1.5. *The strength of gravity compared to the Coulomb force*

(a) Determine the difference in strength between the Newtonian gravitational attraction and the Coulomb force of the interaction of the proton and the electron in a hydrogen atom.

(b) What is the gravitational force of attraction of two objects of 1 kg at a separation of 1 m. Compare with the corresponding electrostatic force of two charges of 1 C at the same distance.

(c) Compute the gravitational force between the Earth and the Sun. If the attractive force was not gravitational but caused by opposite electric charges, then what would the charges be?

1.6. *Falling objects in the gravitational field of the Earth*

(a) Two test particles are in free fall towards the centre of the Earth. They both start from rest at a height of 3 Earth radii and with a horizontal separation of 1 m. How far have the particles fallen when the distance between them is reduced to 0.5 m?

(b) Two new test particles are dropped from the same height with a time separation of 1 s. The first particle is dropped from rest. The second particle is given an initial velocity equal to the instantaneous velocity of the first particle, and it follows after the first one in the same trajectory. How far and how long have the particles fallen when the distance between them is doubled?

1.7. *A Newtonian black hole*

In 1783 the English physicist John Michell used Newtonian dynamics and laws of gravity to show that for massive bodies which were small enough, the escape velocity of the bodies are larger than the speed of light. (The same was emphasized by the French mathematician and astronomer Pierre Laplace in 1796).

(a) Assume that the body is spherical with mass M. Find the largest radius, R, that the body can have in order for it to be a "black hole", i.e. so that light cannot escape. Assume naively that photons have kinetic energy $\frac{1}{2}mc^2$.
(b) Find the tidal force on two bodies m at the surface of a spherical body, when their internal distance is ζ. What would the tidal force be on the head and the feet of a 2 m tall human, standing upright, in the following cases (consider the head and feet as point particles, each weighing 5 kg):
   1. The human is standing on the surface of a black hole with 10 times the Solar mass.
   2. On the Sun's surface.
   3. On the Earth's surface.