

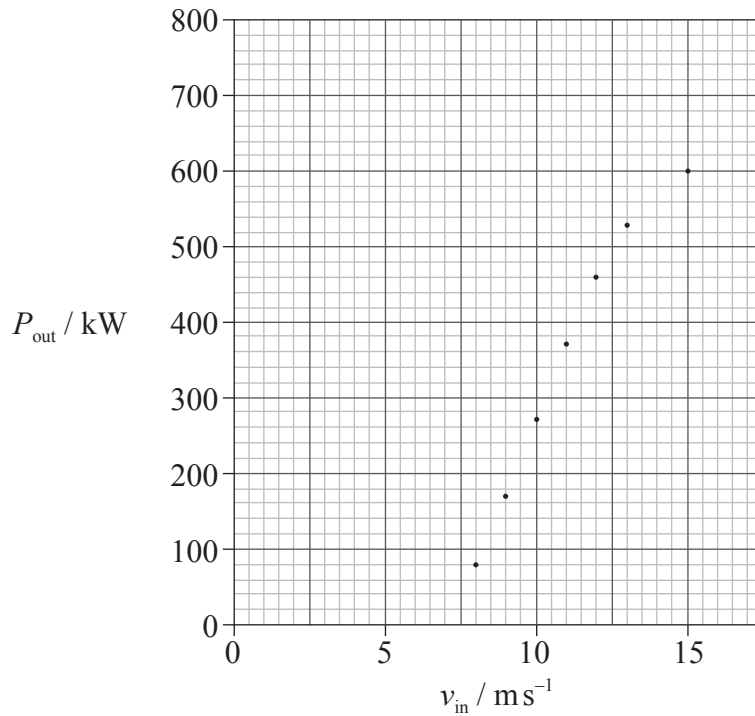
SECTION A

Answer **all** the questions in the spaces provided.

A1. This question is about the electrical power available from a wind turbine.

The maximum electrical power generated by a wind turbine, P_{out} , was measured over a range of incident wind speeds, v_{in} .

The graph below shows the variation with v_{in} of P_{out} . Uncertainties for the data are not shown.



(a) It is suggested that P_{out} is proportional to $\sqrt{v_{\text{in}}}$.

(i) Draw the line of best-fit for the data points. [1]

(ii) State **one** reason why the line you have drawn does not support this hypothesis. [1]

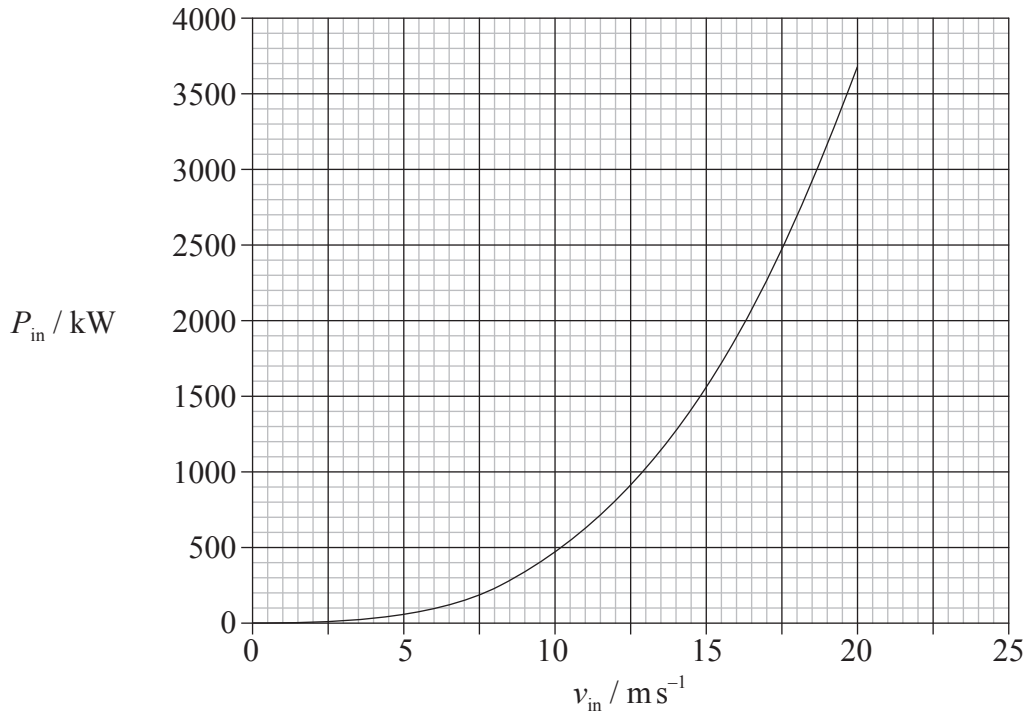
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(iii) The uncertainty in the power at 15 m s^{-1} is 5%. Draw an error bar on the graph to represent this uncertainty. [2]

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(Question A1 continued)

- (b) The theoretical relationship between the available power in the wind, P_{in} , and incident wind speed is shown in the graph below.



