T8-2 *[166 marks]*

1. In nuclear power production, what is one advantage of a nuclear fusion reactor over a nuclear fission reactor? *[1 mark]*

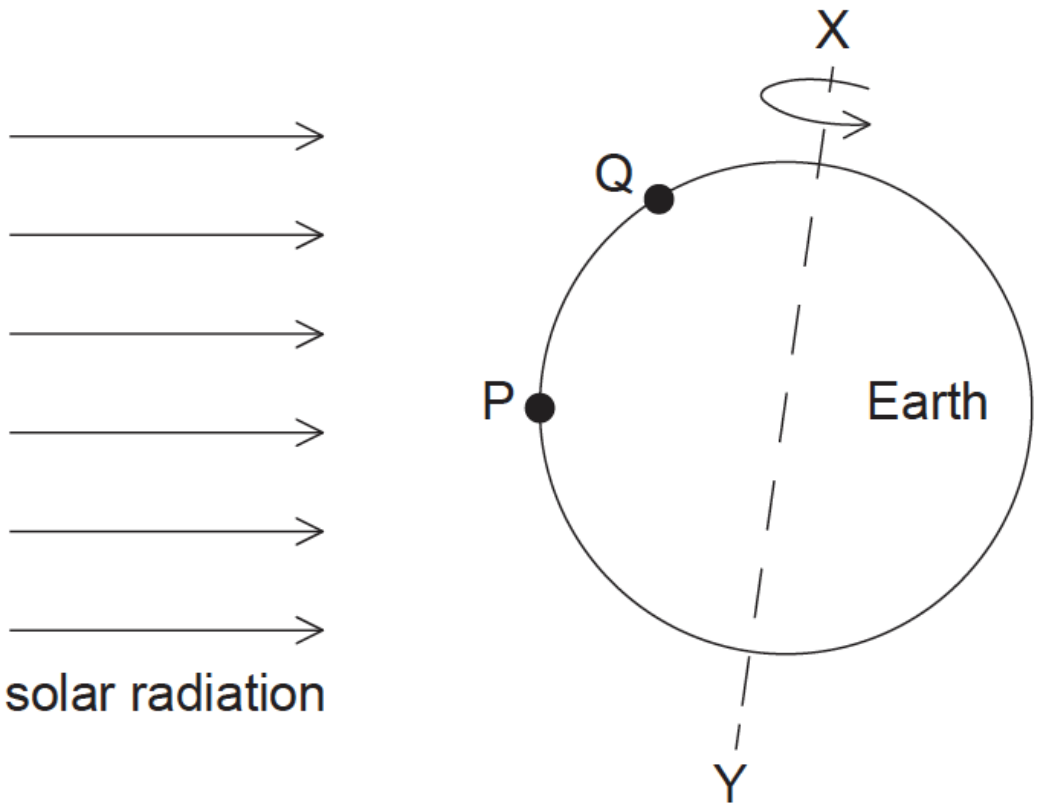
   A. The operating temperature of the fusion reactor is lower.

   B. The nuclear reactants are more easily confined within the core of the fusion reactor.

   C. The disposal of the nuclear waste products from the fusion reactor is more straightforward.

   D. The nuclear fusion reaction is more easily sustained for long periods of time.

2. The Earth rotates about an axis XY, as shown below. *[1 mark]*



   P and Q are positions on the Earth's surface that receive solar radiation from the Sun. Why is the intensity of the solar radiation incident at P significantly greater than the intensity at Q?

   A. The same amount of solar power is spread over a larger surface area at P.

   B. The path length through the Earth's atmosphere of the solar radiation is shorter for P.

   C. The distance travelled by the solar radiation to reach the top of the Earth's atmosphere is shorter for P.

   D. The periodic variations in the solar power radiated from the Sun's surface have more effect at P.

3. Which type of power-production system is most suitable for responding to a sudden high increase in demand for electrical power? *[1 mark]*

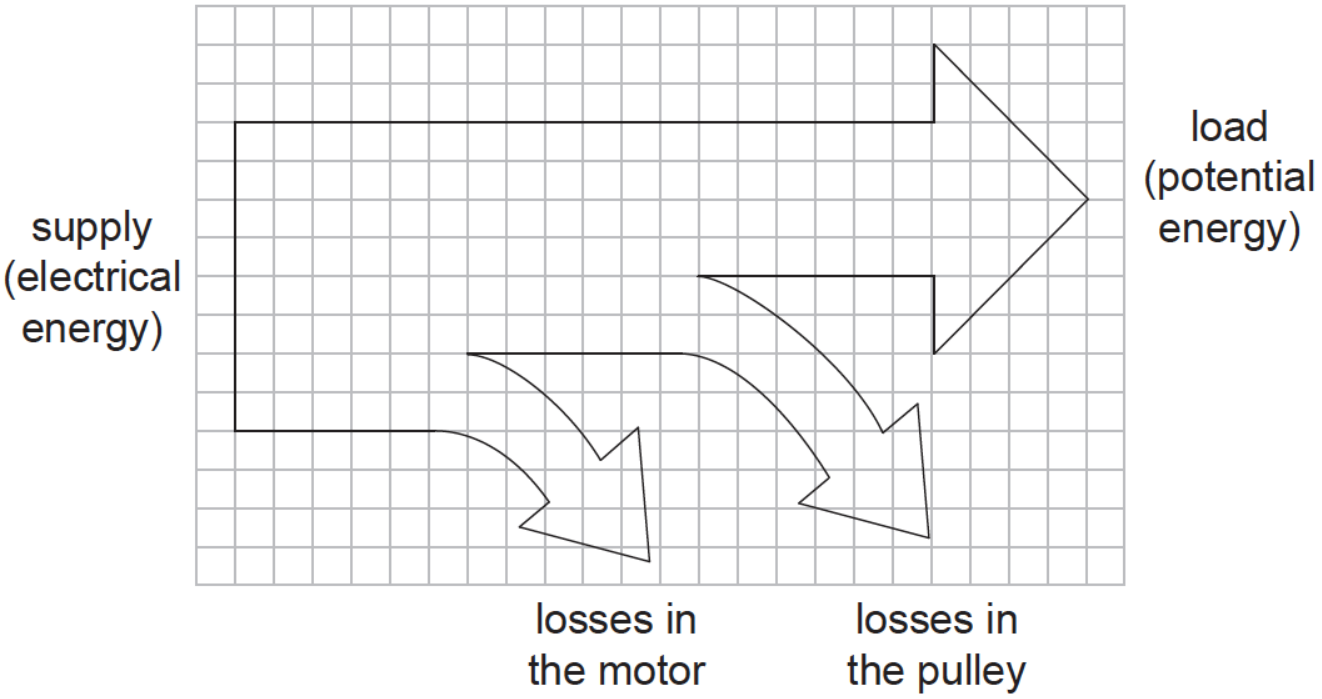
   A. A wind generator

   B. A tidal water storage hydroelectric scheme

   C. An ocean-wave energy converter

   D. A pump storage hydroelectric scheme

4. An electric motor is used to lift a heavy load. The Sankey diagram shows the energy transformations involved in the process. *[1 mark]*



What is the efficiency of the motor?

A. 33%

B. 50%

C. 67%

D. 75%

5. What is the purpose of the moderator in a nuclear power station? *[1 mark]*

A. To absorb fast moving neutrons

B. To slow down fast moving neutrons

C. To initiate a chain reaction

D. To transfer the heat generated to a heat exchanger

6. Methane and carbon dioxide are both greenhouse gases that are believed to cause global warming. The reason for this is that these gases *[1 mark]*

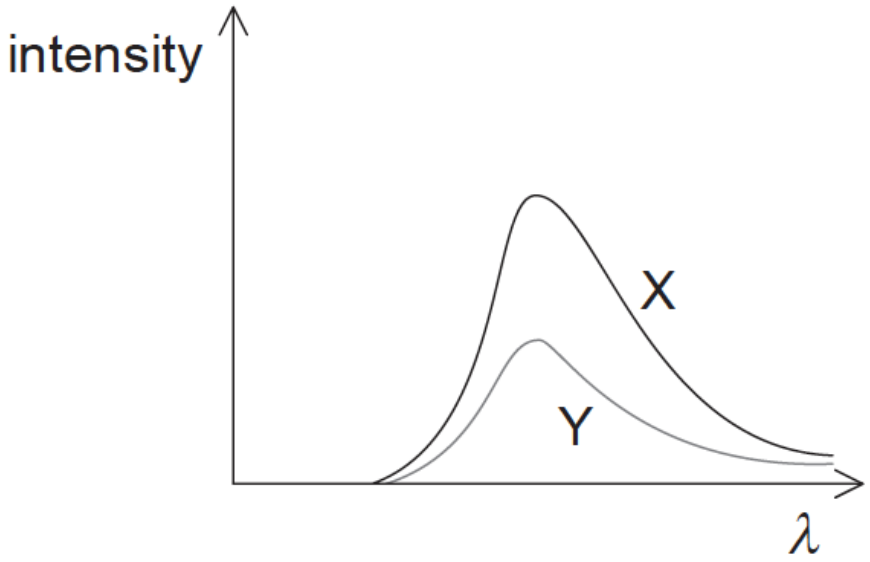
A. absorb incoming radiation from the Sun.

