

(2)

(Total for Question = 8 marks)

3 Electrical power generated by nuclear fission makes an important contribution to world energy needs. However Rutherford, who is credited with the discovery and first splitting of the nuclear atom, later said:

"The energy produced by the breaking down of the atom is a very poor kind of thing. Anyone who expects a source of power from the transformation of these atoms is talking moonshine."

Rutherford carried out experiments that involved firing alpha particles at nitrogen atoms.

(a) (i) Complete the equation for the interaction between nitrogen and alpha particles.

(1)

$$^{14}_{7}\mathrm{N} + {}^{4}_{2}\alpha \rightarrow \ldots\ldots\mathrm{O} + \ldots\ldots{}^{1}\mathrm{p}$$

(ii) This interaction requires a small energy input. Other similar nuclear reactions may give an energy output of no more than 20 MeV, giving some justification to Rutherford's statement. Suggest why Rutherford's statement eventually turned out to be very inaccurate.

(1)

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(b) Uranium-235 is able to undergo fission when it absorbs a neutron to become uranium-236. The equation below shows a possible fission reaction.

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

Use the data in the table to show that the energy released by the fission of one uranium nucleus is about 170 MeV.

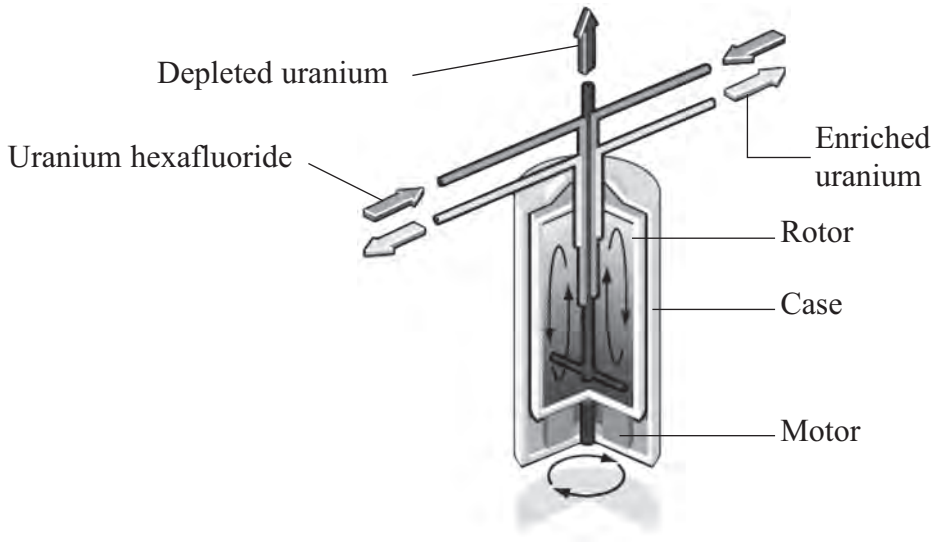
Isotope	Mass / 10^{-27} kg
^{235}U	390.29989
^{141}Ba	233.99404
^{92}Kr	152.64708
^{1}n	1.67493

(4)

(c) Naturally occurring uranium is more than 99% uranium-238. Fuel for a fission reactor requires at least 3% of the uranium to be uranium-235.

Uranium hexafluoride gas is used during the uranium enrichment process. It is fed into a centrifuge, and a rotating cylinder (rotor) sends the uranium-238 to the outside of the cylinder, where it can be drawn off, while the uranium-235 diffuses to the centre of the cylinder.

Gas centrifuge



(i) Give **one** similarity and **one** difference between the nuclei of uranium-238 and uranium-235.

(2)

Similarity .....

Difference .....

(ii) The rotor has a diameter of 30 cm and spins at a rate of 60,000 revolutions per minute.

Calculate the centripetal acceleration at the rim of the rotor.

(2)

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Centripetal acceleration .....

(iii) The rotor is subjected to huge forces because of the high spin rate.

Give **two** mechanical properties essential for the material from which the rotor is made.

(2)

Property 1 .....

Property 2 .....

(d) The waste heat from some power stations is transferred to water.

The San Onofre Nuclear Generating Station in California has reactors with a total output power of 2200 MW. These reactors circulate sea water at an average mass flow rate of 7.0×10^4 kg s^{1}. The water is heated to approximately 11 K above the input temperature as it flows through condensers, before being discharged back into the ocean.

Show that the rate at which energy is removed from the reactors is about 3000 MW, and hence estimate a value for the efficiency of the electrical power generation process.

specific heat capacity of the sea water 3990 J kg ^{1} K ^{1}

(4)

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Efficiency .....

