

B.2 Greenhouse effect

Practice Worksheet – name: _____ date: _____

FORMULAS FOR THIS TOPIC

INTENSITY $I = \frac{P}{A}$ EMISSIVITY $e = \frac{\text{power radiated per unit area}}{\sigma T^4}$ ALBEDO $\alpha = \frac{\text{total scattered power}}{\text{total incident power}}$

MEAN INCOMING INTENSITY $I_{\text{mean}} = \frac{S}{4}$

SECTION A — MULTIPLE CHOICE

A1. The mean intensity of solar radiation arriving at Earth is one quarter of the solar constant because:

- A The atmosphere absorbs three quarters of the radiation
- B Earth presents a disc of area πR^2 to the Sun but has surface area $4\pi R^2$
- C Earth's albedo reflects three quarters of the radiation
- D The Sun only illuminates a quarter of the Earth at any time

A2. Greenhouse gases absorb infrared radiation because:

- A They are denser than other atmospheric gases
- B Their molecular energy levels match infrared photon energies
- C They reflect infrared radiation back to Earth
- D They have higher specific heat capacities

A3. Fresh snow has an albedo of about 0.85. This means that fresh snow:

- A Absorbs 85% of incident radiation
- B Scatters 85% of incident radiation
- C Emits 85% as much as a black body
- D Transmits 85% of incident radiation

SECTION B — SHORT ANSWER

B1. The solar constant is 1360 W m^{-2} and Earth's albedo is 0.30. Calculate the mean absorbed intensity at the Earth's surface. [3 marks]

B2. Outline the mechanism by which greenhouse gases warm the Earth's surface. [4 marks]

B3. Distinguish between the greenhouse effect and the enhanced greenhouse effect. [2 marks]

ANSWER KEY

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Section A

A1: Earth presents a disc of area πR^2 to the Sun but has surface area $4\pi R^2$ — The Sun's rays are intercepted by Earth's cross-section (πR^2), but that power is shared, on average, over the entire spherical surface ($4\pi R^2$) — a purely geometric factor of 4.

A2: Their molecular energy levels match infrared photon energies — The vibrational energy levels of molecules like CO₂ and H₂O are spaced at exactly infrared photon energies, so outgoing IR is absorbed and re-emitted in random directions — partly back towards the surface. N₂ and O₂ lack such IR-active modes.

A3: Scatters 85% of incident radiation — Albedo is the scattered-to-incident power ratio, so 0.85 means 85% reflected and only 15% absorbed — which is why snow-covered regions stay cold and why melting ice creates a warming feedback loop.

Section B

B1: Mean incident intensity: $S/4 = 340 \text{ W m}^{-2}$. Fraction absorbed: $1 - \alpha = 0.70$. Mean absorbed intensity = $0.70 \times 340 \approx 238 \text{ W m}^{-2}$.

B2: The surface, warmed by mostly visible sunlight, re-radiates as infrared (Wien: cooler bodies peak at longer wavelengths). Greenhouse gas molecules have vibrational energy levels matching IR photon energies, so they absorb this outgoing radiation and re-emit it in all directions. The downward fraction returns energy to the surface, raising the equilibrium temperature above what it would be with no atmosphere.

B3: The greenhouse effect is the natural warming caused by IR-absorbing gases, without which Earth would average about $-18 \text{ }^\circ\text{C}$. The enhanced greenhouse effect is the additional warming from increased greenhouse gas concentrations due to human activities — combustion, agriculture and industry.