Back-of-the-Envelope Physics

Winter Term 2023/24

Sheet 1

1. Obtain the area A of an ellipse with semi-axes a and b, using symmetry and that the area of a circle with radius r is πr^2. No integration is allowed!

2. Two stars with mass m_1 and m_2, respectively, move on circular orbits around their common center-of-mass under the influence of gravity. The distance between the stars is r. Calculate the orbital period T as a function of m_1, m_2 and r, including all numerical factors.

3. A particle of mass m moves along the x-axis in a potential

$$U(x) = bx^4$$

Compute the oscillation period T exactly. Compare the result with the estimate obtained using dimensional analysis.

4. Design a simple mechanical device, made of springs and straight frictionless rails, which leads to an (approximate) x^4 potential for the one-dimensional motion of a point particle.

5. A football is kicked from the ground with initial velocity v and angle θ with respect to the horizontal. Neglect friction and the finite size of the ball. Discuss the range R of the ball, using dimensional analysis and guessing the θ dependence. Check and compare with an exact calculation.