

# Astrophysics II - Exercise Sheet 4

EPFL Physics section, Prof. Pascale Jablonka

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## Diverse applications of Radiative Transfer

1. How much time does a photon produced in the core of the sun take, on average, to escape to space ? And what is the length of its trajectory to reach this point ?

*Hint:* First, compute the mean free path of a photon inside the sun due to absorptions and re-emission. Then, consider its trajectory as a random walk and compute the length of this path until it reaches the surface. We adopt here a constant absorption coefficient  $\kappa = 10 \text{ m}^2 \text{ kg}^{-1}$  for simplicity, which corresponds to the depth  $r = R_{\odot}/2$  with  $R_{\odot} = 696\,000 \text{ km}$ , and adopt  $\rho = 1.4 \text{ g cm}^{-3}$  as the mean density of the sun.

2. Write down the expressions of mean intensity, radiative flux and radiation pressure in the Eddington approximation.

By applying this approximation in a plane-parallel gray atmosphere, determine the values  $I_{\text{in}}$  and  $I_{\text{out}}$  as a function of the vertical optical depth.

At which optical depth does the radiation become isotropic to within 1

3. Let

$$I(\theta) = I_0 + I_1 \cos \theta + I_2 \cos^2 \theta + \dots \quad (1)$$

Show, by applying the general radiative transfer equation, that:

$$\frac{dI_{n-1}}{dr} = -\kappa \rho I_n \quad (2)$$

for  $n > 0$ . Use this to show that deep inside a stellar atmosphere, the series converges very quickly.