Problem Set 4 Solutions

Problem 1: B

If a medium is opaque, it is less efficient for energy to be carried out via radiation transport (and conduction is usually only important in white dwarfs).

Problem 2: A

Convection in the outer layers of the Sun causes rising and falling parcels of gas to appear as granules on the solar surface.

Problem 3: D

The equation for the temperature of the planet is given by

$$T_p^4 = \frac{L_*(1-\alpha)}{16\pi a^2 \sigma} \ , \tag{1}$$

which depends on all of these quantities.

Problem 4: C

CO_2 absorbs infrared light much more efficiently than optical light. Therefore most of the Sun's light in the optical makes it through the atmosphere, hits Earth, and is thermalized. The Earth then radiates as a blackbody at IR wavelengths, so this energy that is re-radiated is absorbed by the CO_2, which causes warming in the atmosphere.

Problem 5: A

Problem 6: G

Radial velocities rely on the gravitational tug of the planet on the star, so the mass contributes to this measurement. Gravitational microlensing involves the lensing of light due to the planet's gravitational field, so this depends on mass as well. Planetary transits and direct imaging are more affected by the radius of the planet (and the albedo, in the case of direct imaging).

Problem 7: C

Massive stars fuse only up to ^{56}Fe because heavier elements require an input of energy for fusion. Heavier elements are created in supernova explosive nucleosynthesis.

Problem 8: B

Neutrinos can give us direct information from the core of the Sun because they do not have to random-walk out but can basically free-stream. While they do oscillate between three flavors, this is not why they are able to give us additional information about the Sun than photons.

Problem 9: C

Problem 10: D

Problem 11 (4 points)

$$T_p = \left[\frac{L_*(1-\alpha)}{16\pi a^2\sigma}\right]^{1/4} \approx 234 \text{ K} . \tag{2}$$

This is much lower than the actual temperature, which is higher due to the existence of the greenhouse effect (much more so than on Earth).

Problem 12 (4 points)

One tenth of the Sun's hydrogen is available for burning, so this is $(2\times 10^33 \text{ g})(0.1)(0.71) = 1.4 \times 10^32$ g. If the efficiency of burning is 0.7%, then the rest mass energy available is $0.007(1.4 \times 10^32 \text{ g})c^2 = 8.8 \times 10^{50}$ erg. To get the time, let's say

$$t \approx \frac{E}{L} \approx 2.2 \times 10^{17} \text{ s} \approx 7 \text{ Gyr} . \tag{3}$$