Section 2 – 2nd Homework Problem Set

Problem 1

Calculate the total (negative) gravitational potential energy of a mass M distributed uniformly over a sphere of radius R. (**Hint**: How much additional gravitational potential energy, dU, do you get if you add a layer of thickness dr , with the same average density ρ as the whole sphere, to a core of radius r, also with density ρ? Integrate from 0 to R!) Using your result, make a (very rough) estimate of the total energy that gets released in a white dwarf and a supernova (neutron star) core collapse. Assume both have 1.4 solar masses, but the final radius is either 5000 km (white dwarf) or 10 km (neutron star). Compare to the total rest mass energy Mc^2. (Sun's mass is 2×10^{30} kg)

Problem 2

Take the spherical surface of Earth and the usual coordinate system of longitudes and latitudes (or, equivalently, spherical coordinates θ, ϕ). What would the proper (2-dimensional) metric g_{ij} (i,j = 1,2) on this surface have to look like to yield the right distance Δs (actual linear distance in m) for a small displacement given by $\Delta\theta$ and $\Delta\phi$?

Problem 3

So far, cosmic rays consisting of protons, nuclei, leptons (and some antileptons), neutrinos and all kinds of electromagnetic radiation (photons) have been detected and studied. Using, e.g., a web or literature search, find out what kind of (conjectured or known) particles or waves have not yet been identified with absolute certainty, but are being hunted (with Earth-bound detectors) very actively. Find at least 2 examples, and pick one of them to describe the (putative) particle or wave in a few sentences (how does it fit into the Standard Model or its extensions? why is it expected in cosmic rays? how can it be detected?).