IB · HL · Physics

3 hours 15 questions

Structured Questions

Greenhouse Effect

Albedo & Emissivity / The Solar Constant / Greenhouse Gases / The Greenhouse Effect / Energy Balance Problems

Easy (5 questions)	/57
Medium (5 questions)	/58
Hard (5 questions)	/41
Total Marks	**/156**

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Easy Questions

1 (a) Environmentalists are considering the Sun's rays and the amount of energy received at the surface of the Earth's atmosphere.

Define the solar constant by placing a tick (✓) in the correct box.

The amount of solar radiation across visible wavelengths that is incident in one second on one square meter at the mean distance of the Earth from the Sun	
The amount of solar radiation across all wavelengths that is incident in one minute on one square meter at the mean distance of the Earth from the Sun	
The amount of solar radiation across all wavelengths that is incident in one second on one square meter at the mean distance of the Earth from the Sun	
The amount of solar radiation across all wavelengths that is incident in one second on one square meter at the maximum distance of the Earth from the Sun	

.....

(1 mark)

(b) The solar constant varies year-round for two main reasons.

State the two reasons by completing the gaps in the sentences below.

(i) The Earth has an _____ orbit around the Sun.

[1]

(ii) The Sun's output _____ during its 11-year sunspot cycle.

[1]

.....

(2 marks)

(c) In an experiment looking at solar energy, the total incident power is 1500 W. The albedo of green grass is 0.25.

Calculate the total scattered power when this light is incident on green grass.

(2 marks)

(d) Emissivity relates objects to a black body.

Choose the correct statements about emissivity by placing a tick (✓) next to them.

Calculations of the emissivity assume that the black body is at the same temperature as the object	
Calculations of the emissivity assume that the black body has smaller dimensions than the object	
For a perfect black body, emissivity is equal to 1	
Emissivity = $\frac{\text{total scattered power}}{\text{total incident power}}$	

(3 marks)

2 (a) Climate change scientists are looking to reduce the number of greenhouse gasses in the atmosphere.

Identify the gases that are greenhouse gases by placing a tick (✓) next to them.

Carbon monoxide	
Carbon dioxide	
Methane	
Sulphur dioxide	

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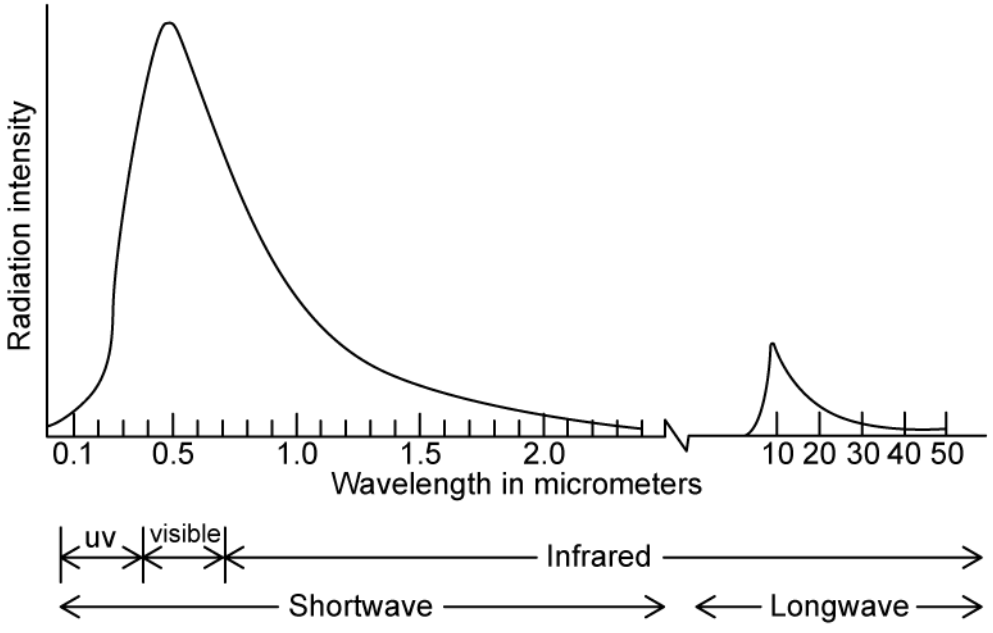
(2 marks)

(b) Greenhouse gases have a natural frequency that falls within one region of the electromagnetic spectrum.

