T8-1 *[166 marks]*

1. Which energy resource is renewable? *[1 mark]*

   A. Natural gas
   B. Uranium
   C. Biogas
   D. Coal

2. For a black-body at absolute temperature T the power emitted per unit area is P. What is the power emitted per unit area when the temperature is decreased to $\frac{1}{2}T$? *[1 mark]*

   A. $\frac{P}{32}$
   B. $\frac{P}{16}$
   C. $\frac{P}{8}$
   D. $\frac{P}{4}$

This question is about alternative energy supplies.

A small island community requires a peak power of 850 kW. Two systems are available for supplying the energy: using wind power or photovoltaic cells.

3a. (i) Outline, with reference to the energy conversions in the machine, the main features of a conventional horizontal-axis wind generator. *[7 marks]*

(ii) The mean wind speed on the island is 8.0 ms^{-1}. Show that the maximum power available from a wind generator of blade length 45 m is approximately 2 MW.

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

(iii) The efficiency of the generator is 24%. Deduce the number of these generators that would be required to provide the islanders with enough power to meet their energy requirements.

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3b. Distinguish between photovoltaic cells and solar heating panels. *[2 marks]*

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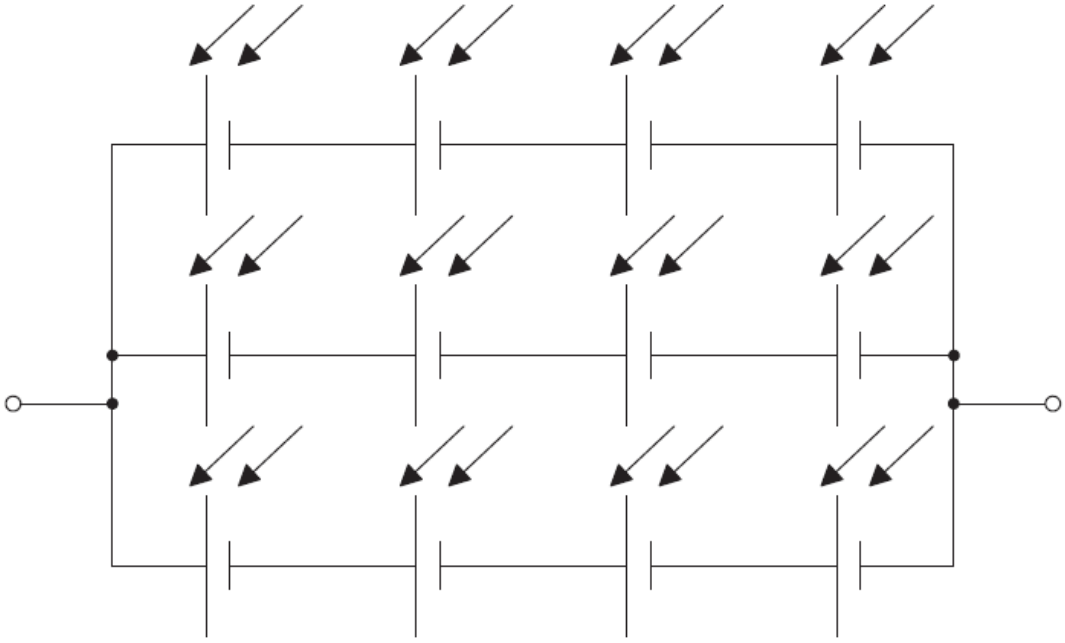
3c. The diagram shows 12 photovoltaic cells connected in series and in parallel to form a module to provide electrical power. *[8 marks]*

