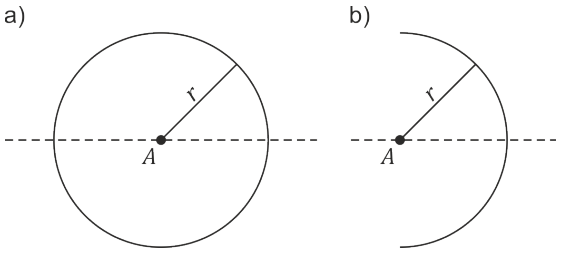
Exercises in Introductory Physics I

Exercise Sheet 11
due to 15.01.24, 11:59 AM

Gravity

1. Calculate the gravitational force $\vec{F}_G$ on a mass m in relation to the distance x from point A (see figure) along the central line (dashed line):



   a) inside and outside of a uniform, hollow sphere (radius r, mass M) (2P)

   b) for a uniform, hollow half-sphere (radius r, mass M) for $|x| > r$. (2P)

2. A space probe ($m_P = 600\,\text{kg}$) is flying to Mars (radius $r_M = 3390\,\text{km}$, mass $M_M = 6.39 \cdot 10^{23}\,\text{kg}$). At height $h_1 = 122.5\,\text{km}$ over the surface of the Mars, the speed of the probe is $v_1 = 21000\,\text{km/h}$. The parachute is supposed to open at a height of $h_2 = 11\,\text{km}$ and a speed of $v_2 = 1650\,\text{km/h}$.

   a) How much work has been done to decelerate the probe between those two points? (*Note: The acceleration of gravity g is not constant in this task!*) (2P)

   b) Unfortunately, the parachute does not open. What is the speed of impact? (*Neglect any friction, assume a constant gravity of* $g = 3.69\,\text{m/s}^2$.) (1P)

3. Derive an expression and calculate the respective values for the first and second cosmic velocities, given as

   a) The minimal velocity required to reach a stable orbit around earth. (1P)

   b) The minimal velocity required to escape the gravity of earth. (1P)

4. Assume that there is a straight tunnel through the earth connecting the north pole with the south pole. An object with a mass m is released at the north pole and falls towards the earth's center.

   a) What is the time needed for the object to reach the south pole (2P)

   b) What is its velocity at the earth's center? (1P)