Use the graph to identify this region.



(1 mark)

(c) There are many mechanisms that can increase the effect of global warming.

Use the words below to complete the sentences to explain how the rate of global warming can be increased.

decrease	**insoluble**	**increase**
carbon dioxide	**emissivity**	**heat absorption**
carbon monoxide	**evaporate**	**solubility**
melt	**albedo**	**water vapour**

(i) Ice and snow will melt leading to a _____ in _____ and hence, an increased rate of _____ _____.

.

[1]

(ii) The _____ of carbon dioxide in the sea will decrease, leading to an increase in atmospheric _____ _____ concentration.

.

[1]

(iii) Surface water will _____. This will lead to an increase in atmospheric _____ _____ concentration.

.

[1]

(3 marks)

(d) As a result of small increases in the temperature of the Earth runaway chain reactions can cause catastrophic climate change.

Identify these chain reactions by placing a tick (✓) next to them.

Rise in sea level due to the melting of ice	
Fall in sea level due to the evaporation of seawater	
Heatwaves	
Heavy Flooding	
Tornadoes	

(3 marks)

3 (a) Scientists are investigating the albedo of different materials.

Define the albedo of a planet.

.....

.....

(2 marks)

(b) State the equation for albedo and explain why it has no units.

.....

.....

(2 marks)

(c) The scientists are investigating the albedo of the following materials:

- New concrete
- Green grass
- Desert sand
- Fresh snow
- Ocean ice
- Fresh asphalt
- Bare soil

Identify the correct order, from lowest to highest, of the albedo for these materials.

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(5 marks)

(d) Describe the properties that affect the Earth's albedo.

(3 marks)

4 (a) State the four main greenhouse gases.

(4 marks)

(b) Describe the two types of radiation absorbed by the Earth's atmosphere.

(2 marks)

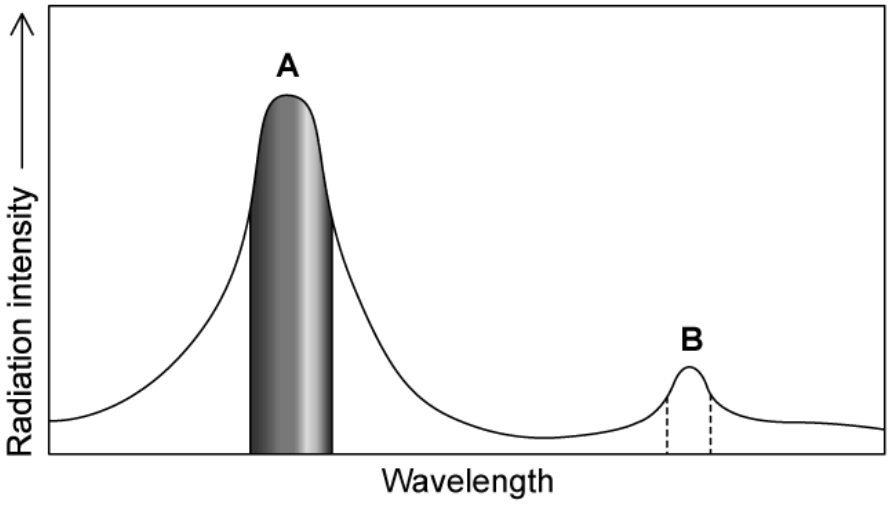
(c) Ozone, carbon dioxide and water vapour are gases found in the atmosphere.

