energy transport

There are three ways in which energy can be transported in stars:

- **Convection** - energy transport by mass motions of elements of the gas.
- **Conduction** - energy transport by exchange of energy during collisions of gas particles (usually electrons).
- **Radiation** - energy transport by the emission and reabsorption of photons generated in the gas.

Let us first consider conduction and radiation (we will consider convection later).

Conduction and radiation are similar processes because they both involve the transfer of energy by direct interaction, either between particles in the case of conduction or between particles and photons in the case of radiation.

Which of the two energy transport mechanisms - conduction and radiation - is dominant in stars? The energy carried by a typical particle, $3kT/2$, is comparable to that carried by a typical photon, hc/λ, but the number density of particles in a star is much greater than that of photons. This means that the energy density in the form of particles is much greater than that in the form of photons, so it might be expected that conduction is a more important mechanism of energy transport in stars than radiation. However, the smaller number of photons is far outweighed by their much larger mean free path between collisions: a photon at a typical point inside a star travels about 10^{-2} m before being absorbed or scattered, whereas a particle only travels around 10^{-10} m. This means that photons can get more easily from a point where the temperature is high to one where it is significantly lower before colliding and transferring energy, resulting in a larger transport of energy. Conduction is therefore negligible in nearly all main sequence stars and radiation is the dominant energy transport mechanism in most stars.

It should be noted that although the mean free path of photons is much larger than the mean free path of particles, it is still very small. This means it takes a long time for a photon to diffuse from the centre of the Sun to its surface, even though the light travel time is only ~2 seconds. In fact, it can be shown that a photon generated near the centre of the Sun will be absorbed and re-emitted $\sim10^{22}$ times before it escapes at the surface and the time it takes to do this is approximately equal to the thermal timescale of the Sun, which is 3×10^7 years. This means that when we observe energy radiated at the solar surface we are usually seeing the results of nuclear reactions which occurred tens of millions of years ago.

We will now turn to the third form of energy transport - convection.