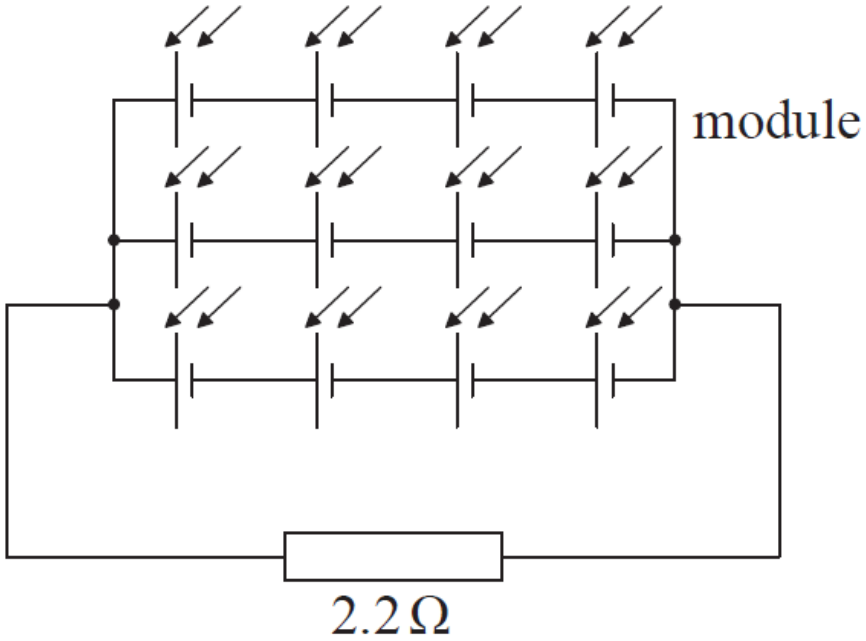


Each cell in the module has an emf of 0.75V and an internal resistance of 1.8Ω.

(i) Calculate the emf of the module.

(ii) Determine the internal resistance of the module.

(iii) The diagram below shows the module connected to a load resistor of resistance 2.2Ω.



Calculate the power dissipated in the load resistor.

(iv) Discuss the benefits of having cells combined in series and parallel within the module.

3d. The intensity of the Sun's radiation at the position of the Earth's orbit (the solar constant) is approximately $1.4\times10^{3}\text{Wm}^{-2}$. *[5 marks]*

(i) Explain why the average solar power per square metre arriving at the Earth is 3.5×10^{2} W.

(ii) State why the solar constant is an approximate value.

(iii) Photovoltaic cells are approximately 20% efficient. Estimate the minimum area needed to supply an average power of 850kW over a 24 hour period.

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4. Which of the following is the primary function of the moderator in a nuclear power station? *[1 mark]*

A. To control the rate of fission reactions
B. To absorb neutrons
C. To prevent the power station from becoming unsafe
D. To slow down neutrons

5. The blades of a certain wind turbine X have radius r. The maximum theoretical available wind power for a given wind speed is P. Another similar turbine Y has blades of radius $2r$. What is the best estimate for the maximum theoretical available wind power from turbine Y? *[1 mark]*

A. $8P$

B. $4P$

C. $\frac{P}{4}$

D. $\frac{P}{8}$

6. The property of the molecules of greenhouse gases which leads to their ability to absorb infrared radiation is their *[1 mark]*

A. resonant frequency.
B. speed of rotation.
C. total electric charge.
D. diameter.

7. Gases in the Earth's atmosphere believed to be responsible for the greenhouse effect include *[1 mark]*

A. sulfur dioxide, nitrous oxide, water.
B. methane, carbon monoxide, ozone.
C. carbon dioxide, sulfur trioxide, carbon monoxide.
D. water, methane, nitrous oxide.

8. In a nuclear power station, in order to increase the chances of a chain reaction *[1 mark]*

A. kinetic energy is removed from the neutrons.

B. kinetic energy is given to the neutrons.

C. some neutrons are absorbed.

D. extra neutrons are added.

9. The original source of the electrical power produced by a wind generator is *[1 mark]*

A. the Sun's radiated energy.

B. the gravitational energy of the Sun and the Moon.

C. nuclear energy stored within atoms in the Earth's atmosphere.

D. the Earth's internal energy.

10. Increasing the temperature of a black-body will have the following effect on its emission spectrum. *[1 mark]*

	Total power radiated	**Peak wavelength of radiation**
A.	increases	decreases
B.	stays the same	decreases
C.	increases	stays the same
D.	stays the same	stays the same

11. The rate of formation of a non-renewable energy resource is *[1 mark]*

A. greater than the rate of consumption of the resource.
B. less than the rate of consumption of the resource.
C. always equal to zero.
D. decreasing as the resource is consumed.