Using both graphs,

- (i) determine the efficiency of the turbine for an incident wind speed of 14ms^{-1} . [3]

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- (ii) suggest, without calculation, how the efficiency of the turbine changes with increasing wind speed. [3]

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Turn over

(Question A1 continued)

- (c) Outline **one** advantage and **one** disadvantage of using wind turbines to generate electrical energy. [2]

Advantage:

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Disadvantage:

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A3. This question is about energy transfers.

- (a) Energy degradation takes place in the energy transformations which occur in the generation of electrical power. Explain what is meant in this context by energy degradation. [2]

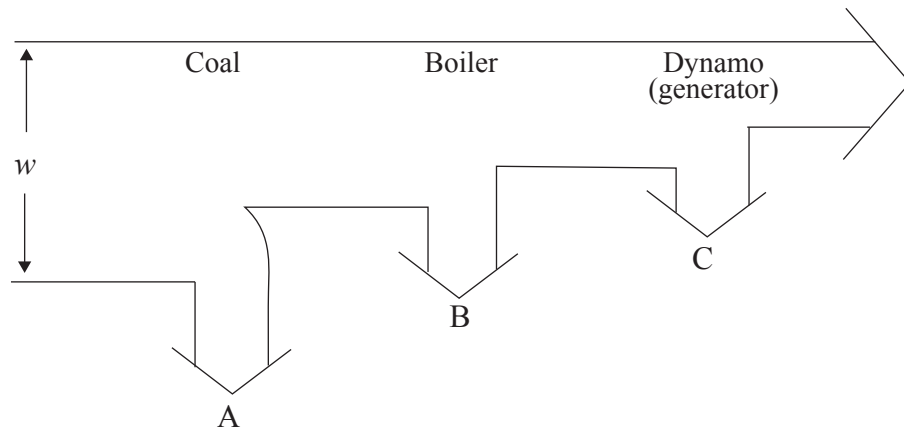
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Some of the energy transformations that take place in a coal-fired power station are represented by the Sankey diagram below.



- (b) (i) State what is represented by the width w . [1]

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- (ii) At the three places marked A, B and C on the diagram, energy is degraded. Identify the process by which the energy is degraded in each of the places. [3]

A:

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B:

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C:

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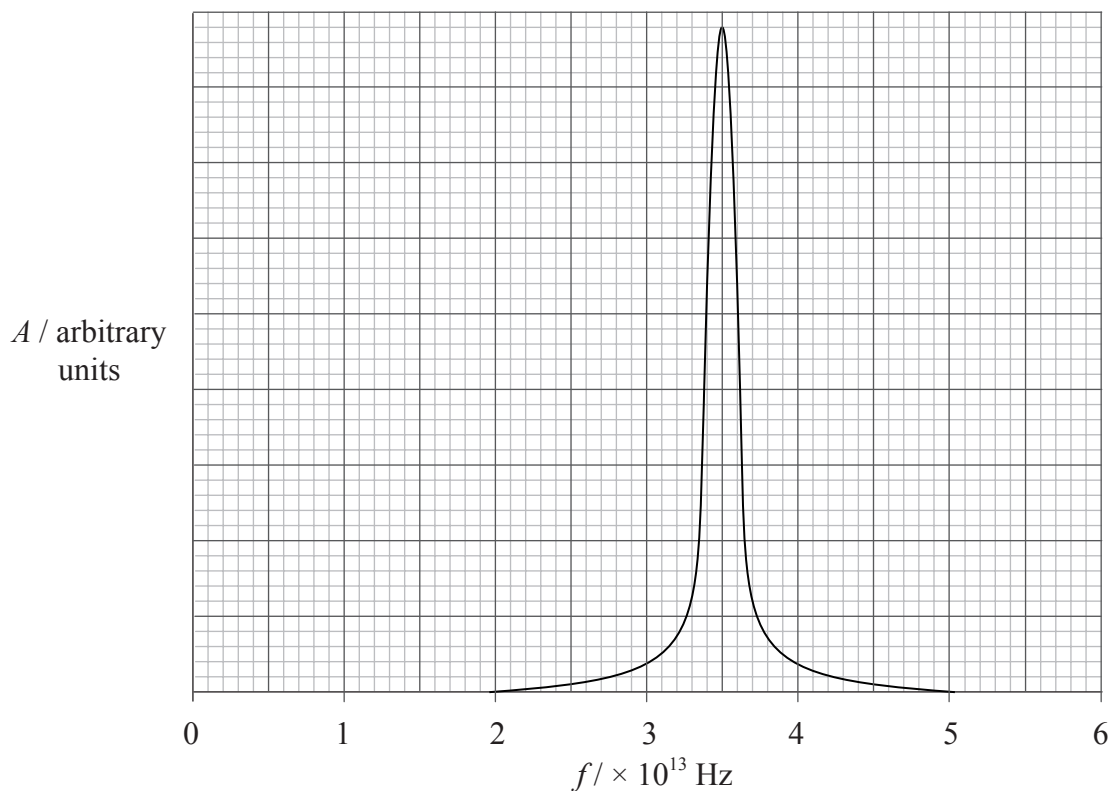
SECTION B