Identify, by placing a tick (✓), the correct statements below.

Statement	Place a tick (✓) here if the statement is correct
Ozone absorbs 100% of the Sun's incoming ultraviolet rays	
Water vapour is the worst absorber of infrared radiation with a wavelength between 0.8 - 35 μm	
Water vapour is one of the most significant contributors to the greenhouse effect	
Ozone is not a significant contributor to the greenhouse effect	
Most of the ultraviolet, infrared and microwave radiation is absorbed by the atmosphere	
The concentration of water vapour in the air increases as the air becomes warmer	
The atmosphere emits a lot of visible radiation	

(4 marks)

(d) The graph shows the radiation intensity against wavelength for both incoming and outgoing solar radiation.



Identify the names of the regions labelled A and B.

(2 marks)

5 (a) Describe the main cause of the enhanced greenhouse effect.

(2 marks)

(b) The following statements outline the resonance model of global warming:

Order	Statements about the resonance model
	The greenhouse gases present in the atmosphere absorb infrared radiation and reflect it towards the Earth's surface
	Visible light is absorbed by the Earth's atmosphere
	Heat energy becomes trapped inside the Earth's atmosphere and accumulates
	The Earth re-radiates radiation as infrared at night
	Incoming radiation from the sun is predominantly ultraviolet and visible
	Some of the re-radiated infrared radiation is absorbed by the Earth's atmosphere and some is reflected into space

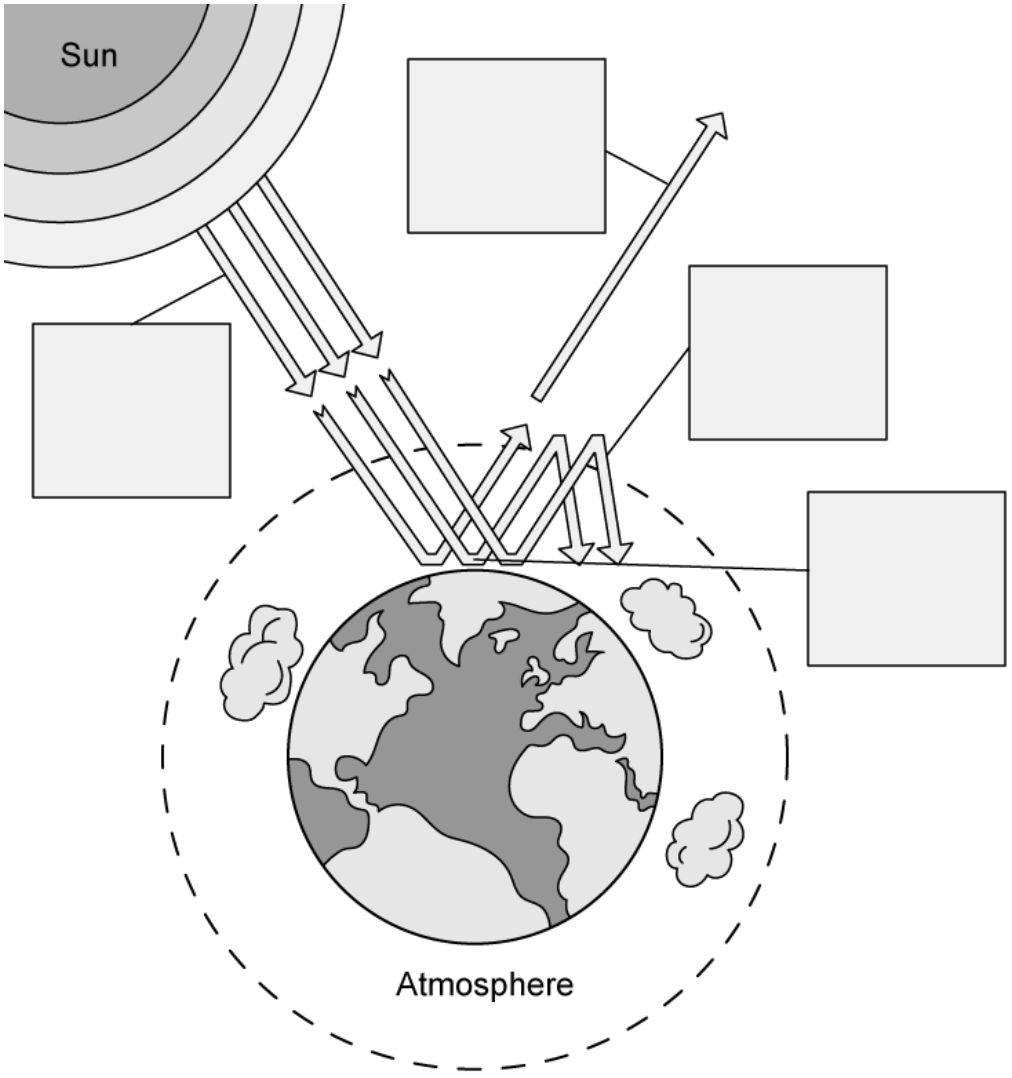
Determine the correct chronological order of the statements by writing the number of the process in the first column of the table.