Part 2 Wind power and the greenhouse effect

12a. A coal-fired power station has a power output of 4.0GW. It has been suggested that a wind farm could replace this power station. Using the data below, determine the area that the wind farm would occupy in order to meet the same power output as the coal-fired power station. *[4 marks]*

Radius of wind turbine blades = 42 m
Area required by each turbine = 5.0×10^4 m^2
Efficiency of a turbine = 30%
Average annual wind speed = 12 m s^{-1}
Average annual density of air = 1.2 kg m^{-3}

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12b. Wind power does not involve the production of greenhouse gases. Outline why the surface temperature of the Earth is higher than would be expected without the greenhouse effect. *[3 marks]*

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12c. The average solar intensity incident at the surface of the Earth is 238 W m^{-2}. *[5 marks]*

(i) Assuming that the emissivity of the surface of the Earth is 1.0, estimate the average surface temperature if there were no greenhouse effect.

(ii) The enhanced greenhouse effect suggests that in several decades the predicted temperature of the atmosphere will be 250 K. The emissivity of the atmosphere is 0.78. Show that this atmospheric temperature increase will lead to a predicted average Earth surface temperature of 292 K.

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13. In a nuclear power station, in order to increase the chances of a chain reaction *[1 mark]*

A. kinetic energy is removed from the neutrons.
B. kinetic energy is given to the neutrons.
C. some neutrons are absorbed.
D. extra neutrons are added.

This question is in **two** parts. **Part 1** is about solar power and climate models. **Part 2** is about gravitational fields and electric fields.

Part 1 Solar power and climate models

14a. Distinguish, in terms of the energy changes involved, between a solar heating panel and a photovoltaic cell. *[2 marks]*

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14b. State an appropriate domestic use for a *[2 marks]*

(i) solar heating panel.

(ii) photovoltaic cell.

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14c. The radiant power of the Sun is 3.90×10^{26} W. The average radius of the Earth's orbit about the Sun is 1.50×10^{11} m. The albedo of the atmosphere is 0.300 and it may be assumed that no energy is absorbed by the atmosphere. *[3 marks]*

Show that the intensity incident on a solar heating panel at the Earth's surface when the Sun is directly overhead is 966 Wm^{-2}.

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14d. Show, using your answer to (c), that the average intensity incident on the Earth's surface is 242 Wm^{-2}. *[3 marks]*

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14e. Assuming that the Earth's surface behaves as a black-body and that no energy is absorbed by the atmosphere, *[2 marks]* use your answer to (d) to show that the average temperature of the Earth's surface is predicted to be 256 K.

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This question is about the greenhouse effect.

The following data are available for use in this question:

Quantity	Symbol	Value
Power emitted by the Sun	P	$3.8 \times 10^{26}\,\text{W}$
Distance from the Sun to the Earth	d	$1.5 \times 10^{11}\,\text{m}$
Radius of the Earth	r	$6.4 \times 10^{6}\,\text{m}$
Albedo of the Earth's atmosphere	α	0.31
Stefan–Boltzmann constant	σ	$5.7 \times 10^{-8}\,\text{Wm}^{-2}\text{K}^{-4}$

15a. Explain why the power absorbed by the Earth is *[3 marks]*

$$\frac{P}{4\pi d^2} \times (1 - \alpha) \times \pi r^2$$

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15b. The equation in (a) leads to the following expression which can be used to predict the Earth's average surface temperature T. *[4 marks]*

$$T = \sqrt[4]{\frac{(1 - \alpha)\,P}{16\pi\sigma d^2}}$$

(i) Calculate the predicted temperature of the Earth.

(ii) Explain why the actual average surface temperature of the Earth is in fact higher than the answer to (b)(i).

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

Part 1 Wind power

16a. Outline in terms of energy changes how electrical energy is obtained from the energy of wind. *[2 marks]*