*This section consists of three questions: B1, B2, and B3. Answer **one** question.*

B1. This question is in **two** parts. **Part 1** is about greenhouse effect and **Part 2** is about motion of a ball falling in oil.

Part 1 Greenhouse effect

(a) The graph shows part of the absorption spectrum of nitrogen oxide (N_2O) in which the intensity of absorbed radiation A is plotted against frequency f .



(i) State the region of the electromagnetic spectrum to which the resonant frequency of nitrogen oxide belongs. [1]

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(ii) Using your answer to (a)(i), explain why nitrogen oxide is classified as a greenhouse gas. [2]

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(Question B1, part 1 continued)

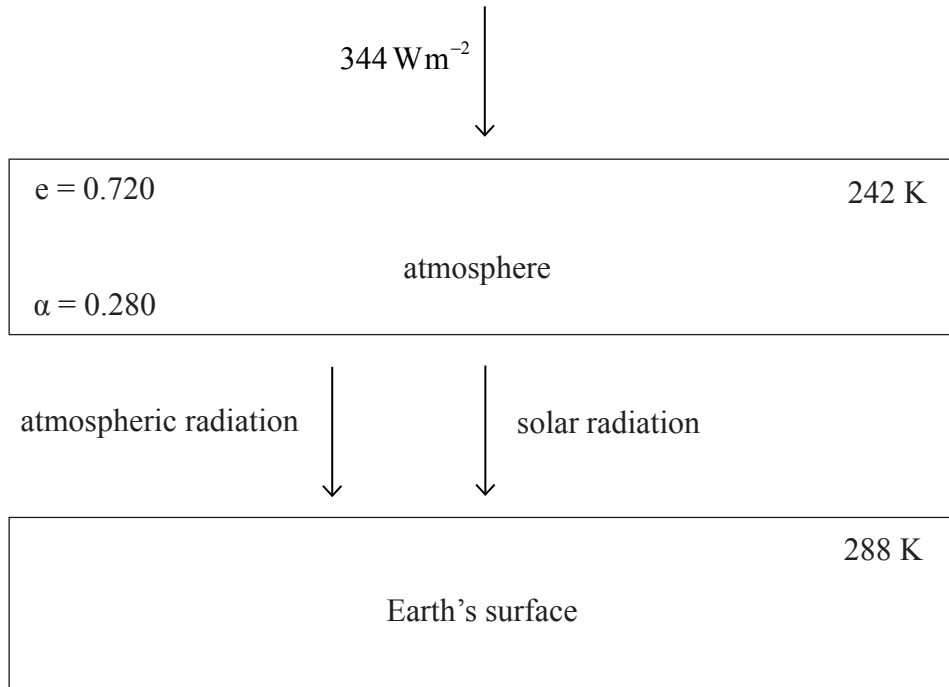
(b) Define *emissivity* and *albedo*.

[3]

Emissivity:

Albedo:

(c) The diagram shows a simple energy balance climate model in which the atmosphere and the surface of Earth are two bodies each at constant temperature. The surface of the Earth receives both solar radiation and radiation emitted from the atmosphere. Assume that the Earth's surface behaves as a black body.



The following data are available for this model.