(6 marks)

(c) The following statements are about the resonance model of global warming.

- Heat is re-emitted in all directions and some becomes trapped within the Earth's atmosphere
- Energy is absorbed by the Earth's surface and re-emitted at longer wavelengths
- The Sun's rays enter the Earth's atmosphere
- Some emitted heat passes through the atmosphere into space

The diagram illustrates the resonance model of global warming.



Complete the diagram by adding the correct statements to the correct labels.

(4 marks)

(d) Describe the main human sources of greenhouse gases.

(4 marks)

Medium Questions

1 (a) Thermal radiation is emitted by all bodies with an absolute temperature. It is often modelled using an idealised 'black body'.

Explain how the temperature of a black body can be estimated based on the frequency of radiation emitted from it.

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(2 marks)

(b) The spectrum of radiation emitted by a sample of glacier ice is examined. The peak frequency of radiation emitted by the ice is 2.25×10^{13} Hz.

Calculate the temperature of the ice in °C.

.....

.....

(2 marks)

(c) The average albedo of fresh snow is 0.9. The average albedo of the glacier ice is 0.25.

(i) Determine the ratio of the amount of light scattered by fresh snow to that of glacier ice.

[2]

(ii) Outline an assumption made in part (i) and give a reason why this assumption may not be correct.

[2]

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(4 marks)

(d) The average intensity of radiation incident on the glacier is expected to change due to global warming.

When the snow melts, it exposes the glacier ice beneath the surface.

Explain how the loss of snow could contribute to global warming.

(3 marks)

2 (a) The intensity of radiation from a source radiating energy at a rate of P follows an inverse square law with the distance, r, from the source.

(i) Derive an expression for intensity of this radiation at distance, r, from the source.

(ii) Outline an assumption made in part (i).

(3 marks)

(b) A planned Mars Rover will be powered using several solar panels each with dimensions of 2800 × 5900 mm. The equipment is tested on Earth at a point where the albedo of Earth's atmosphere is 0.310.

The radiant power of the Sun is 3.90×10^{26} W and the average radius of Earth's orbit around the Sun is 1.50×10^{11} m.

Determine the power, in kW, incident on a single solar heating panel being tested on Earth.

Assume that the Sun is at its highest point and the light from the Sun is normally incident on the panel.

(4 marks)

(c) An astronomer uses the following data for a simple climatic model of Mars without an atmosphere:

Orbital radius between Mars and the Sun = 2.3×10^{11} m

Absorbed solar radiation = 493 W m^{-2}

Determine the average albedo for Mars that is to be used in the modelling.

.....

