Exercise walk-through

7.2
Greenhouse effect and energy balance (full B.2)

International Baccalaureate · IB Diploma · Physics · HL

Ess Climate · 2.1

Reasoning

The Earth energy balance includes incoming solar radiation, reflection, absorption and outgoing infrared radiation. Greenhouse gases absorb and emit infrared radiation. Feedback can alter the response to an initial forcing. mitigation : Actions addressing causes of environmental change. adaptation : Actions reducing harm from environmental impacts.

Exercises 2.1·2.3

2.1 Define emissivity. [1]

2.2 Define albedo and name two factors that change Earth's albedo daily. [3]

2.3 Explain why the mean incoming solar intensity is S/4, not S. [2]

Exercises 2.1·2.3

2.1 Define emissivity. [1]

2.1 The ratio of the power radiated per unit area by a surface to that of an ideal black surface at the same temperature.

2.2 Define albedo and name two factors that change Earth's albedo daily. [3]

2.2 Total scattered power ÷ total incident power; cloud formations and latitude.

2.3 Explain why the mean incoming solar intensity is S/4, not S. [2]

2.3 The planet absorbs over its projected disc (πR^2) but the power spreads over the whole sphere ($4\pi R^2$), so the average over the surface is S/4.

Exercises 2.4·3.1

2.4 Name the four main greenhouse gases. [4]

2.5 State what the enhanced greenhouse effect is. [1]

3.1 A planet orbits at a distance where $S = 2200\ \mathrm{W/m^2}$, with albedo 0.40 and emissivity 1.0. Calculate its equilibrium temperature, stating the balance equation you used. [4]

Exercises 2.4·3.1

2.4 Name the four main greenhouse gases. [4]

2.4 Methane CH_4, water vapour H_2O, carbon dioxide CO_2, nitrous oxide N_2O.

2.5 State what the enhanced greenhouse effect is. [1]

2.5 The augmentation of the greenhouse effect due to human activities.

3.1 A planet orbits at a distance where S = 2200 W/m^2, with albedo 0.40 and emissivity 1.0. Calculate its equilibrium temperature, stating the balance equation you used. [4]

3.1 Absorbed: $0.60 \times 2200/4 = 330$ W/m^2; balance $\sigma T^4 = 330$; $T = (330/5.7\times10^{-8})^{1/4} = 276$ K.

Exercises 3.2·3.3

3.2 Explain, in terms of molecular energy levels, how CO_2 absorbs outgoing infrared and why this raises the surface temperature above the equilibrium value in 3.1-style balance. [4]

3.3 A surface radiates 300 $\mathrm{W/m^2}$ at 300 K. Calculate its emissivity ($\sigma = 5.7\times10^{-8}$ $\mathrm{W \cdot m^{-2} \cdot K^{-4}}$), and the power a black body of the same area and temperature would radiate. [4]

Exercises 3.2·3.3

3.2 Explain, in terms of molecular energy levels, how CO_2 absorbs outgoing infrared and why this raises the surface temperature above the equilibrium value in 3.1-style balance. [4]

3.2 Infrared photons match gaps between CO_2 molecular energy levels, so the molecules absorb them and gain energy; the excited molecules re-emit radiation in all directions, including back towards the surface; this returned energy adds to the surface energy budget, so the surface settles warmer than the no-atmosphere balance temperature.

3.3 A surface radiates 300 W/m^2 at 300 K. Calculate its emissivity ($\sigma = 5.7\times10^{-8}$ W $\cdot$ m^{-2} $\cdot$ K^{-4}), and the power a black body of the same area and temperature would radiate. [4]

3.3 Black body: $\sigma T^4 = 5.7 \times 10^{-8} \times 300^4 = 462$ W/m^2 (461.7); emissivity $= 300/462 = 0.65$. A black body of the same area radiates 462 W per unit area – 1.54× more.