B. transmit the incoming radiation from the Sun and radiation from the Earth.

C. reflect incoming radiation from the Sun.

D. transmit incoming radiation from the Sun and absorb outgoing radiation from the Earth.

7. The graph shows the variation with wavelength of intensity of radiation emitted by two bodies X and Y. X and Y have the same surface area. *[1 mark]*



How do the temperature and the emissivity of X compare with the temperature and the emissivity of Y?

	Temperature	Emissivity
A.	different	different
B.	equal	different
C.	different	equal
D.	equal	equal

8. Methane and carbon dioxide are both greenhouse gases that are believed to cause global warming. The reason for this is that these gases *[1 mark]*

A. absorb incoming radiation from the Sun.

B. transmit the incoming radiation from the Sun and radiation from the Earth.

C. reflect incoming radiation from the Sun.

D. transmit incoming radiation from the Sun and absorb outgoing radiation from the Earth.

This question is about energy sources.

A small island is situated in the Arctic. The islanders require an electricity supply but have no fossil fuels on the island. It is suggested that wind generators should be used in combination with power stations using either oil or nuclear fuel.

9a. Suggest the conditions that would make use of wind generators in combination with either oil or nuclear fuel suitable for the islanders. *[3 marks]*

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9b. Conventional horizontal-axis wind generators have blades of length 4.7m. The average wind speed on the island is $7.0 ms^{-1}$ and the average air density is $1.29 kgm^{-3}$. *[5 marks]*

(i) Deduce the total energy, in GJ, generated by the wind generators in one year.

(ii) Explain why less energy can actually be generated by the wind generators than the value you deduced in (b)(i).

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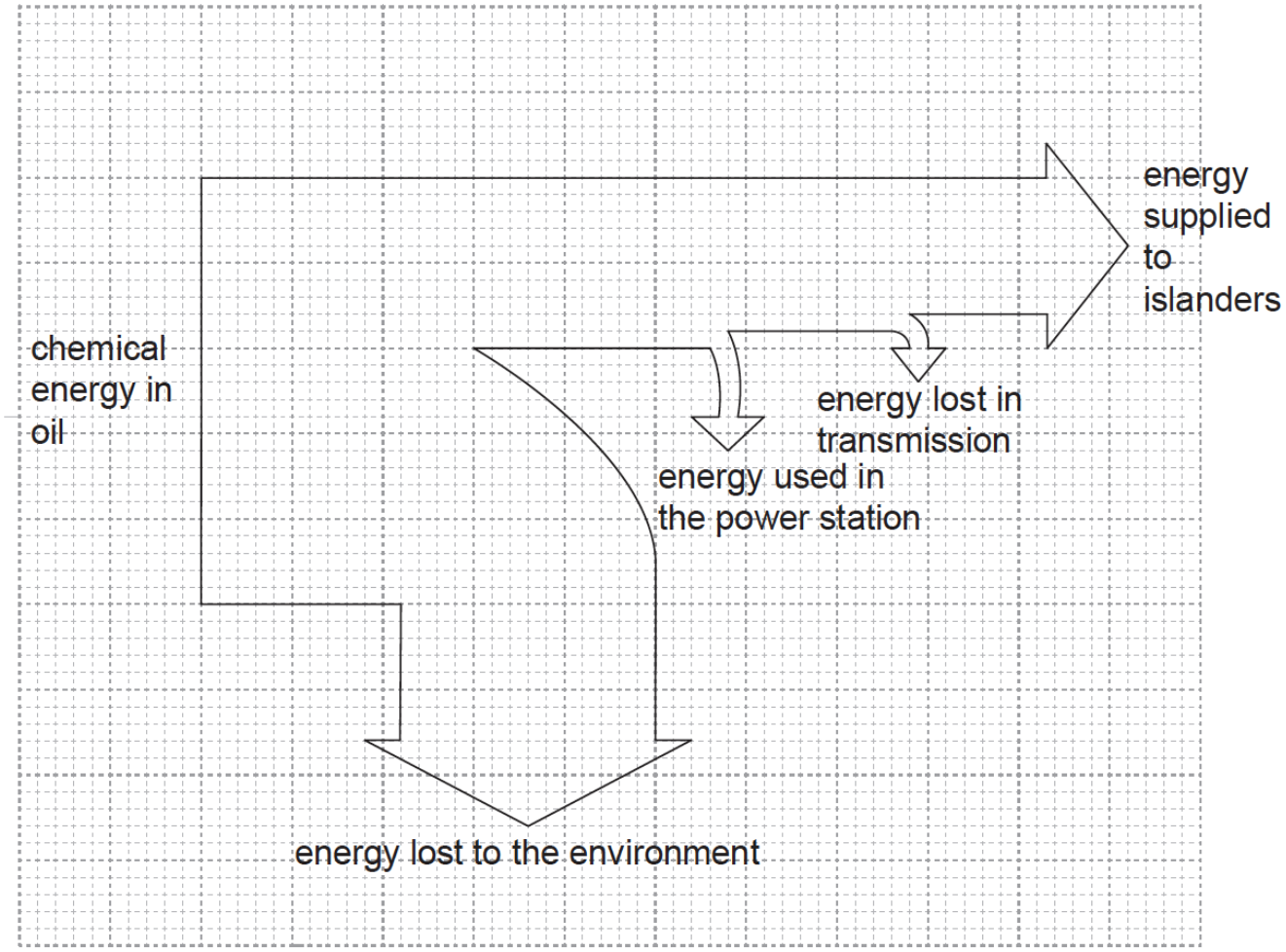
9c. The energy flow diagram (Sankey diagram) below is for an oil-fired power station that the islanders might use. *[4 marks]*



(i) Determine the efficiency of the power station.

(ii) Explain why energy is wasted in the power station.

(iii) The Sankey diagram in (c) indicates that some energy is lost in transmission. Explain how this loss occurs.

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9d. The emissions from the oil-fired power station in (c) are likely to increase global warming by the enhanced greenhouse effect. *[3 marks]*

Outline the mechanism by which greenhouse gases contribute to global warming.

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9e. Nuclear fuel must be enriched before it can be used. Outline why fuel enrichment is needed. *[2 marks]*

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9f. The nuclear equation below shows one of the possible fission reactions in a nuclear reactor. *[3 marks]*

$$\left({}^{1}_{0}\mathrm{n} + {}^{\ldots}_{92}\mathrm{U} \rightarrow {}^{92}_{\ldots}\mathrm{Kr} + {}^{141}_{56}\mathrm{Ba} + \ldots {}^{1}_{0}\mathrm{n}\right)$$

Identify the missing numbers in the equation.

9g. A nuclear reactor requires both control rods and a moderator to operate. Outline, with reference to neutrons, **one** similarity and **two** differences in the function of each of these components. *[3 marks]*

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This question is about energy sources.

A small island is situated in the Arctic. The islanders require an electricity supply but have no fossil fuels on the island. It is suggested that wind generators should be used in combination with power stations using either oil or nuclear fuel.

10a. Suggest the conditions that would make use of wind generators in combination with either oil or nuclear fuel suitable for the islanders. *[3 marks]*

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10b. Conventional horizontal-axis wind generators have blades of length 4.7 m. The average wind speed on the island is 7.0 ms^{-1} and the average air density is 1.29 kg m^{-3}. *[5 marks]*

(i) Deduce the total energy, in GJ, generated by the wind generators in one year.

(ii) Explain why less energy can actually be generated by the wind generators than the value you deduced in (b)(i).

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This question is in two parts. **Part 1** is about renewable energy. **Part 2** is about nuclear energy and radioactivity.