.....

(2 marks)

(d) Determine the ratio $\frac{P_M}{P_E}$

Where P_M is the power of solar radiation incident on the solar panel on Mars and P_E is the power of solar radiation incident on the solar panel on Earth.

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.....

(2 marks)

3 (a) Scientists are studying the planet Venus.

Define the solar constant of Venus.

(2 marks)

(b) Venus is in orbit 108×10^9 m from the Sun. The Sun has a power output of 4×10^{26} W.

Calculate the solar constant of Venus to two significant figures.

(3 marks)

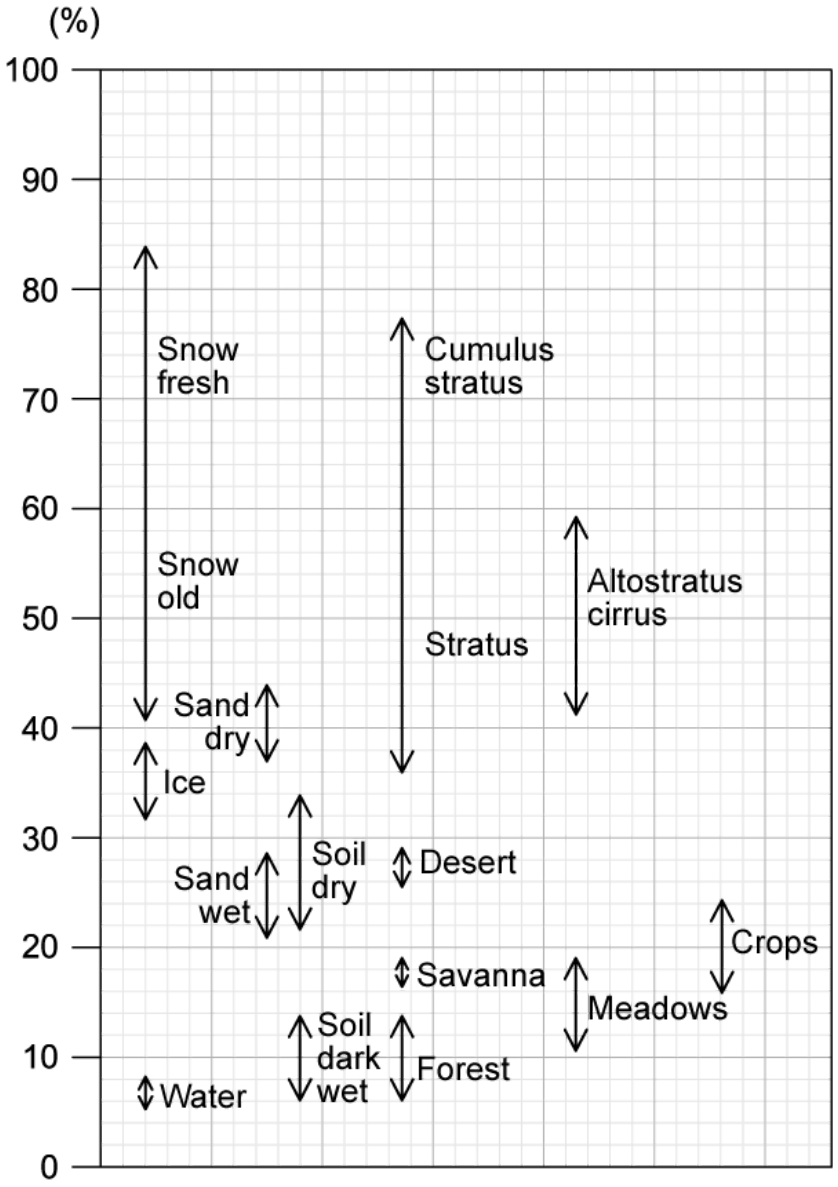
(c) Explain why the solar constant is different for all planets in the solar system.