(Total for Question 16 marks)

4 Records of people walking on fire have existed for thousands of years. Walking across hot coals without getting burned does seem impossible, especially when the coals are at a temperature of 1500 K. However, as long as they do not take too long to walk across the coals, firewalkers won't get burned.

The explanation may have something to do with the relatively small amount of thermal energy involved. Although the coals are hot, the total amount of thermal energy transferred to the soles of the walker's feet is small. This is a little like quenching a red hot metal bar in a trough of cold water. The metal bar cools rapidly, transferring thermal energy to the water, but the rise in temperature of the water is quite small because of the relatively large value for the specific heat capacity of the water.

(a) Describe an experiment you could carry out to measure the specific heat capacity of a metal, assuming that you have a number of metal washers which can be heated to a known temperature in a Bunsen flame and plunged into a container of water. State the measurements that you would need to make and give the theoretical basis of the calculation that you would carry out.

What assumption would you make in calculating the specific heat capacity of the metal?

(4)

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(b) Coals used for firewalking typically glow a dull red, with the peak energy emission taking place at a wavelength of about 2 μm.

(i) To which region of the electromagnetic spectrum does this wavelength belong?

(1)

.....

(ii) Show that a peak wavelength of 2.00 μm corresponds to a black-body temperature of about 1500 K.

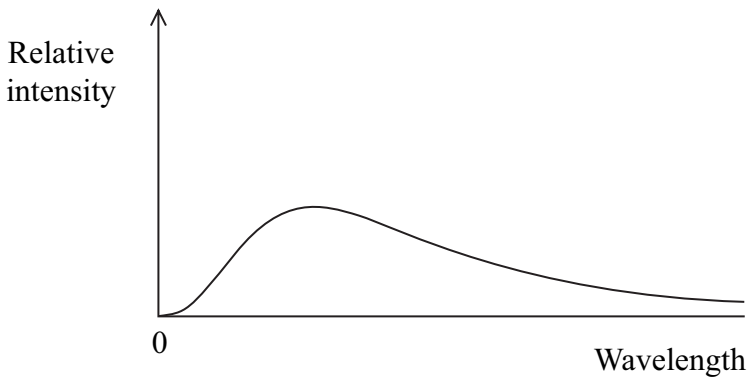
(2)

(iii) The coals have an average radius of 2.5 cm. Assuming that each coal behaves as a black-body radiator, calculate the rate at which energy is radiated from each coal at a temperature of 1500 K.

(3)

(iv) The graph shows the shape of the spectrum for radiation emitted from a black-body radiator at 1500 K. Add a second curve to show the shape of the spectrum for a temperature of 2000 K.

(2)



(Total for Question 12 marks)

5 A car of mass 1200 kg is travelling at a speed of 25 m s^{-1}. During braking, 25% of the kinetic energy of the car is transferred to the brake pads.

Calculate the increase in temperature of the brake pads.

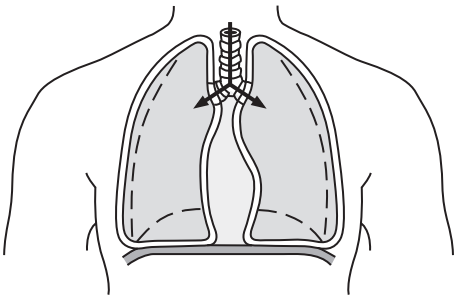
total mass of brake pads = 5.3 kg
specific heat capacity of brake pads = 450 J kg^{-1} K^{-1}

(4)

Increase in temperature =

(Total for Question = 4 marks)

6 When your diaphragm contracts, the pressure in the chest cavity is lowered below atmospheric pressure and air is forced into your lungs.



(a) The diaphragm contracts and the lung capacity increases by 20%. State **two** assumptions you would need to make to calculate the new pressure in the lungs if the initial pressure is known.

(2)

(b) (i) The volume of air inhaled in a typical breath is 2.5×10^{-4} m^3 and an adult takes about 25 breaths per minute. Show that the mass of air taken into the lungs each second is about 1×10^{-4} kg.

Density of air = 1.2 kg m^{-3}

(2)

(ii) If body temperature is 37.6 °C and the temperature outside the body is 20.0 °C, calculate the rate at which energy is used to warm air up to body temperature.

Specific heat capacity of air = 1000 J kg^{-1} K^{-1}

(2)

Rate =

(Total for Question = 6 marks)