Part 1 Renewable energy

A small coastal community decides to use a wind farm consisting of five identical wind turbines to generate part of its energy. At the proposed site, the average wind speed is $8.5 ms^{-1}$ and the density of air is $1.3 kgm^{-3}$. The maximum power required from the wind farm is 0.75 MW. Each turbine has an efficiency of 30%.

11a. (i) Determine the diameter that will be required for the turbine blades to achieve the maximum power of 0.75 MW. *[8 marks]*

(ii) State **one** reason why, in practice, a diameter larger than your answer to (a)(i) is required.

(iii) Outline why the individual turbines should not be placed close to each other.

(iv) Some members of the community propose that the wind farm should be located at sea rather than on land. Evaluate this proposal.

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11b. Currently, a nearby coal-fired power station generates energy for the community. Less coal will be burnt at the power station if the wind farm is constructed. *[7 marks]*

(i) The energy density of coal is 35 MJ kg^{-1}. Estimate the minimum mass of coal that can be saved every hour when the wind farm is producing its full output.

(ii) One advantage of the reduction in coal consumption is that less carbon dioxide will be released into the atmosphere. State **one** other advantage and **one** disadvantage of constructing the wind farm.

(iii) Suggest the likely effect on the Earth's temperature of a reduction in the concentration of atmospheric greenhouse gases.

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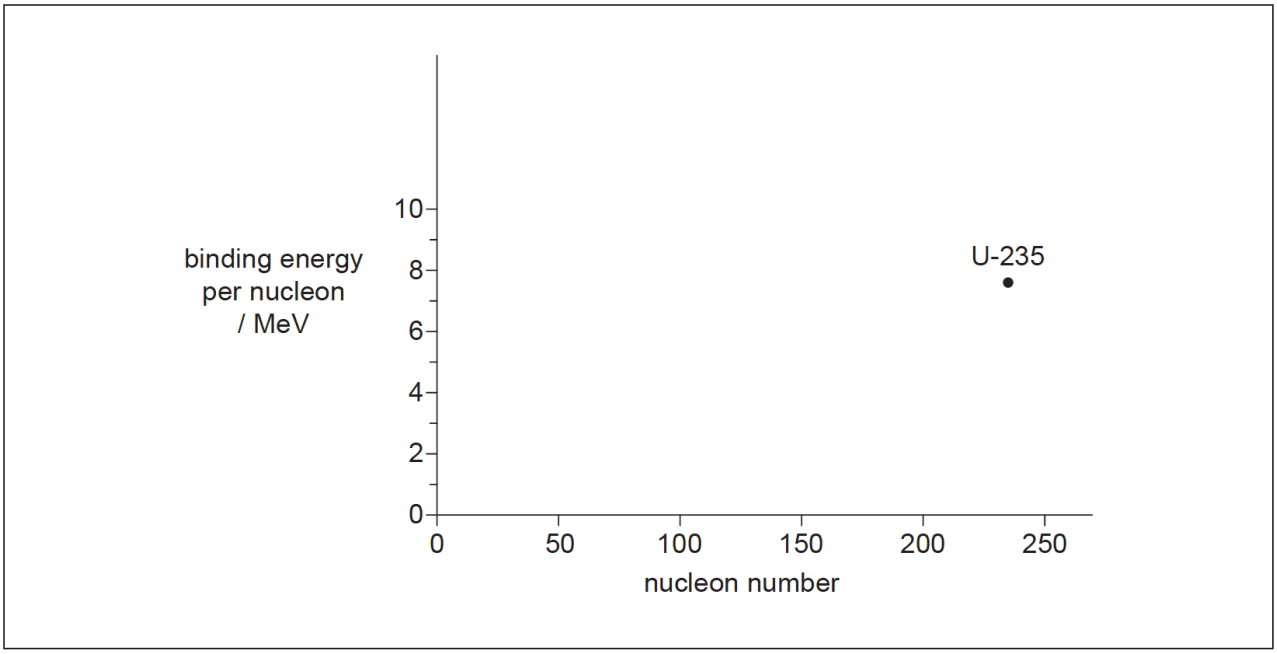
Part 2 Nuclear energy and radioactivity

The graph shows the variation of binding energy per nucleon with nucleon number. The position for uranium-235 (U-235) is shown.



11c. State what is meant by the binding energy of a nucleus. *[1 mark]*

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11d. (i) On the axes, sketch a graph showing the variation of nucleon number with the binding energy per nucleon. *[5 marks]*

(ii) Explain, with reference to your graph, why energy is released during fission of U-235.

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11e. U-235 $\left({}^{235}_{92}\mathrm{U}\right)$ can undergo alpha decay to form an isotope of thorium (Th). *[4 marks]*

(i) State the nuclear equation for this decay.

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

(iii) A sample of rock contains a mass of 5.6 mg of U-235 at the present day. The half-life of U-235 is 7.0×10^{8} years. Calculate the initial mass of the U-235 if the rock sample was formed 2.1×10^{9} years ago.

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12. A natural gas power station has an output of 600 MW and an efficiency of 50%. The mass of natural gas that is burned per second is 20kg. What is the energy density of natural gas? *[1 mark]*

A. 15 $\mathrm{MJkg^{-1}}$
B. 30 $\mathrm{MJkg^{-1}}$
C. 40 $\mathrm{MJkg^{-1}}$
D. 60 $\mathrm{MJkg^{-1}}$

13. A black body has kelvin temperature *T* and surface area *A*. The total power radiated by the body is *P*. What is the new power radiated when *T* is doubled and *A* is halved? *[1 mark]*

A. 4*P*
B. 8*P*
C. 16*P*
D. 32*P*

14. Which of the following best defines non-renewable fuels? *[1 mark]*

A. They produce a lot of degraded energy in comparison with renewable fuels.
B. They have very high energy density but produce greenhouse gases.
C. They cannot be produced again.
D. Their rate of consumption is much greater than the rate at which they are being produced.

15. The average intensity of the solar radiation incident on a planet is 200 W m^{-2}. The albedo of the planet is 0.6. The average temperature of the planet is constant. *[1 mark]*

Which of the following is a correct statement about the intensity of radiation reflected and radiated by the planet?

	Intensity reflected by planet	Intensity radiated by planet
A.	$120\,W\,m^{-2}$	$80\,W\,m^{-2}$
B.	$120\,W\,m^{-2}$	less than $80\,W\,m^{-2}$
C.	$80\,W\,m^{-2}$	$120\,W\,m^{-2}$
D.	$80\,W\,m^{-2}$	less than $120\,W\,m^{-2}$

16. A uranium nuclear fission reactor that attempts to operate without a moderator would *[1 mark]*

A. suffer core meltdown.
B. not require uranium enrichment.
C. produce too much energy.
D. produce very little energy.

17. A black body has absolute temperature *T* and surface area *A*. The intensity of the radiation emitted by the body is *I*. Another black body of surface area 2*A* has absolute temperature 2*T*. What is the intensity of radiation emitted by this second black body? *[1 mark]*

A. 4*I*

B. 8*I*

C. 16*I*

D. 32*I*

18. In the production of energy from nuclear fission, fuel enrichment means increasing, in the fuel rods, the amount of *[1 mark]*

A. uranium-238.

B. plutonium-239.

C. uranium-235.

D. uranium-235 and plutonium-239.

19. In a wind generator, the kinetic energy of the wind cannot be completely converted into mechanical kinetic energy. This is because *[1 mark]*

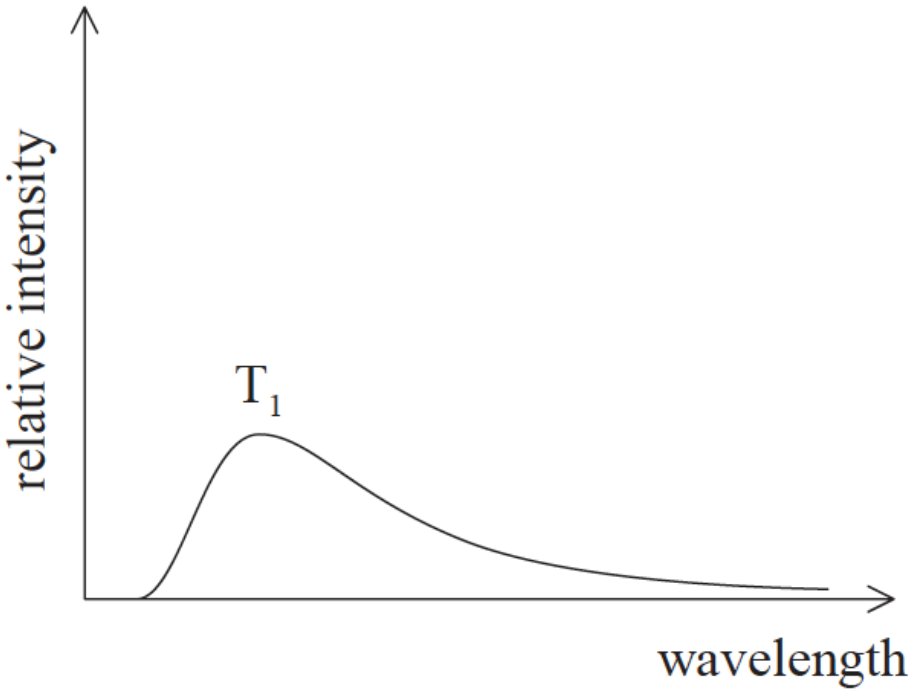
A. momentum is not conserved in the collisions between air molecules and the blades.