(2 marks)

(d) Explain why the incident radiative power on the upper atmosphere of Venus is 675 W m^{-2}.

(3 marks)

4 (a) The graph shows the range of albedos for different materials on Earth.



Identify the materials or values of the following albedos:

(i) The material(s) with the greatest range.

[1]

(ii) The most common albedo value found on Earth.

[2]

(iii) The average albedo for ice.

[1]

(iv) The material likely to reflect the most energy from the Sun.

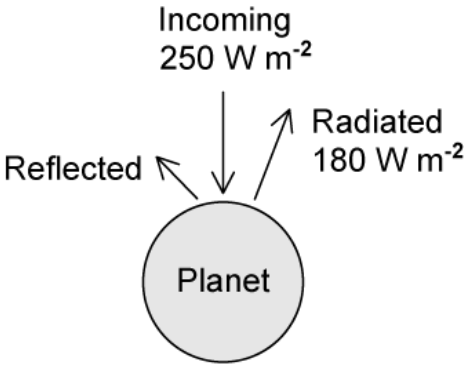
[1]

(5 marks)

(b) Determine the ratio $\frac{\text{energy absorbed by ice}}{\text{energy reflected by ice}}$.

(2 marks)

(c) A scientist is investigating the climate model of a planet where the incoming radiation intensity is 250 W m^{-2} and the radiated radiation intensity is 180 W m^{-2}. The temperature of the planet remains constant.



Calculate the reflected radiation intensity of the planet.

(2 marks)

(d) Calculate the albedo of the planet in part (c).

.....

.....

(2 marks)

5 (a) Compare and contrast the roles of carbon dioxide and water vapour in the greenhouse effect.

(3 marks)

(b) The intensity of solar radiation incident at the top of the Earth's atmosphere is 1450 W m^{-2}. Assume that 55% of the incoming solar energy reaches the Earth's surface and 45% of the incident energy is absorbed by a person sunbathing. The person is 1.5 m tall and an average of 30 cm wide.

Determine the amount of solar energy absorbed by the person sunbathing for 150 minutes.

(5 marks)

(c) The person sunbathing wishes to absorb less solar energy from the sun.

Explain in terms of albedo why getting in the sea will make him cooler.

(4 marks)

(d) The man's body is now lying horizontal but fully submerged in the seawater. The scattered solar radiation from his body under the water is 9.3 W.

Calculate the albedo of the seawater.

(3 marks)

Hard Questions

1 (a) Outline how the temperature of a black body can be estimated.