- average temperature of the atmosphere of Earth = 242 K
- emissivity, e of the atmosphere of Earth = 0.720
- average albedo, α of the atmosphere of Earth = 0.280
- solar intensity at top of atmosphere = 344 W m^{-2}
- average temperature of the surface of Earth = 288 K

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(Question B1, Part 1 (c) continued)

Use the data to show that the

- (i) power radiated per unit area of the atmosphere is 140 W m^{-2} . [2]

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- (ii) solar power absorbed per unit area at the surface of the Earth is 248 W m^{-2} . [1]

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- (d) It is hypothesized that, if the production of greenhouse gases were to stay at its present level then the temperature of the Earth’s atmosphere would eventually rise by 6.0 K . Calculate the power per unit area that would then be

- (i) radiated by the atmosphere. [1]

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- (ii) absorbed by the Earth’s surface. [1]

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- (e) Estimate, using your answer to (d)(ii), the increase in temperature of Earth’s surface. [3]

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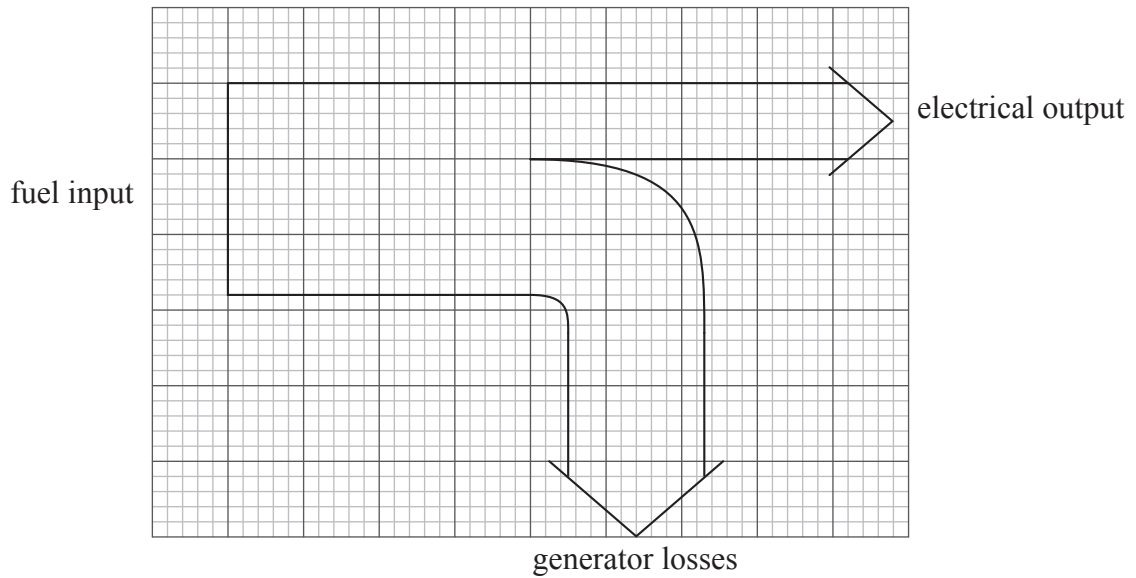
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(Question B1 continued)

Part 2 Fossil fuels

- (a) A Sankey diagram for the generation of electrical energy using fossil fuel as the primary energy source is shown.



- (i) State what is meant by a fuel. [1]

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- (ii) State **two** examples of fossil fuels. [2]

- 1.
- 2.

- (iii) Explain why fossil fuels are said to be non-renewable. [2]

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(Question B1, part 2 continued)

(iv) Use the Sankey diagram to estimate the efficiency of production of electrical energy and explain your answer. [2]

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(b) Despite the fact that fossil fuels are non-renewable and contribute to atmospheric pollution there is widespread use of such fuels. Suggest **three** reasons for this widespread use. [3]

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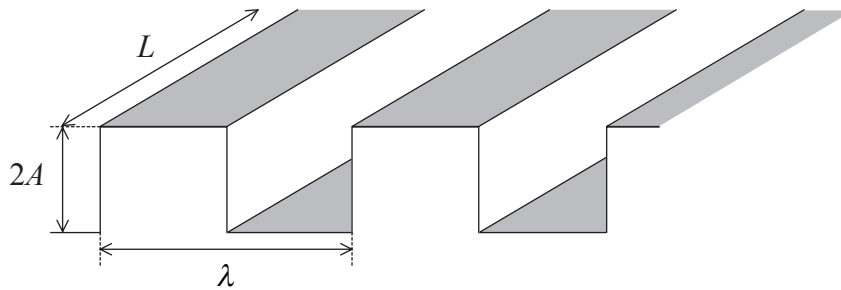
B3. This question is in **two** parts. **Part 1** is about wave power. **Part 2** is about the albedo of the Earth.