B. the density of the air depends on the temperature of the air.

C. the air molecules cannot be brought completely to rest in collisions with the blades.

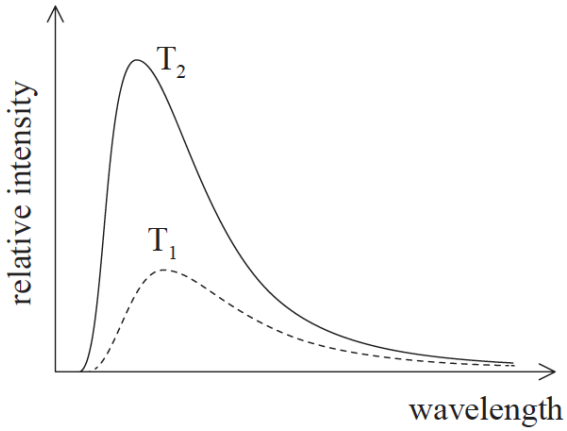
D. the wind speed does not remain constant.

20. The graph shows the emission spectrum for a black body at absolute temperature T_1. *[1 mark]*

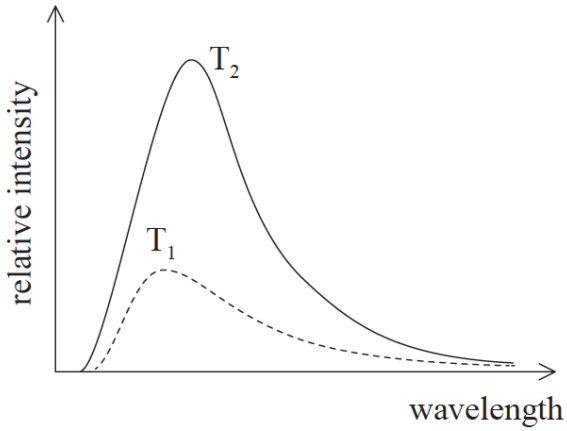


Which graph shows the emission spectrum for the same black body at an absolute temperature T_2 where $T_2 > T_1$? The original graph is shown as a dotted line.

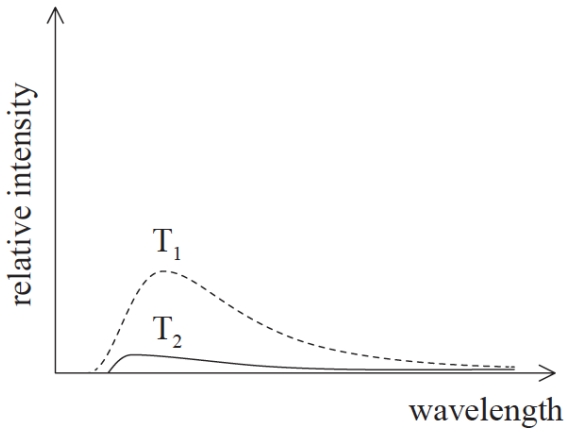
A.



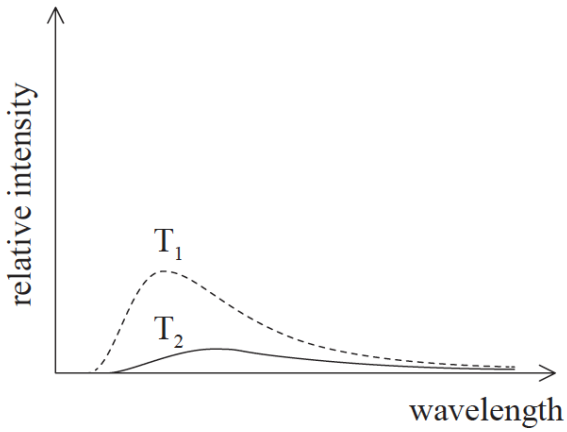
B.



C.



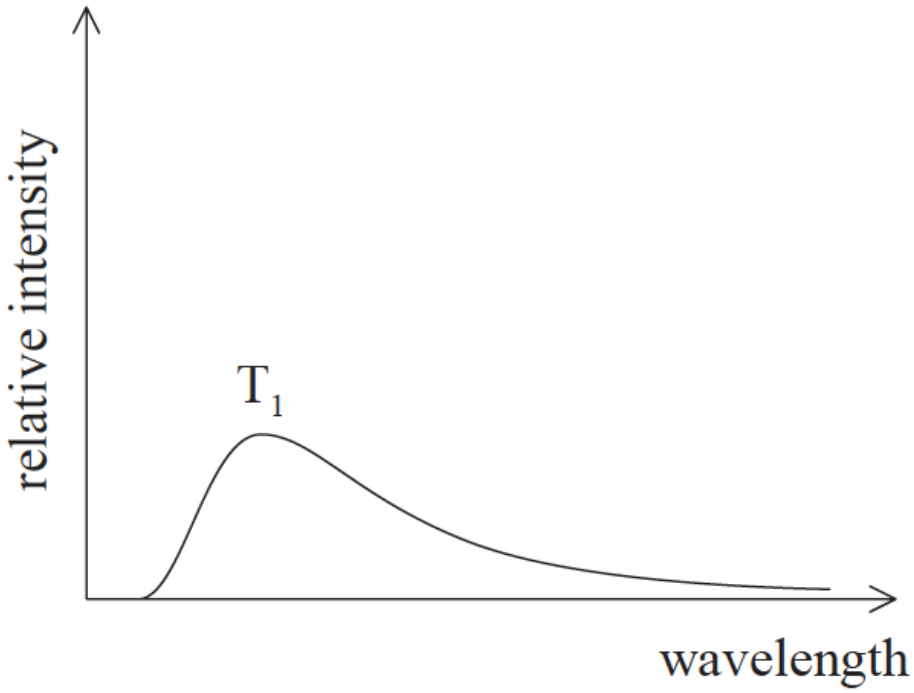
D.



21. Changes in the climate are leading to a reduction in ice cover on Earth. Which of the following describes, for Earth, the change in albedo and the change in the rate of energy absorption? *[1 mark]*

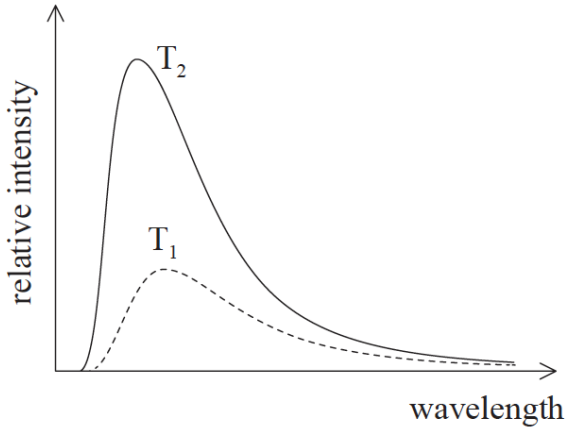
	Change in albedo	Change in rate of energy absorption
A.	decrease	decrease
B.	decrease	increase
C.	increase	increase
D.	increase	decrease

22. The graph shows the emission spectrum for a black body at absolute temperature T_1. *[1 mark]*

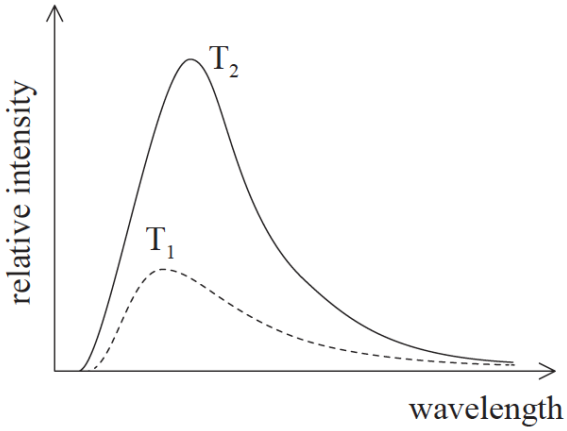


Which graph shows the emission spectrum for the same black body at an absolute temperature T_2 where $T_2 > T_1$? The original graph is shown as a dotted line.