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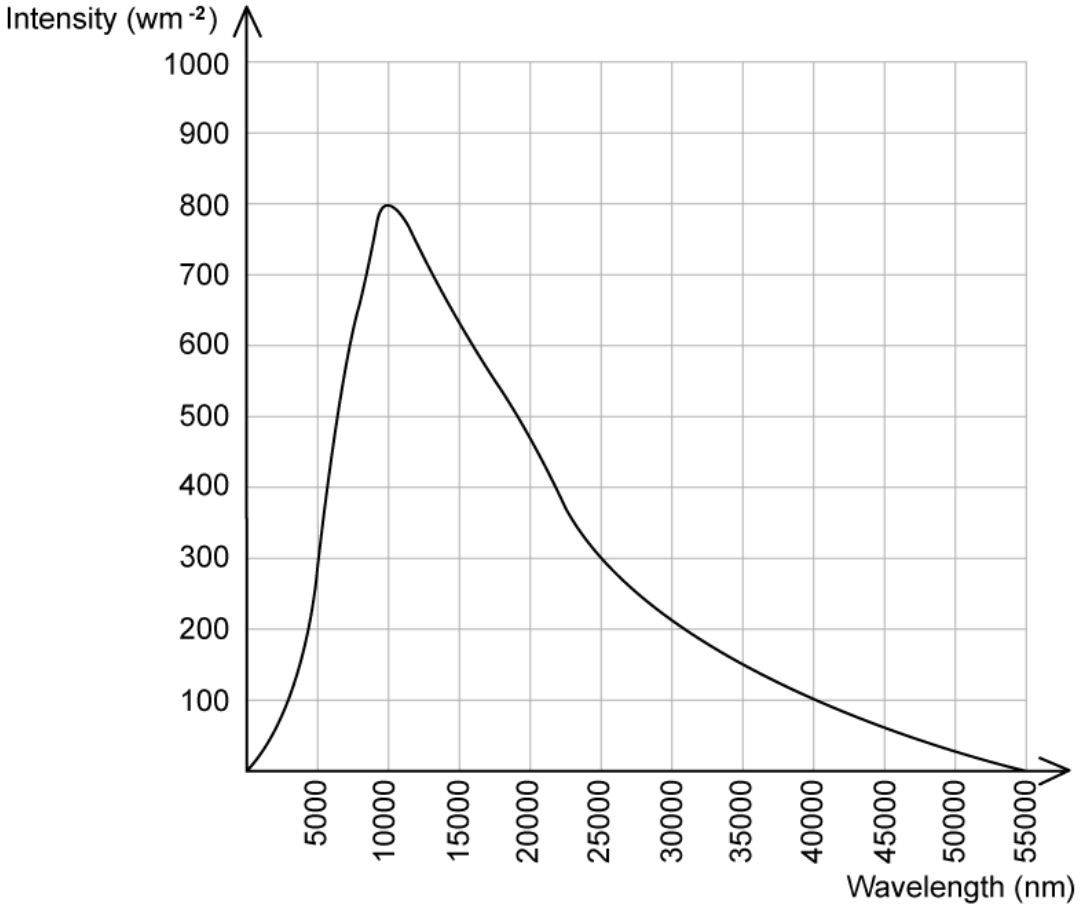
(2 marks)

(b) The spectrum of radiation emitted by a sample of glacier ice is examined. The variation of the intensity with wavelength is plotted as shown on the graph below.



Calculate the temperature of the radiation emitted by the ice.

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(2 marks)

(c) Suggest whether fresh snow or ocean ice has a higher albedo. Give a reason for your answer.

(2 marks)

(d) Suggest why the values of the intensity of incident radiation upon the Earth's surface are expected to rise as the climate changes.

(5 marks)

2 (a) One possible model of climate change is that the Earth will eventually have no atmosphere.

(i) Draw a suitable diagram to illustrate this model.

[1]

(ii) Evaluate this model.

[2]

(3 marks)

(b) Obtain an expression for the average intensity of light at the surface of the Earth in terms of albedo and the solar constant.

(4 marks)

3 (a) A team of engineers are designing solar panels to power a Mars Rover on the surface of Mars.

Derive an expression for the intensity of radiation at a distance, *r* emitted from a point source.

(2 marks)

(b) A planned Mars Rover will be powered using several solar panels each with dimensions of 2700 × 4900 mm. The equipment is tested on Earth at a point where the albedo of Earth's atmosphere is 0.390. The following additional information is available:

- The radiant power of the Sun is 3.90×10^{26} W
- The average radius of Earth's orbit around the Sun is 1.50×10^{11} m
- Orbital radius between Mars and the Sun = 2.3×10^{11} m
- Absorbed solar radiation on Mars = 493 W m^{-2}

Determine the ratio $\frac{P_M}{P_E}$.

Where P_M is the power of solar radiation incident on the solar panel on Mars and P_E is the power of solar radiation incident on the solar panel on Earth.

Assume that the Sun is at its highest point and the light from the Sun is normally incident on the panel.

(6 marks)

4 (a) An industrial kiln is used for 'firing' ceramic and pottery items at very high temperatures.

The kiln emits electromagnetic radiation of peak wavelength, $\lambda_{max} = 3.75 \times 10^{-6}$ m and has a surface area of 150 m^2.

