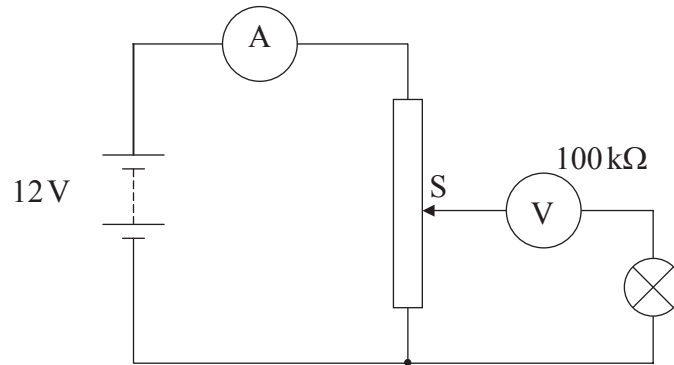


A2. This question is about an electric circuit.

A particular filament lamp is rated at 12 V, 6.0 mA. It just lights when the potential difference across the filament is 6.0 V.

A student sets up an electric circuit to measure the I - V characteristic of the filament lamp.

In the circuit, shown below, the student has connected the voltmeter and the ammeter into the circuit **incorrectly**.



The battery has e.m.f. 12 V and negligible internal resistance. The ammeter has negligible resistance and the resistance of the voltmeter is 100 k Ω . The maximum resistance of the variable resistor is 15 Ω .

(a) Explain, without doing any calculations, whether there is a position of the slide S at which the lamp will be lit. [3]

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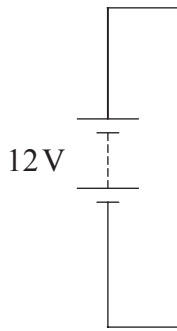
(b) Estimate the maximum reading of the ammeter. [2]

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(This question continues on the following page)

(Question A2 continued)

- (c) Complete the circuit diagram below showing the correct position of the voltmeter and of the ammeter in order to determine the I - V characteristic of the filament lamp. [2]



(Question B1 continued)

Part 2 Specific heat and a domestic shower

(a) Define *specific heat capacity*. [1]

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(b) Equal masses of two different solid substances A and B are at the same temperature. The specific heat capacity of substance A is greater than the specific heat capacity of substance B. The two substances now have their temperatures raised by the same amount.

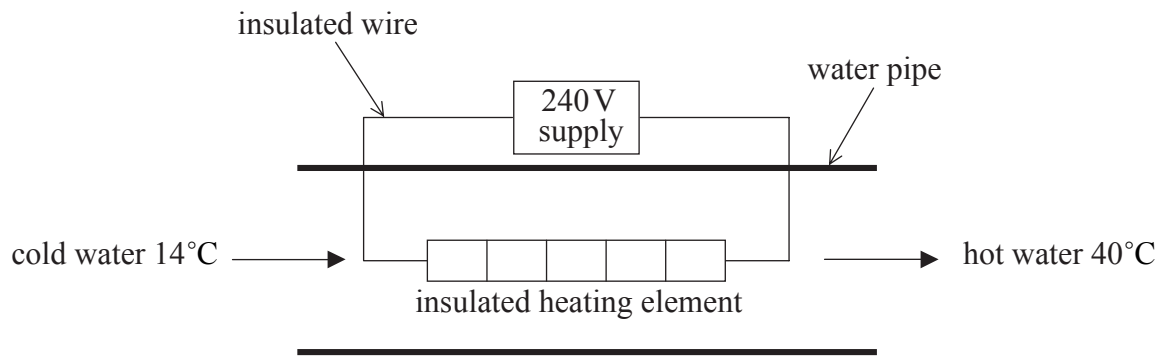
Explain which substance will have the greater increase in internal energy assuming both remain in the solid phase. [2]

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(This question continues on the following page)

(Question B1, part 2 continued)

(c) The diagram below shows part of the heating circuit of a domestic shower.