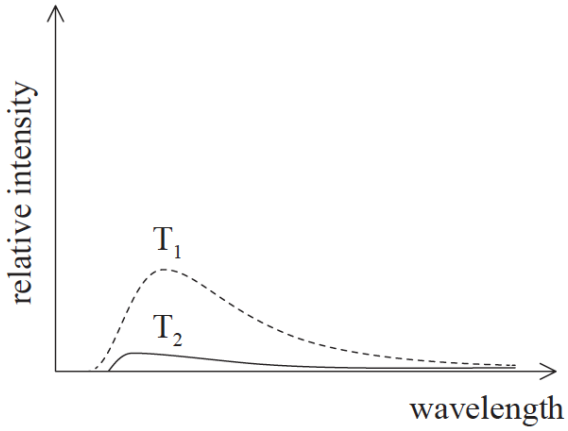
A.



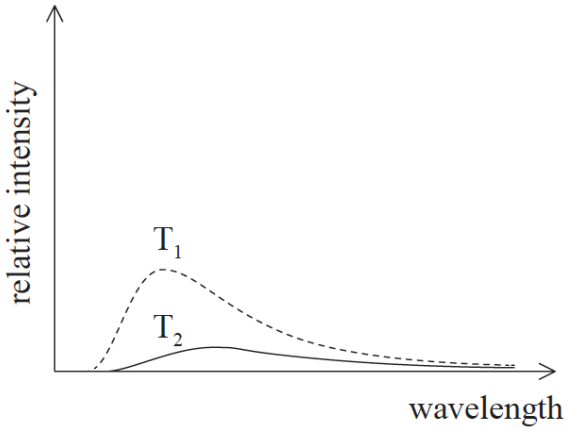
B.



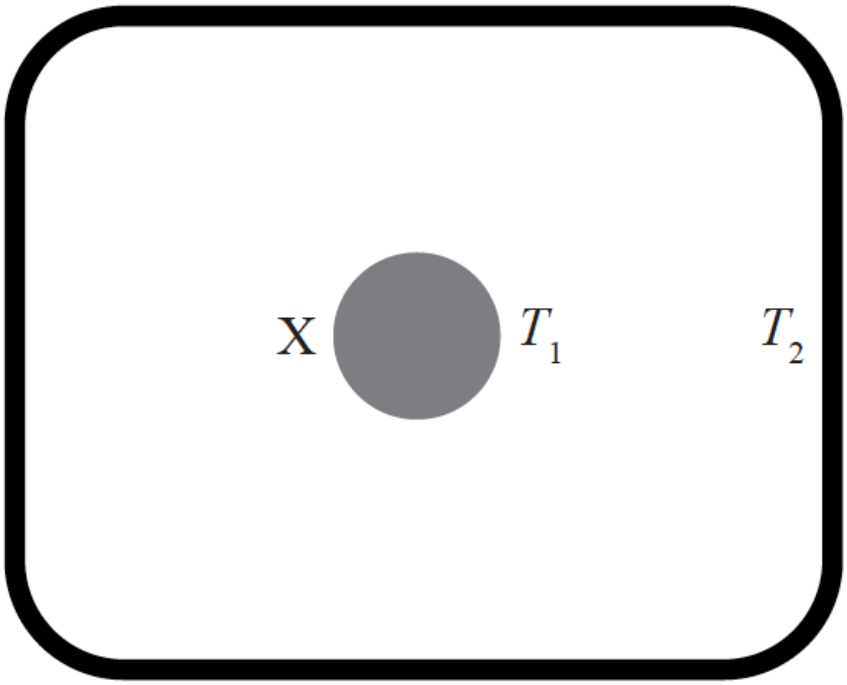
C.



D.



23. A body X of emissivity e is at temperature T_1. X is inside a box whose walls act as a black body of temperature T_2. T_1 is greater than T_2. *[1 mark]*



What is the net intensity of radiation leaving body X?

A. $\sigma {T_1}^4$

B. $e\sigma {T_1}^4$

C. $e\sigma {T_1}^4 - \sigma {T_2}^4$

D. $e\sigma \left({T_1}^4 - {T_2}^4\right)$

24. In a hydroelectric power plant, water of density 10^3kgm^{-3} falls through an average height of 100m. The volume of water flowing through the pipes per second is $10\text{m}^3\text{s}^{-1}$. What is the maximum power generated? *[1 mark]*

A. 10^4W

B. 10^5W

C. 10^6W

D. 10^7W

25. The greenhouse effect can be explained by the fact that the infrared radiation emitted by the surface of Earth *[1 mark]*

A. is absorbed by the atmosphere and then re-radiated in all directions.

B. raises the temperature of the upper atmosphere.

C. is trapped by the upper atmosphere.

D. is absorbed by the atmosphere and then all of it is re-radiated back to the surface of Earth.

26. A black body has absolute temperature T and surface area A. The intensity of the radiation emitted by the body is I. Another black body of surface area $2A$ has absolute temperature $2T$. What is the intensity of radiation emitted by this second black body? *[1 mark]*

A. $4I$

B. $8I$

C. $16I$

D. $32I$

This question is about a tidal power station.

A tidal power station is built for a coastal town. Sea water is stored in a tidal basin behind a dam at high tide and released in a controlled manner between high tides, so that it passes through turbines to generate electricity.

The following data are available.

Difference between high and low tide water level = 1.8m
Density of sea water = $1.1\times10^{3}\text{kgm}^{-3}$
Surface area of basin = $1.4\times10^{5}\text{m}^{2}$
Overall efficiency of power station = 24%

27a. (i) Show that the mass of sea water released between successive high and low tides is about 2.8×10^{8} kg. *[5 marks]*

(ii) Calculate the electrical energy produced between successive high and low tides.

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27b. (i) Identify **one** mechanism through which energy is transferred to the surroundings during the electricity generation process. *[2 marks]*

(ii) State why the energy transferred to the surroundings is said to be degraded.

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This question is in **two** parts. **Part 1** is about solar radiation and the greenhouse effect. **Part 2** is about a mass on a spring.

Part 1 Solar radiation and the greenhouse effect

The following data are available.

Quantity	Symbol	Value
Radius of Sun	R	$7.0\times10^{8}\,\text{m}$
Surface temperature of Sun	T	$5.8\times10^{3}\,\text{K}$
Distance from Sun to Earth	d	$1.5\times10^{11}\,\text{m}$
Stefan-Boltzmann constant	σ	$5.7\times10^{-8}\,\text{W m}^{-2}\,\text{K}^{-4}$

28a. State the Stefan-Boltzmann law for a black body. *[2 marks]*

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28b. Deduce that the solar power incident per unit area at distance d from the Sun is given by *[2 marks]*

$$\frac{\sigma R^2 T^4}{d^2}$$

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28c. Calculate, using the data given, the solar power incident per unit area at distance *d* from the Sun. *[2 marks]*

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28d. State **two** reasons why the solar power incident per unit area at a point on the surface of the Earth is likely to be different from your answer in (c). *[2 marks]*

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28e. The average power absorbed per unit area at the Earth's surface is $240 Wm^{-2}$. By treating the Earth's surface as a black body, show that the average surface temperature of the Earth is approximately 250K. *[2 marks]*

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28f. Explain why the actual surface temperature of the Earth is greater than the value in (e). *[3 marks]*

