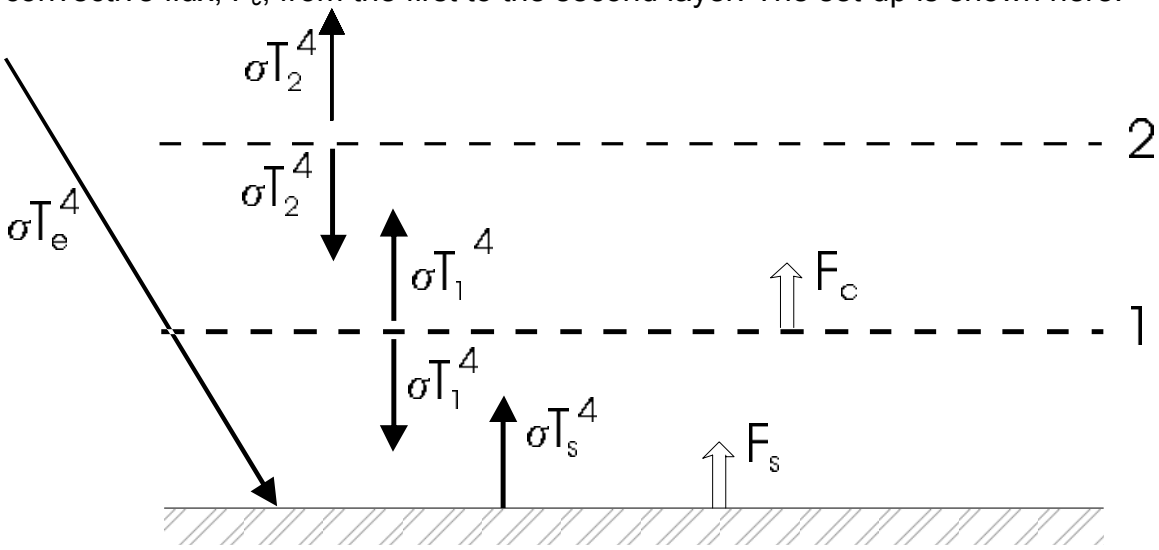
Climate Physics and Chemistry

Problem

Consider the simple two-layer earth-atmosphere system in radiative convective equilibrium as discussed in class. Each atmospheric layer is considered completely transparent to shortwave radiation, and completely opaque to longwave radiation. The amount of incoming shortwave radiation is characterized by the effective blackbody temperature, T_e. In addition to the radiative fluxes, there is a turbulent flux F_s from the surface to the first atmospheric layer, and a convective flux, F_c, from the first to the second layer. The set-up is shown here:



For convective neutrality, we require that $T_1=T_2+\Delta T$ and $T_s=T_1+\Delta T$, where ΔT is specified.

1.) In the equilibrium state, find expressions for the net rate of radiative cooling of heating of each layer and the surface.

2.) The rate of entropy generation or destruction owing to radiation in each layer is given by Q/T, where Q is the radiative heating rate and T is the absolute temperature. Find an expression for the net entropy production by radiation in this system, assuming that the mass of each layer and the ground are all the same.

3.) Entropy is a state variable and must therefore be constant when the system is stationary. Given the answer to 2) above, what additional entropy source or sink must exist? What physical process(es) are responsible for this source or sink?