Cold water enters the shower unit and flows over an insulated heating element. The heating element is rated at 7.2kW, 240V. The water enters at a temperature of 14°C and leaves at a temperature of 40°C. The specific heat capacity of water is $4.2 \times 10^3 \text{ J kg}^{-1} \text{ K}^{-1}$.

(i) Estimate the flow rate of the water. [4]

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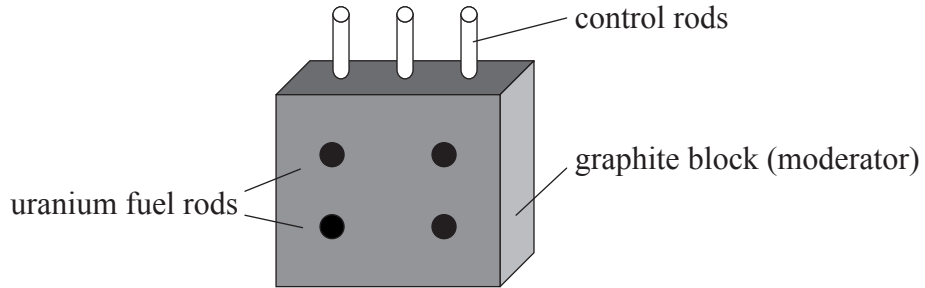
(ii) Suggest **one** reason why your answer to (c)(i) is only an estimate. [1]

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B2. This question is about nuclear power production.

- (a) The purpose of a nuclear power station is to produce electrical energy from nuclear energy. The diagram below is a representation of the principal components of a nuclear reactor pile used in a certain type of nuclear power station that uses uranium as a fuel.



The function of the moderator is to slow down the neutrons produced in a reaction such as that described above.

Explain,

- (i) why it is necessary to slow down the neutrons. [3]

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- (ii) the function of the control rods. [2]

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(This question continues on the following page)

(Question B2 continued)

(b) With reference to the concept of fuel enrichment in a nuclear reactor explain,

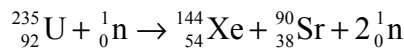
(i) the advantage of enriching the uranium used in a nuclear reactor. [3]

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(ii) from an international point of view, a possible risk to which fuel enrichment could lead. [2]

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(c) A particular nuclear reactor uses uranium-235 as its fuel source. When a nucleus of uranium-235 absorbs a neutron, the following reaction can take place.



The following data are available.

$$\text{rest mass of } {}^{235}_{92}\text{U} = 2.1895 \times 10^5 \text{ MeV c}^{-2}$$

$$\text{rest mass of } {}^{144}_{54}\text{Xe} = 1.3408 \times 10^5 \text{ MeV c}^{-2}$$

$$\text{rest mass of } {}^{90}_{38}\text{Sr} = 8.3749 \times 10^4 \text{ MeV c}^{-2}$$

$$\text{rest mass of } {}^1_0\text{n} = 939.56 \text{ MeV c}^{-2}$$

(i) Show that the energy released in the reaction is approximately 180 MeV. [1]

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(ii) State the form in which the energy appears. [1]

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(This question continues on the following page)

(Question B2 continued)

(d) The energy released by 1 atom of carbon-12 during combustion is approximately 4 eV.

(i) Using the answer to (c)(i), estimate the ratio

$$\frac{\text{energy density of uranium-235}}{\text{energy density of carbon-12}} \quad [3]$$

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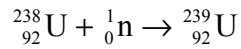
(ii) Suggest, with reference to your answer in (d)(i), **one** advantage of uranium-235 compared with fossil fuels. [1]

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(Question B2 continued)

- (e) When a uranium-238 nucleus absorbs a neutron the following reaction can take place.



The isotope uranium-239 is radioactive and decays with a half-life of 23 minutes to form an isotope of neptunium-239 (Np-239).