Part 1 Wave power

(a) Outline how the energy of a wave can be converted to electrical energy. [2]

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(b) A wave on the surface of water is assumed to be a square-wave of height $2A$, as shown.



The wave has wavelength λ , speed v and has a wavefront of length L . For this wave,

(i) show that the gravitational potential energy E_p stored in one wavelength of the wave is given by

$$E_p = \frac{1}{2} A^2 \lambda g \rho L$$

where ρ is the density of the water and g is the acceleration of free fall. [3]

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(ii) deduce that the gravitational wave power P per unit length of the wavefront is given by

$$P = \frac{1}{2} A^2 v g \rho$$
 [2]

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(Question B3, part 1 continued)

- (c) The density of sea-water is $1.2 \times 10^3 \text{ kg m}^{-3}$. Using the expression in (b)(ii), estimate the gravitational power per metre length available in a wave of height 0.60 m. [2]

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- (d) In practice a water wave is approximately sinusoidal in cross-section. Outline whether a sine wave of the same height as in (b) transfers a greater **or** a smaller amount of power than that derived in (b)(ii). [2]

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- (e) List **two** advantages of the utilisation of wave power rather than photovoltaic cells for the generation of electric power. [2]

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(Question B3 continued)

Part 2 Albedo of the Earth

- (a) Outline the mechanism by which a gas, such as carbon dioxide, absorbs infra-red radiation. [2]

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- (b) State, with reference to your answer in (a), why carbon dioxide is known as a greenhouse gas. [1]

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- (c) State the **name** of another greenhouse gas. [1]

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- (d) In the last fifty years the amount of carbon dioxide in the Earth's atmosphere has increased significantly. Explain

- (i) why this increase could account for global warming. [1]

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- (ii) what effect this has had on the average albedo of the Earth. [3]

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(Question B3, part 2 continued)

- (e) It has been estimated that doubling the amount of carbon dioxide in the Earth's atmosphere changes the albedo of the Earth by 0.01. Use the data to show that this doubling will lead to a change of about 3 W m^{-2} in the intensity being reflected by the Earth into space. [3]

Average intensity received at Earth from the Sun = 340 W m^{-2}
Average albedo = 0.30

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- (f) State **one** reason why the answer to (e) is an estimate. [1]

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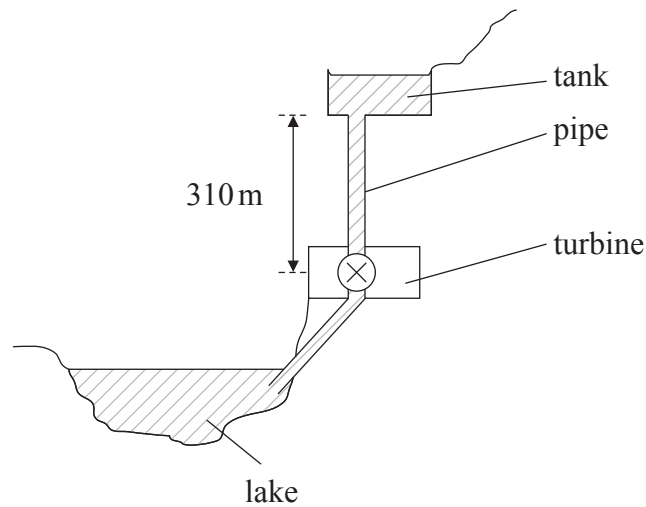
SECTION B

*This section consists of three questions: B1, B2 and B3. Answer **one** question.*

B1. This question is in **two** parts. **Part 1** is about a pumped-storage power station. **Part 2** is about forces and energies.

Part 1 Pumped-storage power station

(a) The diagram, not to scale, shows a pumped-storage power station used for the generation of electrical energy.



Water stored in the tank is allowed to fall through a pipe to a lake via a turbine. The turbine is connected to an electrical generator. The pumped-storage ac generator system is reversible so that water can be pumped from the lake to the tank.

The tank is 50 m deep and has a uniform area of $5.0 \times 10^4 \text{ m}^2$. The height from the bottom of the tank to the turbine is 310 m. The density of water is $1.0 \times 10^3 \text{ kg m}^{-3}$.