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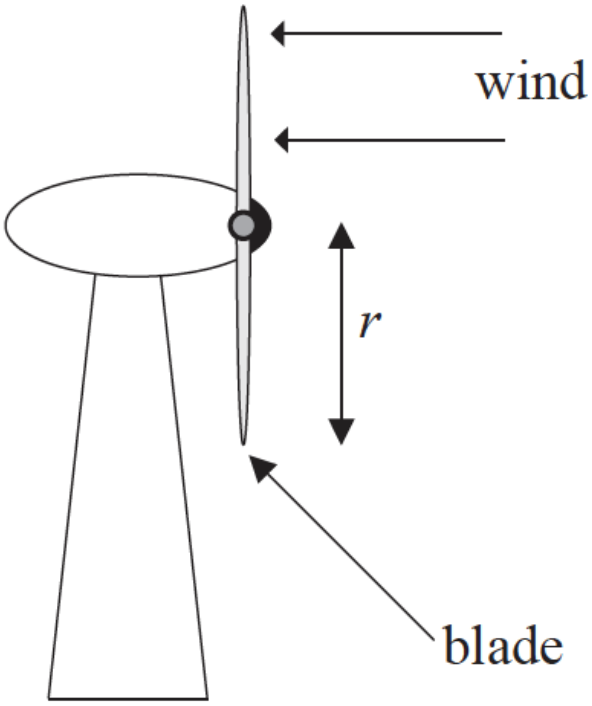
16b. Air of density ρ and speed v passes normally through a wind turbine of blade length r as shown below. *[5 marks]*



(i) Deduce that the kinetic energy per unit time of the air incident on the turbine is

$$\frac{1}{2}\pi\rho r^2 v^3$$

(ii) State **two** reasons why it is impossible to convert all the available energy of the wind to electrical energy.

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16c. Air is incident normally on a wind turbine and passes through the turbine blades without changing direction. The following data are available. *[3 marks]*

Density of air entering turbine = 1.1 kg m^{-3}
Density of air leaving turbine = 2.2 kg m^{-3}
Speed of air entering turbine = 9.8 m s^{-1}
Speed of air leaving turbine = 4.6 m s^{-1}
Blade length = 25 m

Determine the power extracted from the air by the turbine.

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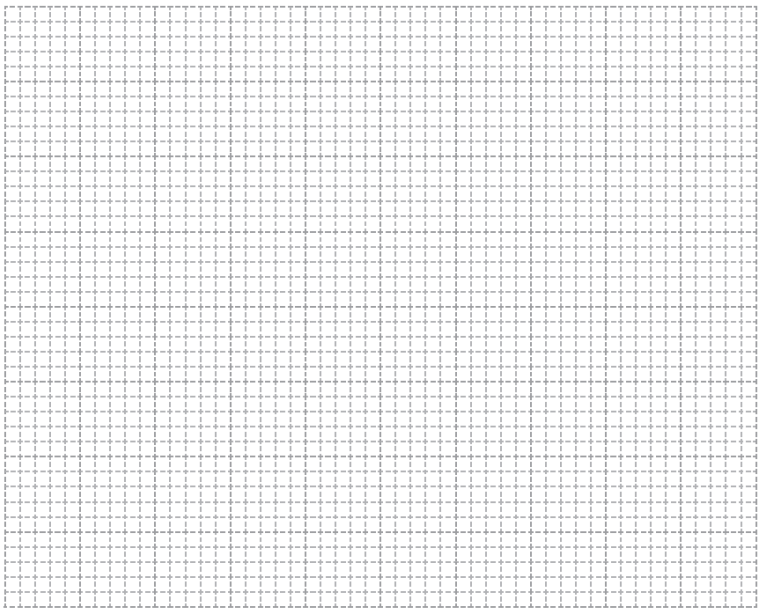
16d. A wind turbine has a mechanical input power of 3.0×10^5W and generates an electrical power output of 1.0×10^5W. On the grid below, construct and label a Sankey diagram for this wind turbine. *[3 marks]*



16e. Outline **one** advantage and **one** disadvantage of using wind turbines to generate electrical energy, as compared to using fossil fuels. *[2 marks]*

Advantage:

Disadvantage:

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Part 2 Melting of the Pobeda ice island

17a. 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 marks]*

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.

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17b. 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 marks]*

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This question is about electrical generation using nuclear power.

Exposure to radiation is a safety risk both to miners of uranium ore and to workers in nuclear power plants.

