

## First exercise sheet on Relativity and Cosmology I

Winter term 2018/19

**Release:** Mon, Oct. 15<sup>th</sup>

**Submit:** Mon, Oct. 22<sup>nd</sup> in lecture

**Discuss:** Thu, Oct. 25<sup>th</sup>

### **Exercise 1** (10 points): *Newtonian Gravity I: Radial motion of a mass point*

Consider a mass  $m$  in the gravitational field of a mass  $M \gg m$ , such that  $M$  sits at the origin. At some initial time  $t = 0$ ,  $m$  is located at a distance  $r(0) = R$  and has an initial velocity  $\dot{r}(0) = v_0 > 0$ , so that it undergoes one-dimensional motion.

**1.1** When is the solution  $r(t)$  unbounded?

**1.2** Give an explicit solution for  $r(t)$  for the lowest initial velocity that allows for an unbounded solution.

### **Exercise 2** (10 points): *Newtonian Gravity II: Potential of a homogeneous spherical shell*

Consider a spherical shell of a mass  $M$  with constant density  $\rho$ . Denote the inner radius with  $R_1$  and the outer radius with  $R_2$ .

Calculate the Newtonian potential at a distance  $r$  from the origin. Distinguish between the cases  $r < R_1$ ,  $R_1 < r < R_2$ , and  $r > R_2$ . Take care of continuity (why?) and boundary conditions at  $r \rightarrow 0^+$  and  $r \rightarrow +\infty$ .