The Power Within

In lecture, we've talked about $E = mc^2$ — Einstein's famous formula relating mass and energy. It's an incredible concept; let's see how far we can stretch its validity.

(a) Nick just learned about mass-energy equivalence and is hoping to harness his own mass energy. He steps on a scale and weighs in at roughly 60 kilograms. Calculate (in joules, which are $\frac{kg*m^2}{s^2}$) Nick's mass energy.

(b) That value doesn't really mean anything intrinsically; the power of units is that it allows us to compare this quantity to something else! Compare Nick's mass energy to the energy of a punch (about 300 joules) and to that of a lightning strike (1×10^9 joules).

(c) Could Nick undergo nuclear fusion as is? Why or why not?

(c) Suddenly, by some unknown mechanism, Nick begins radiating as a blackbody! An initial measurement of Nick from a nearby mountaintop puts his luminosity at about 50 gigawatts (one watt is one joule per second). How much brighter will he seem from San Jose (68 km away) than Venus at its closest approach (38 million kilometers away)? How long does he have until he runs out of energy?

I See Dead Stars

Jesslyn is observing distant stars from her perch at the Big C. She's incredibly interested in the lives and deaths of stars; luckily, she is immortal, so she won't have much trouble recording stellar lifespans.

(a) One night, Jesslyn notices a huge explosion on the sky! She rushes to her spectrometer, which notes some hydrogen spectral lines. What could the source of the explosion be?

(b) What is the difference between a novae and supernovae type Ia? Which can only happen once, and which can repeat?

(c) Would a more massive white dwarf be larger or smaller than a less massive white dwarf? Why?

(d) For high-mass stars ($8M_\odot < M_\odot < 20M_\odot$), the final end product after expelling their outer layers in a supernova explosion is a neutron star. Neutron stars are even more dense than white dwarfs, and a teaspoon of a neutron star would weigh more than a billion tons! What balances the inward force of gravity on a neutron star? Is there a maximum mass for neutron stars?

(e) When chatting with her friend the next day, Jesslyn has an existential crisis and realizes that the Sun might swallow her up as it becomes a red giant. She reminds herself, though, that she is immortal, so she should start thinking about what life will be like if the Sun were to expand all the way out here. What would the surface gravity of the Sun be? What about its density?