18a. Outline why uranium ore needs to be enriched before it can be used successfully in a nuclear reactor. *[3 marks]*

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18b. (i) One possible waste product of a nuclear reactor is the nuclide caesium-137 $\left(^{137}_{55}\mathrm{Cs}\right)$ which decays by the emission of a beta-minus (β–) particle to form a nuclide of barium (Ba). *[6 marks]*

State the nuclear reaction for this decay.

$$^{137}_{55}\mathrm{Cs} \rightarrow \,^{\cdots\cdots}_{\cdots\cdots}\mathrm{Ba} + \,^{\cdots\cdots}_{\cdots\cdots}\beta^{-} + \cdots\cdots$$

(ii) The half-life of caesium-137 is 30 years. Determine the fraction of caesium-137 remaining in the waste after 100 years.

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18c. Some waste products in nuclear reactors are good absorbers of neutrons. Suggest why the formation of such waste products requires the removal of the uranium fuel rods well before the uranium is completely used up. *[2 marks]*

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19. In a nuclear fission reaction neutrons are passed through a moderator. The reason for this is to reduce the *[1 mark]*

A. number of the neutrons.
B. kinetic energy of the neutrons.
C. the number of collisions between neutrons.
D. potential energy of the neutrons.

20. Wind of speed v is incident normally on a wind turbine of radius r. The maximum theoretical power output of the turbine is P. For wind of speed $2v$ incident normally on a similar turbine of radius $\frac{1}{2}r$, the maximum theoretical power will be *[1 mark]*

A. $\frac{1}{2}P$.
B. P.
C. $2P$.
D. $4P$.

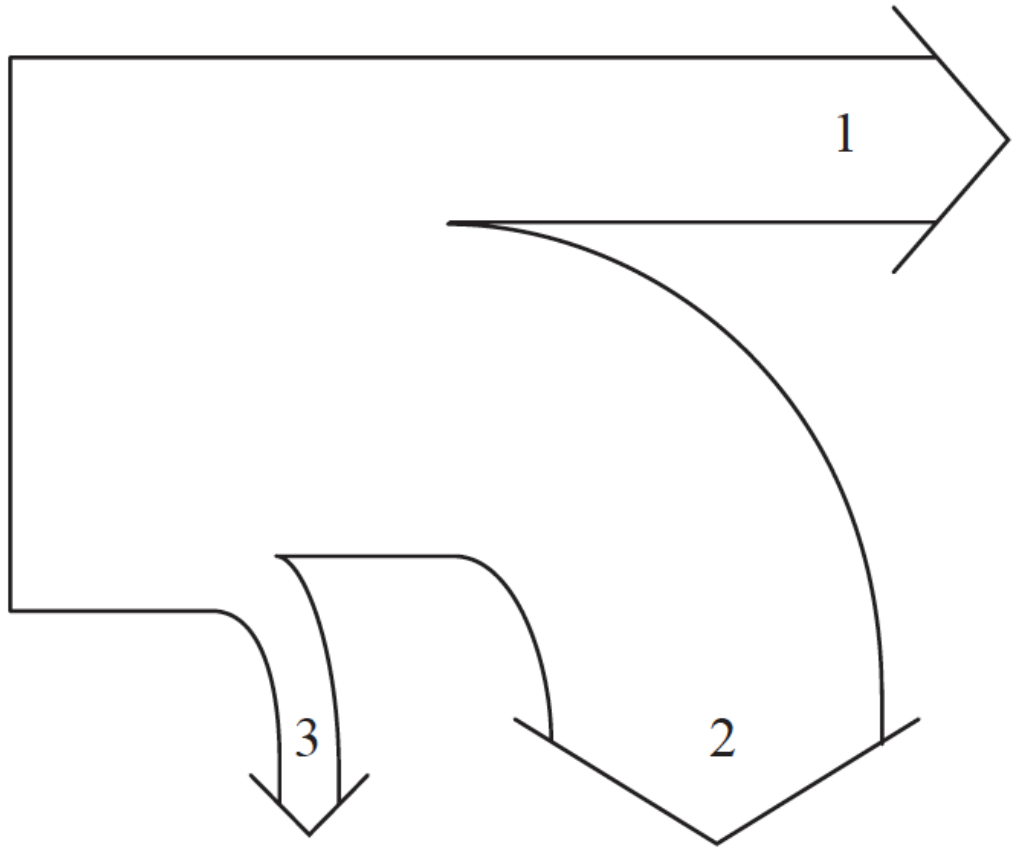
21. Which of the following geographical features has the lowest albedo? *[1 mark]*

A. Polar ice cap
B. Desert
C. Ocean
D. White cliffs

22. Which of the following alternatives would be the most likely to increase the enhanced greenhouse effect? *[1 mark]*

A. Replacement of oil and coal fired power stations with natural gas fired power stations
B. Forests being cut down without being replanted
C. Greater use of combined heating and power systems
D. Use of motor vehicles powered by a combination of electricity and oil products

23. The Sankey diagram of a fossil-fuelled power station is shown below. *[1 mark]*



Which of the following best identifies the thermal energy removed by water and the useful electrical energy output of the station?