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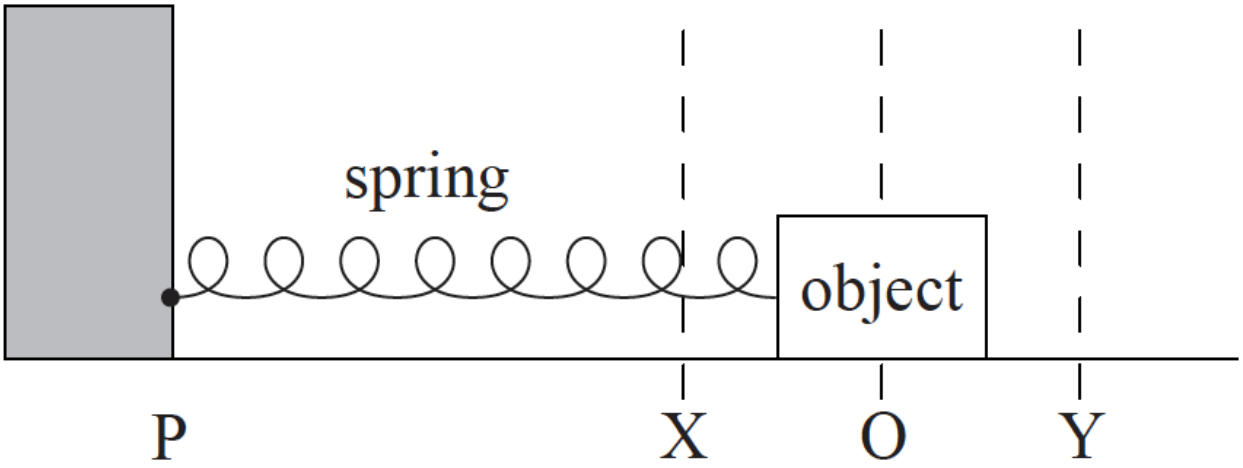
Part 2 A mass on a spring

An object is placed on a frictionless surface and attached to a light horizontal spring.



The other end of the spring is attached to a stationary point P. Air resistance is negligible. The equilibrium position is at O. The object is moved to position Y and released.

28g. Outline the conditions necessary for the object to execute simple harmonic motion. *[2 marks]*

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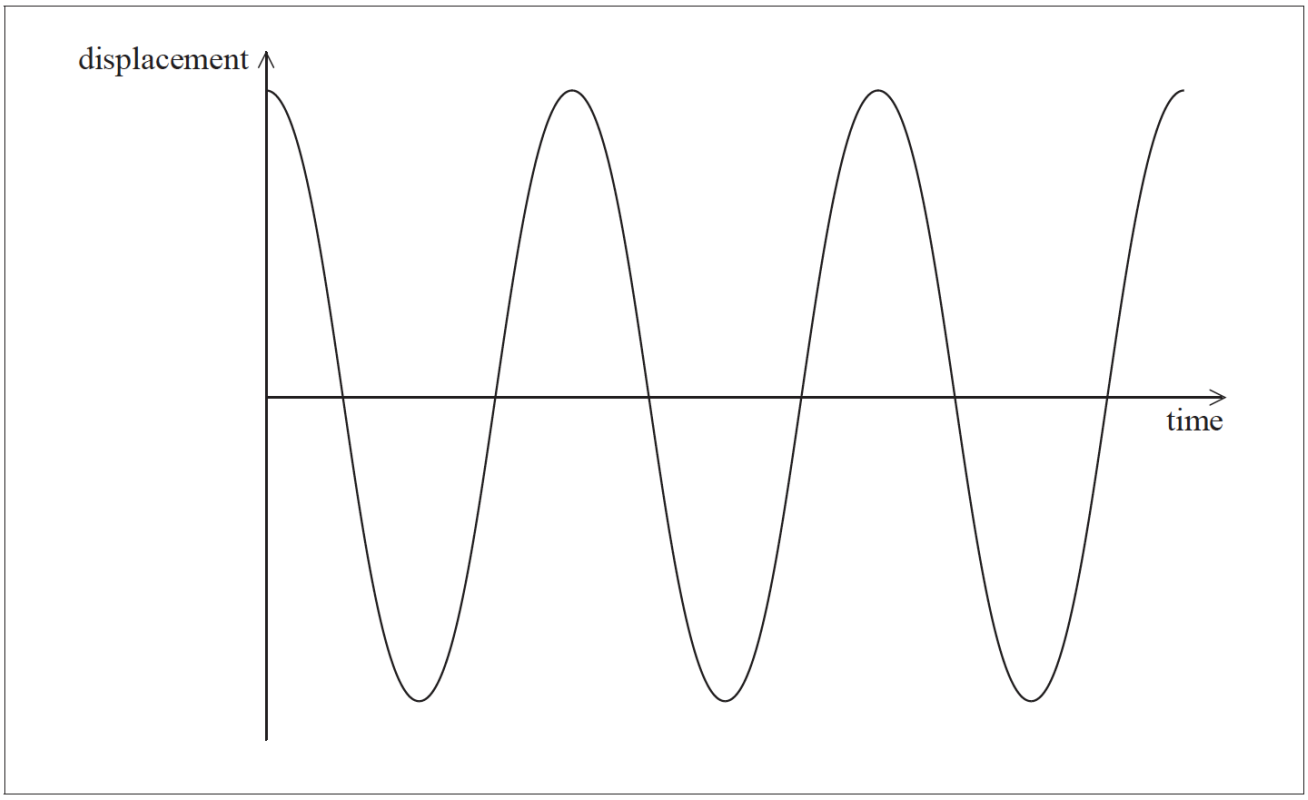
28h. The sketch graph below shows how the displacement of the object from point O varies with time over three time periods. *[4 marks]*



(i) Label with the letter A a point at which the magnitude of the acceleration of the object is a maximum.

(ii) Label with the letter V a point at which the speed of the object is a maximum.

(iii) Sketch on the same axes a graph of how the displacement varies with time if a **small** frictional force acts on the object.

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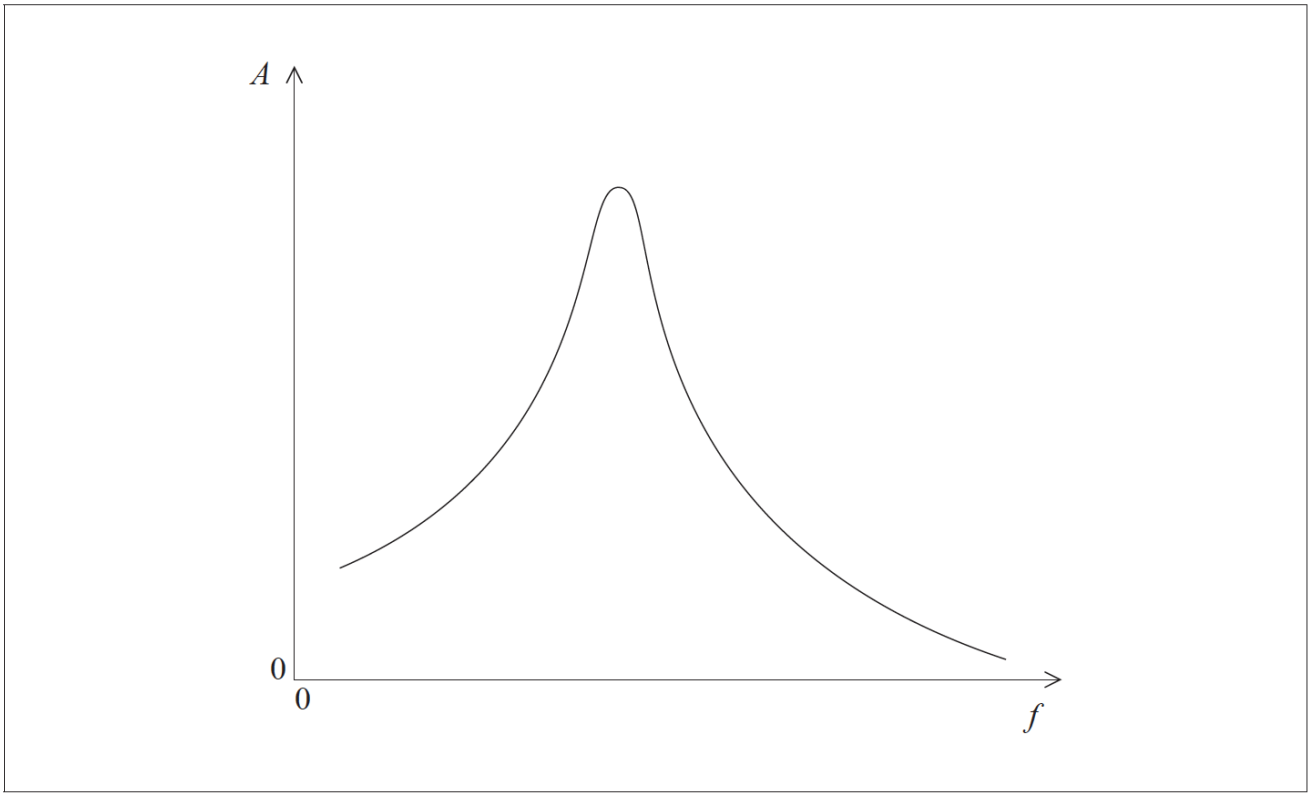
28i. Point P now begins to move from side to side with a small amplitude and at a variable driving frequency *f*. The frictional force is still small. *[4 marks]*

At each value of *f*, the object eventually reaches a constant amplitude *A*.

