Homework #2: Due in class Thursday February 9th

Explain the difference between nuclear fusion and nuclear fission:

Nuclear fusion involves the joining together of light nuclei (ones with relatively small numbers of protons and neutrons – such as hydrogen) to form heavier nuclei. Nuclear fission involves the breaking apart of heavy nuclei (such as uranium) to form lighter fragments.

Nuclear fusion is the process that provides the power source for the Sun and other stars. Nuclear fission is not important astronomically, but it powers nuclear reactors on Earth. Controlled nuclear fusion has not yet been achieved on a commercially useful scale on Earth.

Non-examinable aside: nuclear fission can be *spontaneous* (a heavy nucleus breaks apart into lighter fragments at a random moment for no particular reason), or it can be triggered by a collision between the nucleus and a neutron. Since fission releases neutrons, this opens the possibility of a *chain reaction* – if each fission reaction releases, on average, more than one neutron that goes on to initiate another fission reaction, the process can run away. Controlled chain reactions go on within nuclear reactors, uncontrolled ones in atomic bombs.

Bonus aside: when uranium nuclei undergo fission, the neutrons produced are generally too energetic to initiate further fissions. Only neutrons from fissions of the uranium 235 isotope – which is less common than uranium 238 in natural uranium that you mine – are immediately able to trigger a chain reaction. As a result, you need relatively pure uranium 235 to make a bomb… this is why we're worried about countries that are trying to *enrich* uranium by separating the 235 isotope from the more common 238 isotope.

How does the number of Solar neutrinos passing through your body every second during the night compare to the number during the day?

Neutrinos pass freely through the Earth, so the number is the same

The electric power consumption for the whole US is about 5×10^{11} watts. Suppose we attempted to replace the mix of existing power stations (oil, coal, nuclear etc) that generate the power with solar panels that generate an average of 10 watts per square meter.

(a) How large an area, in square kilometers, would need to be covered entirely by solar panels?

Area = 5×10^{11} watts / 10 watts m^{-2} = 5×10^{10} m^2
Converting to square km (note that are 1000 x 1000 = 10^6 square meters in a square km)…

Area = 50,000 km^2

(b) What problems can you envisage if such a scheme was attempted?

50,000 km^2 could be a square area of land 140 miles on a side. This is about 20% of the land area of Colorado so such a scheme is not inconceivable – there's almost certainly enough cheap land in sunny areas of the Western US that could be used, though I imagine there would be strenuous environmental objections (the beautiful deserts of Utah and Arizona would be good spots for Solar energy!). Practically, the power from the Sun would probably be less reliable than existing sources of energy (nothing at night, much less when it was cloudy), and some of the largest energy markets on the East coast are far from reliably sunny locations. Moreover, currently the price of solar cells is not competitive with other energy sources.

A star has the same size (radius) as the Sun, but a higher surface temperature. How does the amount of infrared radiation the star emits compare to that of the Sun (be careful with this…)?

The amount of infrared radiation emitted by the hotter star would be larger (a hotter star emits more thermal radiation per unit area at *all wavelengths* than a cooler one, though the peak of the spectrum does shift to shorter wavelengths).