- (i) Define *radioactive half-life* and explain what is meant by an isotope. [2]

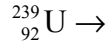
Radioactive half-life:

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Isotope:

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- (ii) Complete the reaction equation for this decay. [3]



- (iii) The isotope neptunium-239 undergoes radioactive β^- decay to form an isotope of plutonium. Outline **one** advantage and **one** disadvantage of this decay in relation to nuclear power production. [4]

Advantage:

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Disadvantage:

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B3. This question is in **two** parts. **Part 1** is about mechanical power. **Part 2** is about radioactive decay.

Part 1 Mechanical power

(a) Define *power*. [1]

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(b) A car is travelling with constant speed v along a horizontal straight road. There is a total resistive force F acting on the car.

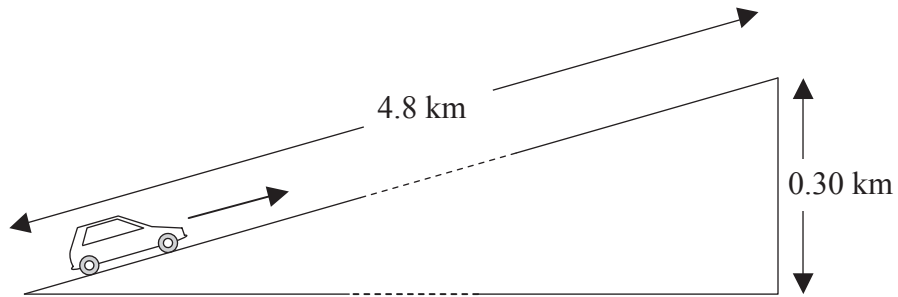
Deduce that the power P to overcome the force F is $P=Fv$. [2]

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(Question B3, part 1 continued)

- (c) A car drives up a straight incline that is 4.8 km long. The total height of the incline is 0.30 km.



The car moves up the incline at a steady speed of 16 ms^{-1} . During the climb, the average friction force acting on the car is $5.0 \times 10^2 \text{ N}$. The total weight of the car and the driver is $1.2 \times 10^4 \text{ N}$.

- (i) Determine the time it takes the car to travel from the bottom to the top of the incline. [2]

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- (ii) Determine the work done against the gravitational force in travelling from the bottom to the top of the incline. [1]

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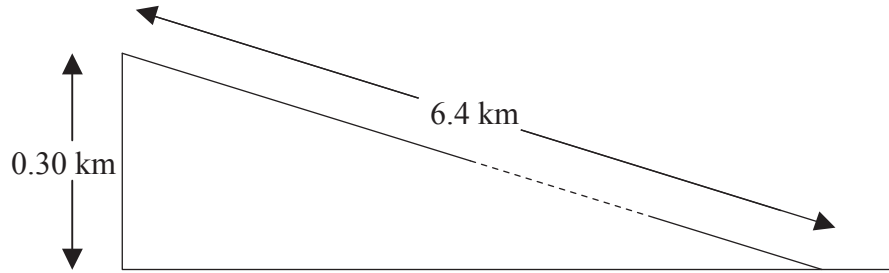
- (iii) Using your answers to (c)(i) and (c)(ii), calculate a value for the minimum power output of the car engine needed to move the car from the bottom to the top of the incline. [4]

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(Question B3, part 1 continued)

- (d) From the top of the incline, the road continues downwards in a straight line. At the point where the road starts to go downwards, the driver of the car in (c), stops the car to look at the view. In continuing his journey, the driver decides to save fuel. He switches off the engine and allows the car to move freely down the hill. The car descends a height of 0.30 km in a distance of 6.4 km before levelling out.



The average resistive force acting on the car is $5.0 \times 10^2 \text{ N}$.

