

Greenhouse Effect [39 marks]

The ratio $\frac{\text{distance of Mars from the Sun}}{\text{distance of Earth from the Sun}} = 1.5$.

1a. Show that the intensity of solar radiation at the orbit of Mars is about 600 W m^{-2} . [2 marks]

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1b. Determine, in K, the mean surface temperature of Mars. Assume that Mars acts as a black body. [2 marks]

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- 1c. The atmosphere of Mars is composed mainly of carbon dioxide and has a pressure less than 1 % of that on the Earth. Outline why the greenhouse effect is not significant on Mars. [2 marks]

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The Sun has a radius of $7.0 \times 10^8 \text{ m}$ and is a distance $1.5 \times 10^{11} \text{ m}$ from Earth. The surface temperature of the Sun is 5800 K.

- 2a. Show that the intensity of the solar radiation incident on the upper atmosphere of the Earth is approximately 1400 W m^{-2} . [2 marks]

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- 2b. The albedo of the atmosphere is 0.30. Deduce that the average intensity over the entire surface of the Earth is 245 W m^{-2} . [2 marks]

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- 2c. Estimate the average surface temperature of the Earth. [2 marks]

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3. The average surface temperature of the Earth is actually 288 K. [2 marks]

Suggest how the greenhouse effect helps explain the difference between the temperature estimated in (c) and the actual temperature of the Earth.

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

Part 1 Greenhouse effect

- 4a. Describe what is meant by the greenhouse effect in the Earth's atmosphere. [3 marks]

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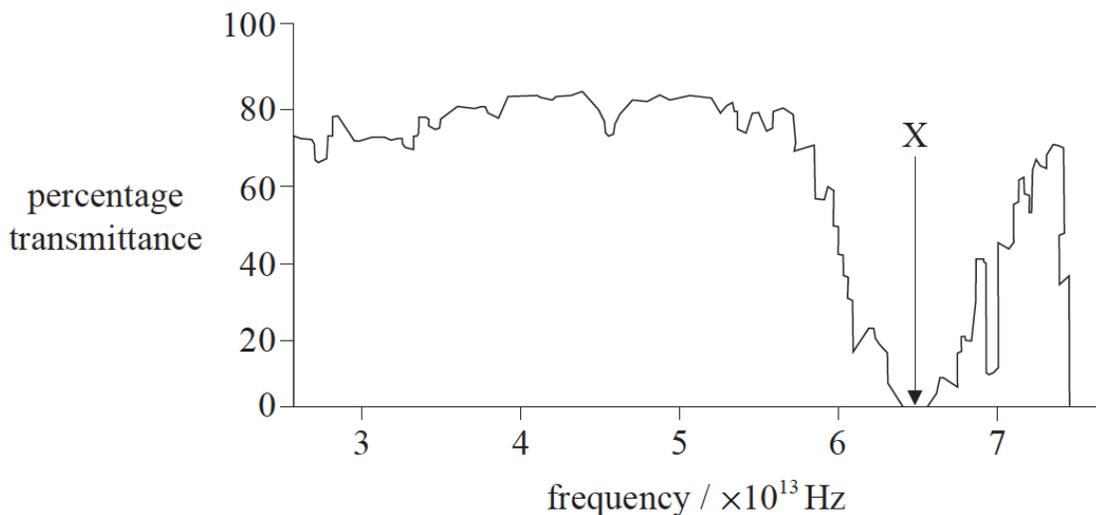
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- 4b. The graph shows the variation with frequency of the percentage transmittance of electromagnetic waves through water vapour in the atmosphere. [9 marks]



Part 2 Energy balance of the Earth

5a. The intensity of the Sun's radiation at the position of the Earth is approximately 1400 W m^{-2} [2 marks]

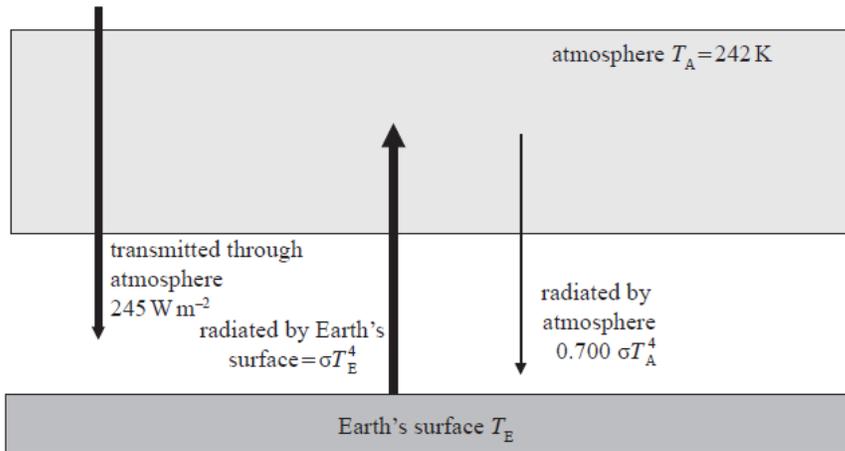
Suggest why the average power received per unit area of the Earth is 350 W m^{-2} .

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5b. 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 $T_A = 242 \text{ K}$.

- (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 W m^{-2} .
- (iii) By reference to the energy balance of the Earth's surface, calculate T_E .

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5c. (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 (CO₂) is a greenhouse gas. State **one** source and **one** sink (object that removes CO₂) of this gas.

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