The graph shows the variation with *f* of *A*.



(i) With reference to resonance and resonant frequency, comment on the shape of the graph.

(ii) On the same axes, draw a graph to show the variation with *f* of *A* when the frictional force acting on the object is increased.

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This question is in **two** parts. **Part 1** is about solar radiation and the greenhouse effect. **Part 2** is about orbital motion.

Part 1 Solar radiation and the greenhouse effect

The following data are available.

Quantity	Symbol	Value
Radius of Sun	R	$7.0\times10^{8}\,\text{m}$
Surface temperature of Sun	T	$5.8\times10^{3}\,\text{K}$
Distance from Sun to Earth	d	$1.5\times10^{11}\,\text{m}$
Stefan-Boltzmann constant	σ	$5.7\times10^{-8}\,\text{W m}^{-2}\,\text{K}^{-4}$

29a. State the Stefan-Boltzmann law for a black body. *[2 marks]*

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29b. Deduce that the solar power incident per unit area at distance d from the Sun is given by $\frac{\sigma R^2 T^4}{d^2}$. *[2 marks]*

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29c. Calculate, using the data given, the solar power incident per unit area at distance *d* from the Sun. *[2 marks]*

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29d. State **two** reasons why the solar power incident per unit area at a point on the surface of the Earth is likely to be different from your answer in (c). *[2 marks]*

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29e. The average power absorbed per unit area at the Earth's surface is $240 Wm^{-2}$. By treating the Earth's surface as a black body, show that the average surface temperature of the Earth is approximately 250K. *[2 marks]*

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29f. Explain why the actual surface temperature of the Earth is greater than the value in (e). *[3 marks]*

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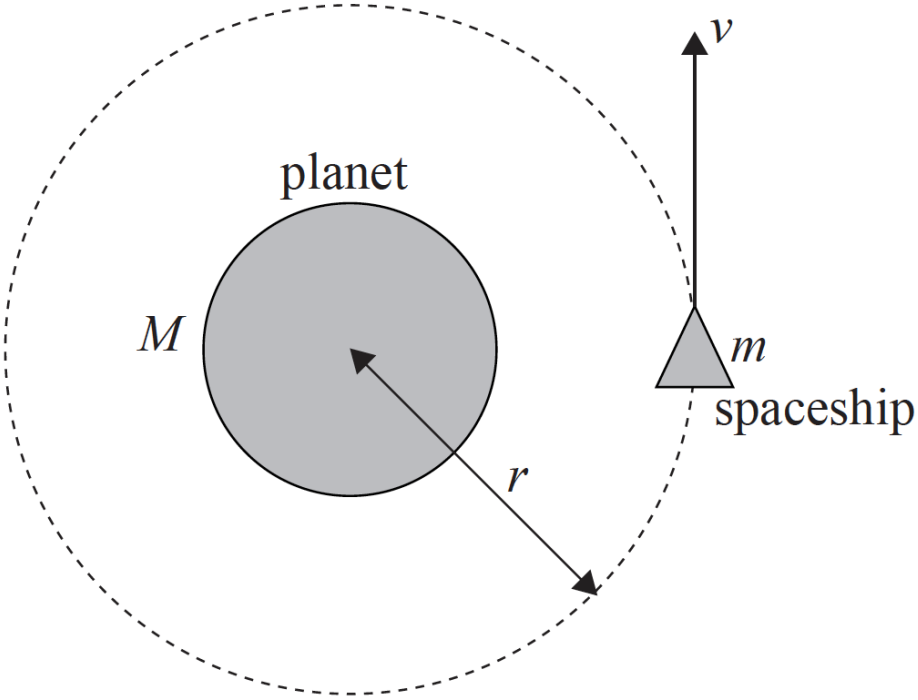
Part 2 Orbital motion

A spaceship of mass *m* is moving at speed *v* in a circular orbit of radius *r* around a planet of mass *M*.



(not to scale)

29g. (i) Identify the force that causes the centripetal acceleration of the spaceship. *[4 marks]*

(ii) Explain why astronauts inside the spaceship would feel "weightless", even though there is a force acting on them.

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29h. Deduce that the speed of the spaceship is $v = \sqrt{\frac{GM}{r}}$. *[2 marks]*

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29i. The table gives equations for the forms of energy of the orbiting spaceship. *[4 marks]*

Form of Energy	Equation
Kinetic	$E_K = \frac{GMm}{2r}$
Gravitational potential	$E_P = -\frac{GMm}{r}$
Total (kinetic + potential)	$E = -\frac{GMm}{2r}$

The spaceship passes through a cloud of gas, so that a small frictional force acts on the spaceship.

(i) State and explain the effect that this force has on the total energy of the spaceship.

(ii) Outline the effect that this force has on the speed of the spaceship.

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30. In the production of electric power, an advantage of using photovoltaic cells rather than fossil fuels is that the photovoltaic cells *[1 mark]*

A. can be effective in any location.
B. can be used continuously.
C. have low initial set-up costs.
D. are more environmentally friendly when in use.

31. What is the main role of the control rods and the main role of the moderator in a thermal fission reactor? *[1 mark]*

	Control Rods	Moderator
A.	decrease neutron speed	decrease neutron speed
B.	decrease neutron speed	absorb neutrons
C.	absorb neutrons	decrease neutron speed
D.	absorb neutrons	absorb neutrons

32. The surface temperature of a black-body emitter is doubled. By what factor does the power emitted by the body increase? *[1 mark]*

A. 32
B. 16
C. 4
D. 2

33. In the production of electric power, an advantage of using photovoltaic cells rather than fossil fuels is that the photovoltaic cells *[1 mark]*

A. can be effective in any location.
B. can be used continuously.
C. have low initial set-up costs.
D. are more environmentally friendly when in use.

34. Which option is not a possible solution to reduce the enhanced greenhouse effect? *[1 mark]*

A. Decommission nuclear power plants
B. Replace the use of coal and oil with natural gas
C. Use combined heating and power (CHP) systems
D. Use hybrid motor vehicles

35. In a nuclear fission reactor, the role of the moderator is to *[1 mark]*

A. absorb neutrons to shut down the reactor.
B. speed neutrons up to increase the rate of energy production.
C. slow neutrons down to decrease the rate of energy production.
D. slow neutrons down to make a chain reaction more likely.

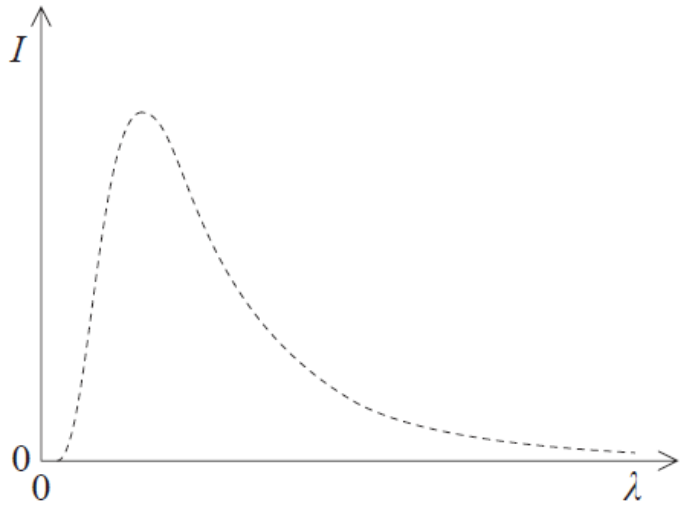
36. The use of which energy source enhances the greenhouse effect the most? *[1 mark]*

A. Wood
B. Coal
C. Wind
D. Tidal

37. Which of the following correctly describes the energy transformation within photovoltaic cells and within solar heating panels? *[1 mark]*

	Photovoltaic cells	Solar heating panels
A.	solar to thermal	solar to electrical
B.	solar to thermal	solar to thermal
C.	solar to electrical	solar to electrical
D.	solar to electrical	solar to thermal

38. The graph shows the spectrum of a black-body. *[1 mark]*



Which graph shows the spectrum of a body of emissivity 0.5 at the same temperature as the black-body? (The original graph is shown dotted.)

