Astrophysics
Density of stars

1. Using $R_\odot = 6.96\times10^8$ m and $M_\odot = 1.989\times10^{30}$ kg, find $\overline{\rho_\odot}$ the average density of the Sun.

2. Compare this value to the density of water: 1g/cm^3.

3. Calculate the density of Sirius, the brightest star in the sky with 2.3 $M_\odot$ and 1.6 $R_\odot$.

4. Calculate the density of Betelgeuse, use 10 $M_\odot$ and 1000 $R_\odot$ at its maximum. Compare this to the density of the air we breathe: At sea level and at 20°C dry air has a density of approximately 1.2 kg/m^3. Betelgeuse is a tenuous ghostly object for which it is difficult to define what is meant by "surface".

5. Calculate the density of Sirius B, white dwarf binary companion of Sirius. Use 1.053 $M_\odot$ and 0.008 $R_\odot$ (smaller than Earth). Electron degeneracy pressure is responsible for maintaining hydrostatic equilibrium in a white dwarf. Compare this to the densest material on Earth (not counting subatomic particles), iridium metal (22.65 g/cm^3).

6. Calculate the acceleration due to gravity at the surface of this star. Use $g = \frac{GM}{r^2}$.

7. Calculate the classical escape velocity at the surface of this star. Remember that the potential energy of a particle of mass m at a distance r from a massive object is of mass M is
$$U = -\frac{GMm}{r}$$
and that to escape this particle must be able to reach infinity.

8. Neutron stars are held together by gravity and supported by neutron degeneracy pressure. Use 1.4 $M_\odot$ and R = 10 km. Compare your result to the typical density of an atomic nucleus: $\rho_{nuc} \approx 2.3\times10^{17}$ kg/m^3.

9. Calculate the acceleration due to gravity at the surface of this star.

10. Calculate the classical escape velocity at the surface of this star.

11. For a star of mass M, calculate the classical radius for which the escape velocity becomes equal to the speed of light. This distance is called the ***Scwharzchild radius***, beyond which a collapsing neutron star becomes a black hole, not even light can escape the gravitational attraction of the massively dense object.

12. Using the same method as above, calculate how close a photon can go close to a black hole of mass M, an still be able to escape. This distance is called the ***event horizon*** and nothing crossing this point can hope to escape the gravitational attraction of the black hole.