	Thermal energy removed	Useful electrical energy output
A.	2	1
B.	2	3
C.	3	1
D.	1	2

24. World energy resources include coal, nuclear fuel and geothermal energy. Which of the following lists these resources in order of energy use in the world? *[1 mark]*

A. nuclear, geothermal, coal

B. nuclear, coal, geothermal

C. coal, geothermal, nuclear

D. coal, nuclear, geothermal

25. Which of the following processes leads to the production of a nucleus of plutonium-239 from a nucleus of uranium-238? *[1 mark]*

A. Neutron capture by uranium nucleus

B. Radioactive decay of uranium nucleus

C. Electron capture by uranium nucleus

D. Nuclear ssion of uranium nucleus

26. Surface X has a temperature T_X and emissivity ε_x. Surface Y has a temperature T_Y and emissivity ε_y. The two surfaces emit radiation at the same rate. *[1 mark]*

What is the ratio $\frac{T_X}{T_Y}$?

A. $\left(\frac{\varepsilon_y}{\varepsilon_x}\right)^{\frac{1}{4}}$

B. $\left(\frac{\varepsilon_x}{\varepsilon_y}\right)^{\frac{1}{4}}$

C. $\left(\frac{\varepsilon_y}{\varepsilon_x}\right)^{4}$

D. $\left(\frac{\varepsilon_x}{\varepsilon_y}\right)^{4}$

27. Large areas of rainforests are cut down and burned every year. The result of these actions is *[1 mark]*

A. reduced albedo.

B. reduced carbon fixation.

C. increased evaporation rate.

D. increased mass of atmospheric methane.

28. World energy resources include coal, nuclear fuel and geothermal energy. Which of the following lists these resources in order of energy use in the world? *[1 mark]*

A. nuclear, geothermal, coal

B. nuclear, coal, geothermal

C. coal, geothermal, nuclear

D. coal, nuclear, geothermal

29. Which of the following describes the role of the atmosphere in the greenhouse effect? *[1 mark]*

A. The atmosphere is transparent to all solar radiation.

B. The atmosphere absorbs infrared radiation from the ground.

C. The atmosphere scatters red light more than blue light.

D. Clouds in the atmosphere prevent absorption of infrared radiation.

This question is in **two** parts. **Part 1** is about power production and global warming. **Part 2** is about electric charge.

Part 1 Power production and global warming

30a. A nuclear power station uses uranium-235 (U-235) as fuel. Outline the *[7 marks]*

(i) processes and energy changes that occur through which thermal energy is produced.

(ii) role of the heat exchanger of the reactor and the turbine in the generation of electrical energy.

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30b. The Drax power station produces an enormous amount of carbon dioxide, a gas classified as a greenhouse gas. *[3 marks]*
Outline, with reference to the vibrational behaviour of molecules of carbon dioxide, what is meant by a greenhouse gas.

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31. A nuclide of deuterium $\left({}_{1}^{2}\mathrm{H}\right)$ and a nuclide of tritium $\left({}_{1}^{3}\mathrm{H}\right)$ undergo nuclear fusion. *[5 marks]*

(i) Each fusion reaction releases 2.8×10^{-12}J of energy. Calculate the rate, in kg s^{-1}, at which tritium must be fused to produce a power output of 250 MW.