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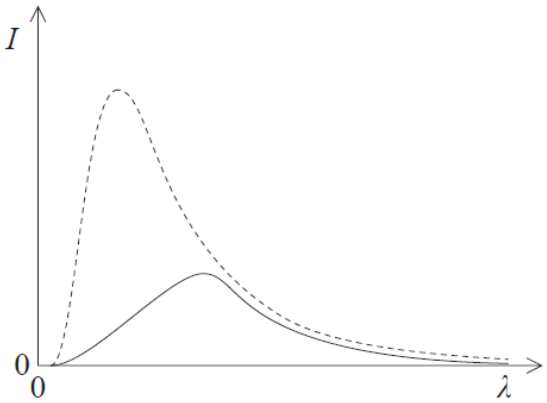
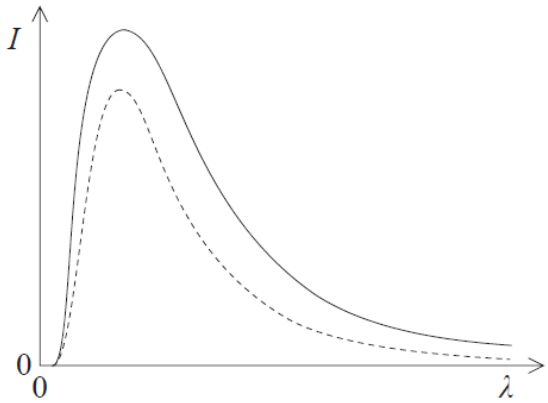
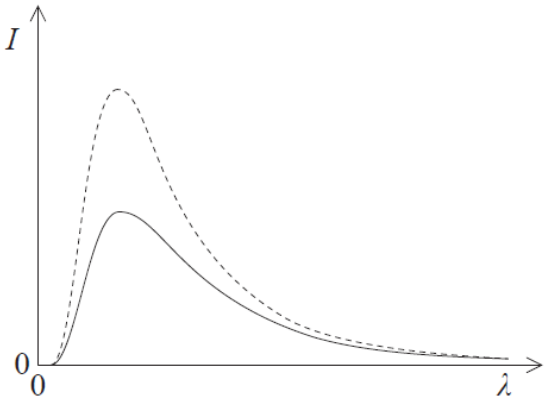


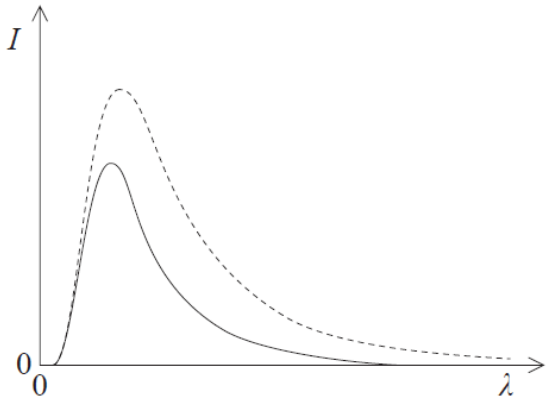
B.



C.



D.



39. A student states that the following factors may lead to global warming *[1 mark]*

I. decreased albedo of the Earth's surface
II. increase in volcanic activity
III. deforestation.

Which of the above statements are correct?

A. I and II only
B. II and III only
C. I and III only
D. I, II and III

This question is about nuclear power production.

40. State **two** advantages of power production using fossil fuels compared to using nuclear fuels. *[2 marks]*

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This question is in **two** parts. **Part 1** is about Newton's laws and momentum. **Part 2** is about the greenhouse effect.

Part 1 Newton's laws and momentum

41a. State the condition for the momentum of a system to be conserved. *[1 mark]*

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41b. A person standing on a frozen pond throws a ball. Air resistance and friction can be considered to be negligible. *[5 marks]*

(i) Outline how Newton's third law and the conservation of momentum apply as the ball is thrown.

(ii) Explain, with reference to Newton's second law, why the horizontal momentum of the ball remains constant whilst the ball is in flight.

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41c. The maximum useful power output of a locomotive engine is 0.75 M W. The maximum speed of the locomotive as it travels along a straight horizontal track is 44 m s^{-1}. Calculate the frictional force acting on the locomotive at this speed. *[2 marks]*

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41d. The locomotive engine in (c) gives a truck X a sharp push such that X moves along a horizontal track and collides with a stationary truck Y. As a result of the collision the two trucks stick together and move off with speed *v*. The following data are available. *[4 marks]*

Mass of truck X=3.7×10^3 kg
Mass of truck Y=6.3×10^3 kg
Speed of X just before collision=4.0 m s^{-1}

(i) Calculate *v*.

(ii) Determine the kinetic energy lost as a result of the collision.

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41e. The trucks X and Y come to rest after travelling a distance of 40 m along the horizontal track. Determine the average frictional force acting on X and Y. *[3 marks]*

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Part 2 The greenhouse effect

41f. Nuclear fuels, unlike fossil fuels, produce no greenhouse gases. *[5 marks]*

(i) Identify **two** greenhouse gases.

(ii) Discuss, with reference to the mechanism of infrared absorption, why the temperature of the Earth's surface would be lower if there were no greenhouse gases present in the atmosphere.

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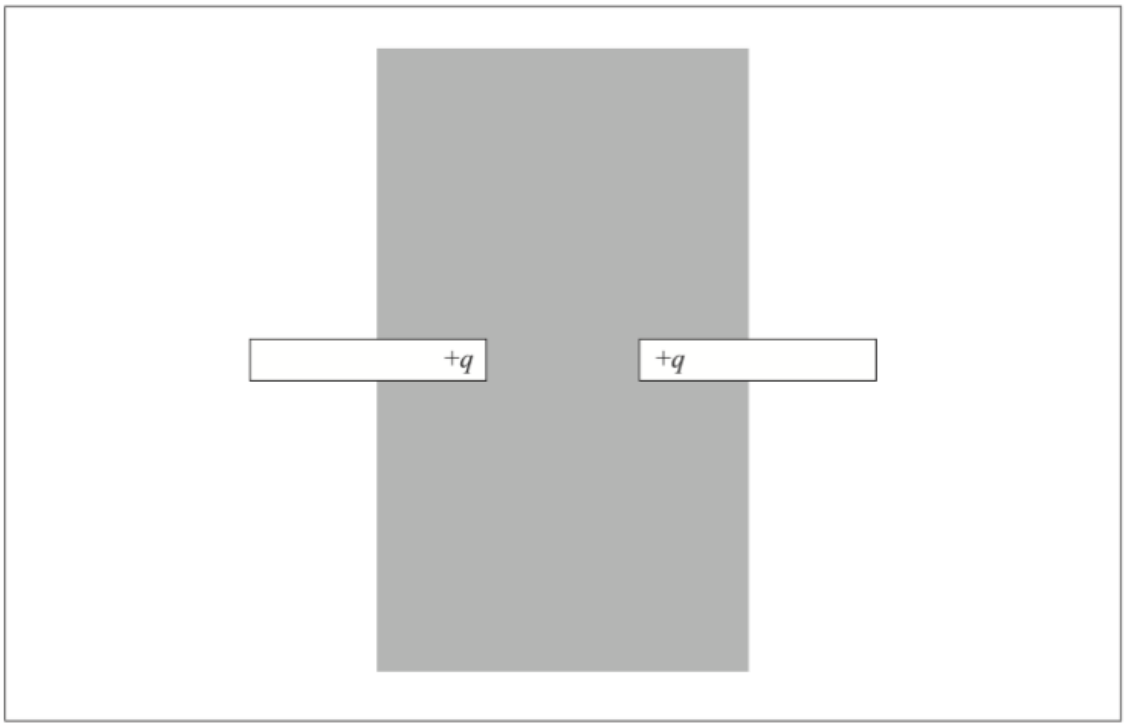
Part 2 Electric charge

42. Two plastic rods each have a positive charge $+q$ situated at one end. The rods are arranged as shown. *[2 marks]*



Assume that the charge at the end of each rod behaves as a point charge. Draw, in the shaded area on the diagram, the electric field pattern due to the two charges.