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(Question B1, part 1 continued)

- (i) Show that the maximum energy that can be delivered to the turbine by the falling water is about 8×10^{12} J. [3]

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- (ii) The flow rate of water in the pipe is $400 \text{ m}^3 \text{ s}^{-1}$. Calculate the power delivered by the falling water. [2]

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(Question B1, part 1 continued)

(b) The energy losses in the power station are shown in the following table.

Source of energy loss	Percentage loss of energy
friction and turbulence of water in pipe	27
friction in turbine and ac generator	15
electrical heating losses	5

(i) Calculate the overall efficiency of the conversion of the gravitational potential energy of water in the tank into electrical energy. [1]

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(ii) Sketch a Sankey diagram to represent the energy conversion in the power station. [2]

(This question continues on the following page)



(Question B1, part 1 continued)

(c) The electrical power produced at the power station is transmitted by cables to the consumer.

(i) Outline how the energy losses in transmission are minimized. [3]

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(ii) State **one** advantage and **one** disadvantage that a pumped-storage system has compared to a tidal water storage system. [2]

Advantage:

Disadvantage:

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(Question B3, part 1 continued)

- (c) Intensive scientific effort is devoted to developing nuclear fusion as a future energy source. Discuss what could be the social and environmental benefits of using nuclear fusion as compared with nuclear fission as an energy source. [3]

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(Question B3 continued)

Part 2 Global warming

(a) One reason often suggested for global warming is the enhanced greenhouse effect.

(i) State what is meant by the enhanced greenhouse effect. [1]

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(ii) State **two** other possible causes of global warming. [2]

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(Question B3, part 2 continued)

- (b) One effect of global warming is to melt the Antarctic ice sheet. The following data are available for the Antarctic ice sheet and the Earth's oceans.

Area of ice sheet	= $1.4 \times 10^7 \text{ km}^2$
Average thickness of ice	= $1.5 \times 10^3 \text{ m}$
Density of ice	= 920 kg m^{-3}
Density of water	= 1000 kg m^{-3}
Area of Earth's oceans	= $3.8 \times 10^8 \text{ km}^2$

Using the data, determine the

- (i) mass of the Antarctic ice. [2]

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- (ii) change in mean sea level if all the Antarctic ice sheet were to melt and flow into the oceans. [3]

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- (c) Outline the difference, if any, that the melting of oceanic ice sheets makes to the mean sea level of the Earth. [2]

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(Question B1, part 1 continued)

(e) Methane is classified as a greenhouse gas.

(i) Describe what is meant by a greenhouse gas. [2]

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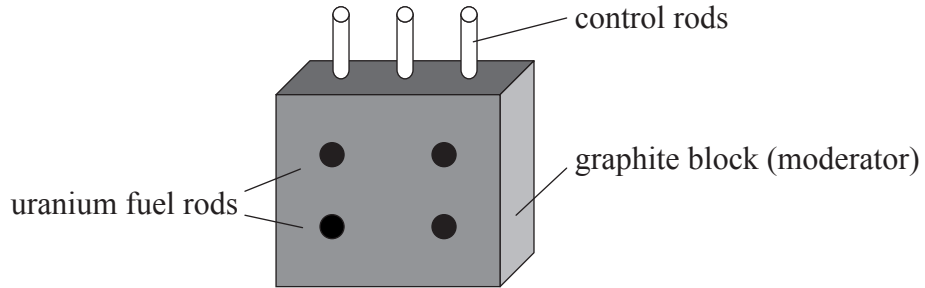
(ii) Electromagnetic radiation of frequency 9.1×10^{13} Hz is in the infrared region of the electromagnetic spectrum. Suggest, based on the information given in (b)(ii), why methane is classified as a greenhouse gas. [2]

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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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(Question B2 continued)

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

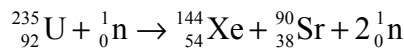
(i) the advantage of enriching the uranium used in a nuclear reactor. [3]

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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.

- rest mass of ${}_{92}^{235}\text{U} = 2.189 \times 10^5 \text{ MeV c}^{-2}$
- rest mass of ${}_{54}^{144}\text{Xe} = 1.346 \times 10^5 \text{ MeV c}^{-2}$
- rest mass of ${}_{38}^{90}\text{Sr} = 8.375 \times 10^4 \text{ MeV c}^{-2}$
- rest mass of ${}_0^1\text{n} = 940.0 \text{ MeV c}^{-2}$

(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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