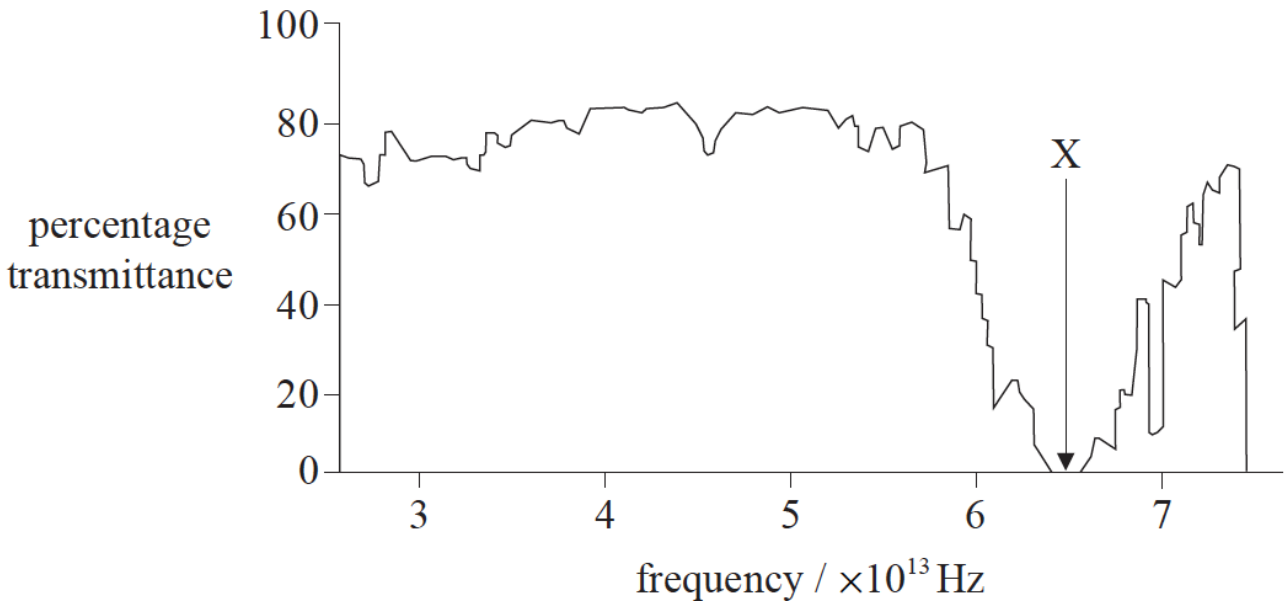
(ii) State **two** problems associated with sustaining this fusion reaction in order to produce energy on a commercial scale.

This question is in **two** parts. **Part 1** is about the greenhouse effect. **Part 2** is about an electric motor.

Part 1 Greenhouse effect

32a. Describe what is meant by the greenhouse effect in the Earth's atmosphere. *[3 marks]*

32b. The graph shows the variation with frequency of the percentage transmittance of electromagnetic waves through water vapour in the atmosphere. *[9 marks]*



(i) Show that the reduction in percentage transmittance labelled X occurs at a wavelength equal to approximately 5 μm.

(ii) Suggest, with reference to resonance, the possible reasons for the sharp reduction in percentage transmittance at a wavelength of 5 μm.

(iii) Explain how the reduction in percentage transmittance, labelled X on the graph opposite, accounts for the greenhouse effect.

(iv) Outline how an increase in the concentration of greenhouse gases in the atmosphere may lead to global warming.

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33. What is the phenomenon that best explains why greenhouse gases absorb infrared radiation? *[1 mark]*

A. Resonance
B. Interference
C. Refraction
D. Diffraction

34. In which of the following places will the albedo be greatest? *[1 mark]*

A. A forest
B. A grassland
C. An ocean
D. A polar ice cap

35. A wind turbine produces a power P when the wind speed is v. Assuming that the efficiency of the turbine is constant, the best estimate for the power produced when the wind speed becomes $2v$ is *[1 mark]*

A. $2P$.
B. $4P$.
C. $6P$.
D. $8P$.

36. A spherical black body has absolute temperature T_1. The surroundings are kept at a lower absolute temperature T_2. What is the net power per unit area lost by the body? *[1 mark]*

A. $\sigma {T_1}^4$
B. $\sigma {T_2}^4$
C. $\sigma \left({T_1}^4 - {T_2}^4\right)$
D. $\sigma \left({T_1}^4 + {T_2}^4\right)$

37. The design of a nuclear power station includes an electrical generator. The function of the generator is to convert *[1 mark]*

A. nuclear energy to kinetic energy.
B. kinetic energy to thermal energy.
C. thermal energy to electrical energy.
D. kinetic energy to electrical energy.

