

## Back-of-the-Envelope Physics

### Winter Term 2023/24

#### Sheet 7

1. How high do you have to lift a car with mass  $M = 1500\text{ kg}$  so that its potential energy in the gravitational field on the surface of the Earth amounts to 1 kWh? Discuss some implications.

2. Assume that all the cars in Germany (about 48 million) would be battery electric vehicles and estimate the amount of electrical energy that would be needed to power them during one year. Compare the result with the yearly electricity production in Germany of about 600 TWh.

3. How large would an area covered with photovoltaic (PV) modules have to be in Germany in order to nominally produce 600 TWh per year? Compare with the total land area in Germany of  $360000\text{ km}^2$ .

Assume that one square meter of PV has a peak power of 200 W. Every kW of installed peak power produces about 1000 kWh of electrical energy in one year.

4. The heat of evaporation for water is about 2.3 MJ/kg. Reproduce this value based on your everyday experience and by making reasonable guesses for the required input quantities.

5. Estimate the Hawking temperature of a black hole with a mass equal to  $4 \cdot 10^6$  solar masses.

6. An observer moving with acceleration  $a$  relative to flat spacetime should experience thermal radiation with temperature  $T$  (Unruh effect). Estimate the relation between  $T$  and  $a$  using dimensional analysis. Evaluate the result numerically for an acceleration  $a = 5g$ .