Estimate

- (i) the acceleration of the car down the incline. [5]

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- (ii) the speed of the car at the bottom of the incline. [2]

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- (e) In fact, for the last few hundred metres of its journey down the hill, the car travels at constant speed. State the value of the frictional force acting on the car whilst it is moving at constant speed. [1]

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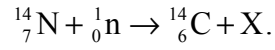
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Turn over

(Question B3 continued)

Part 2 Radioactive decay

- (a) Carbon-14 is a radioactive isotope with a half-life of 5500 years. It is produced in the atmosphere by neutron bombardment of nitrogen. The equation for this reaction is



- (i) Explain what is meant by isotopes. [1]

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- (ii) Identify the particle X. [1]

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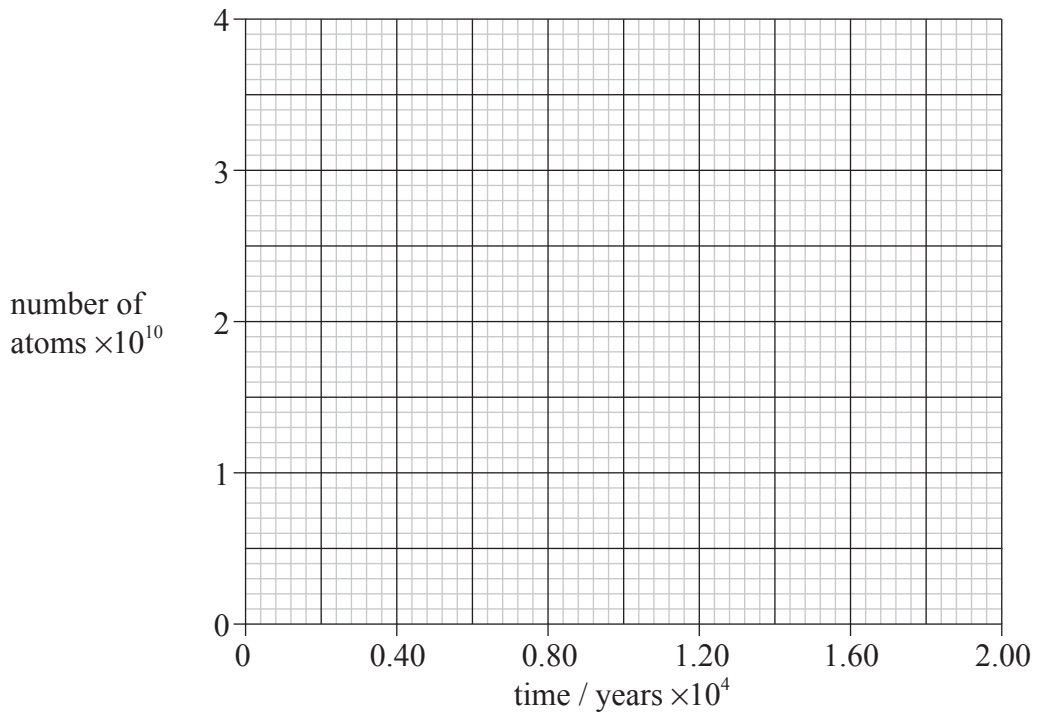
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(Question B3, part 2 continued)

- (b) Each gram of a living tree contains approximately 4×10^{10} atoms of carbon-14.

On the axes below, draw a graph to show the variation with time of the number of carbon-14 atoms in one gram of wood from a tree. Your graph should indicate the number of atoms for a period of 1.8×10^4 years after the tree has died. (Half-life of carbon-14 = 5500 years)

[3]



- (c) The activity of a radioactive sample is proportional to the number of atoms in the sample. The activity per gram of carbon from a living tree is 9.6 disintegrations per minute. The activity per gram of carbon in burnt wood found at an ancient campsite is 1.9 disintegrations per minute.

- (i) Estimate the number of atoms of carbon-14 in the burnt wood. [1]

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- (ii) From the graph you have drawn in (b), estimate the age of the burnt wood. [1]

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A2. The resistive force F that acts on an object moving at speed v in a stationary fluid of constant density is given by the expression

$$F = kv^2$$

where k is a constant.

(a) State the derived units of

(i) force F . [1]

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(ii) speed v . [1]

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(b) Use your answers in (a) to determine the derived units of k . [1]

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