This question is in **two** parts. **Part 1** is about a nuclear reactor. **Part 2** is about simple harmonic oscillations.

Part 1 Nuclear reactor

38a. The reactor produces 24 MW of power. The efficiency of the reactor is 32 %. In the fission of one uranium-235 nucleus 3.2×10^{-11}J of energy is released. *[4 marks]*

Determine the mass of uranium-235 that undergoes fission in one year in this reactor.

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38b. Explain what would happen if the moderator of this reactor were to be removed. *[3 marks]*

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38c. During its normal operation, the following set of reactions takes place in the reactor. *[3 marks]*

$^{1}_{0}\mathrm{n} + ^{238}_{92}\mathrm{U} \rightarrow ^{239}_{92}\mathrm{U}$ (I)

$^{239}_{92}\mathrm{U} \rightarrow ^{239}_{93}\mathrm{Np} + ^{0}_{-1}e + \bar{\nu}$ (II)

$^{239}_{93}\mathrm{Np} \rightarrow ^{239}_{94}\mathrm{Pu} + ^{0}_{-1}e + \bar{\nu}$ (III)

(i) State the name of the process represented by reaction (II).

(ii) Comment on the international implications of the product of these reactions.

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Part 2 Energy balance of the Earth

39a. The intensity of the Sun's radiation at the position of the Earth is approximately 1400 W m^{-2}. *[2 marks]*

Suggest why the average power received per unit area of the Earth is 350 W m^{-2}.

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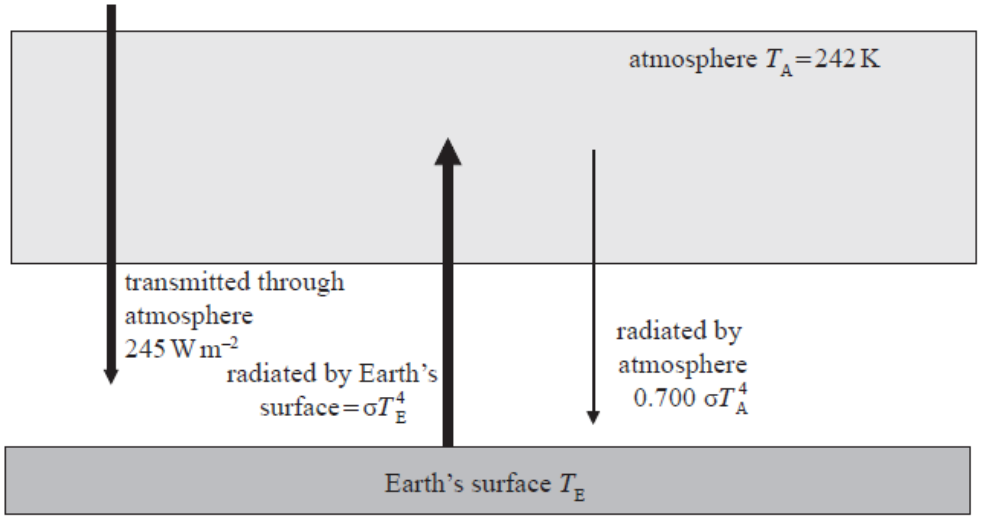
39b. The diagram shows a simplified model of the energy balance of the Earth's surface. The diagram shows radiation entering or leaving the Earth's surface only. *[4 marks]*



The average equilibrium temperature of the Earth's surface is T_E and that of the atmosphere is T_A = 242K.

(i) Using the data from the diagram, state the emissivity of the atmosphere.

(ii) Show that the intensity of the radiation radiated by the atmosphere towards the Earth's surface is $136 Wm^{-2}$.

(iii) By reference to the energy balance of the Earth's surface, calculate T_E.

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39c. (i) Outline a mechanism by which part of the radiation radiated by the Earth's surface is absorbed by greenhouse gases in the atmosphere. *[7 marks]*

(ii) Suggest why the incoming solar radiation is not affected by the mechanism you outlined in (c)(i).

(iii) Carbon dioxide (CO_2) is a greenhouse gas. State **one** source and **one** sink (object that removes CO_2) of this gas.

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