Première Euro: Greenhouse-test

The expression of the power emitted by a source of emissivity e and of temperature T is given by Stefan-Boltzmann law: $P = \sigma \cdot e \cdot A \cdot T^4$ with $\sigma = 5.68 \times 10^{-8}\ \mathrm{W \cdot m^{-2} \cdot K^{-4}}$.
The power radiated by a source in the form of electromagnetic radiated is distributed uniformly over spheres centered on the source; the surface of a sphere of radius d is given by $4\pi \cdot d^2$; therefore, the intensity at a distance d is given by: $I(\mathrm{W \cdot m^{-2}}) = \frac{P(\mathrm{W})}{4\pi \cdot d^2}$

Wien's law: $\lambda_{\max} \cdot T = 2.90 \times 10^{-3}\ \mathrm{m \cdot K}$

Albedo is defined as a ratio: $a = \frac{Reflected\ power}{Incident\ power}$

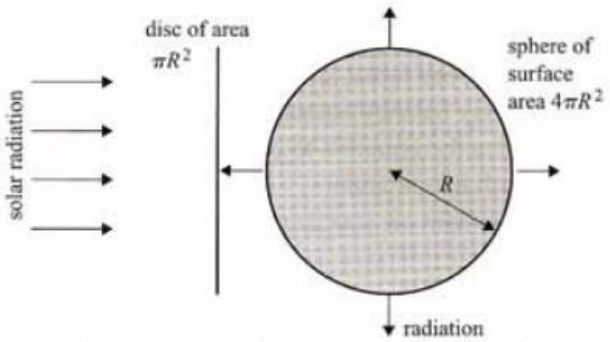
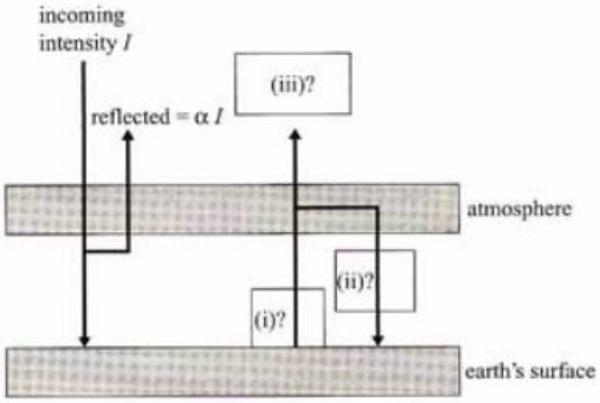


Figure 2.3 The radiation reaching the earth falls on a disc of area πR^2, where R is the radius of the earth.

We consider that the sun emits a total power of $P = 3.9 \times 10^{26}$ W.
We take the average earth-sun distance $d = 1.5 \times 10^{11}$ m.
We take $\alpha = 0.3$, the average value of the albedo on Earth; radius of the Earth: $R = 6370$ km.

1. Find out how many millions of tons of the sun's matter is transformed in energy every second. Knowing the Sun is already 4.5 billion years old, and that its mass was originally 2×10^{30} kg, how many billion years has it got left? Consider only 10% of its mass is used to fuel fusion and that for every four hydrogen nuclei that fuse into one helium nucleus, approximately 0.7% of the mass is effectively converted into energy.
2. Find out what the temperature on earth would be without any atmosphere. Explain your reasoning.
3. In fact, thanks to its atmosphere, the mean temperature on earth is 15°C. Show that the Earth radiates essentially in the infra-red and explain what happens if we take the atmosphere into account; complete the following sketch with the meanings of the different boxes I, II and III.



4. Write the energy balance equation to calculate the fraction t of the energy radiated by the earth that actually leaves the earth.