Calculate the energy radiated per second.

(4 marks)

(b) Justify each of the following safety features in the kiln by referring to thermal energy transfer.

(i) The installation of chimneys and vents.

[1]

(ii) Air space created below and around the kiln.

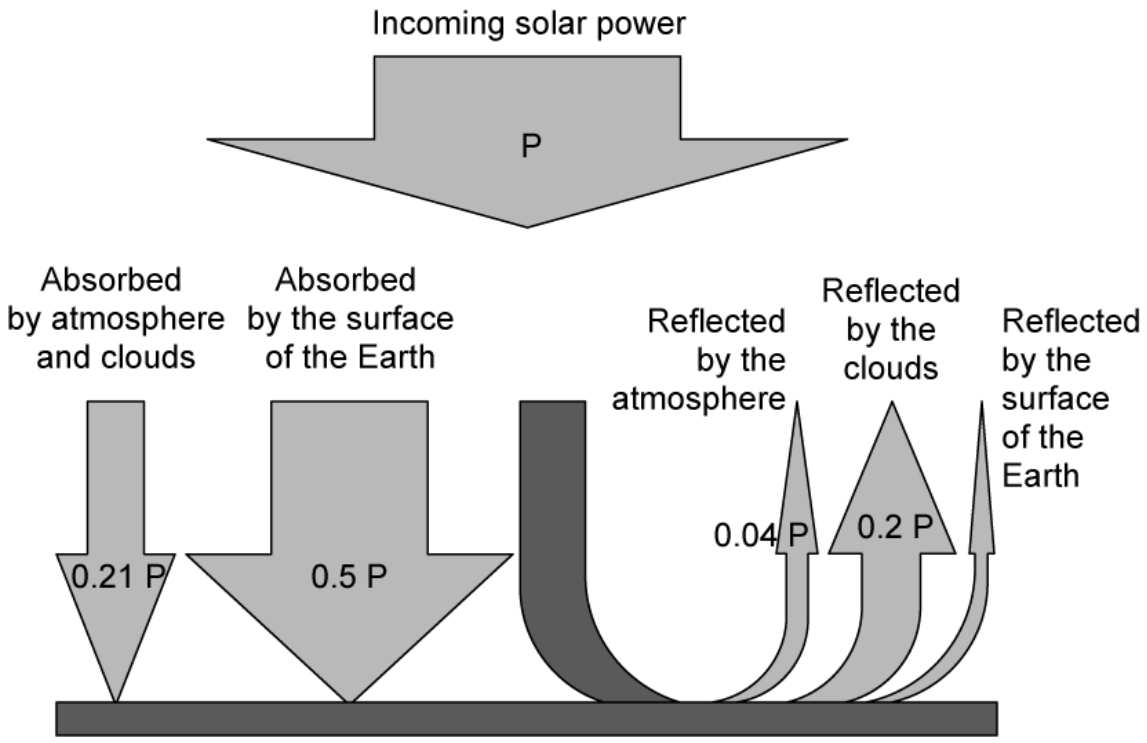
[1]

(iii) Shiny reflective surfaces fixed around the inside of the exterior walls.

[1]

(3 marks)

5 (a) The diagram shows a simple climate model for the Earth. The incoming solar power is *P* W and most of the subsequent absorbed and reflected solar powers are indicated on the diagram. Some of the information is missing.



Determine the average albedo of the Earth predicted by this model.

(2 marks)

(b) The power of the Sun's radiation at the position of the Earth is 4.16×10^{18} W. The radius of the Earth is 6.0×10^{6} m and the temperature of the Earth's surface is 15°.

Determine the emissivity of the surface of the Earth.

(3 marks)

(c) The Earth's atmosphere reaches 1.0×10^7 m above the Earth's surface and its emissivity is 0.81.

Calculate the temperature of the Earth's atmosphere in degrees celsius.

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(3 marks)