

# Tyngdpunkten 2025

Easier, English

November 2025

Each problem can give at most 10 points. Well-motivated graphical solutions always give maximal points. Good luck!

**1. The Leaning Tower of Pisa** According to legend, the Italian scientist Galileo Galilei dropped two stones of different sizes from the Leaning Tower of Pisa at the end of the 16th century. The goal was to demonstrate that the stones fall equally fast, despite having different masses. The stones landed simultaneously after 3.4 s. From what height were they dropped? You may neglect air resistance.

**2. Bräntberget** Jöns-Harald is standing at the top of Bräntberget (position  $A$ , 48 m above the lowest ground level) and pushes a large stone that begins to slide down the slope. When the stone later is at position  $B$ , it is 12 m above the lowest ground level. What is the stone's speed at position  $B$ ?

*Hint:* You may assume that the stone slides without friction throughout the entire process and that the stone's radius is negligible compared to the height of Bräntberget.

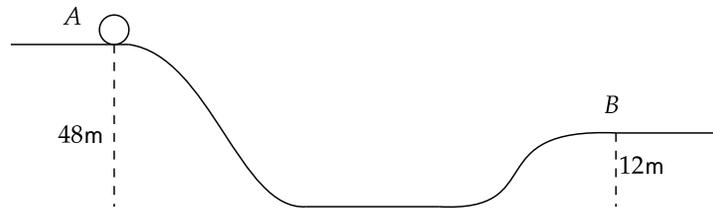


Figure 1: Bräntberget

**3. The sunken cathedral**<sup>1</sup> In a pool with a depth of  $H = 2.5$  m there is a body with a volume of  $V = 8$  dm<sup>3</sup>, consisting of a hemisphere and a cylinder (see Figure 2). The body is *glued firmly* to the bottom (the glue has dried, so the body is fixed in place), and the area of the contact surface is  $A = 20$  cm<sup>2</sup>. You may assume that water has a density of  $\rho = 1000$  kg/m<sup>3</sup> and that the atmospheric pressure is  $P_0 = 100$  kPa.

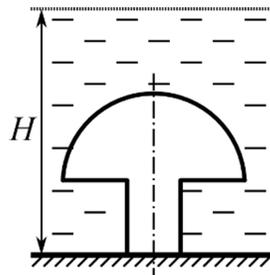


Figure 2: The setup.

- Determine the pressure near the bottom.
- Determine the force with which the water acts on the body, both its magnitude and its direction!

<sup>1</sup>A good piece by Claude Debussy, by the way :)

**4. Swedish carbon dioxide production** Approximate the mass of all the carbon dioxide produced by Swedish cars during one year. You can assume that all fuel is octane  $C_8H_{18}$ . Every octane molecule gives 8  $CO_2$  molecules when the fuel is used.

*Remark:* For this question, it is primarily your reasoning which is assessed and not your exact numerical answer. There are also many ways to solve this exercise.

**5. Air bubble in Nydala!** An air bubble (large enough that surface tension is negligible) is located in Nydala lake, a still freshwater lake. Assume constant temperature and that the bubble can be approximated as an ideal gas. At the depth  $h_0 = 2$  m the bubble has radius  $r$ . The bubble slowly rises to the surface. What volume does it have at the depth  $h = 1$  m?

**6. Two charged plates** Two large parallel metal plates are placed above each other so that the distance between them is very small. The plates carry charges  $+Q$  and  $-Q$ , respectively. At a certain moment, the plates are connected via a resistor, as shown in Figure 3. Explain qualitatively what happens in a few sentences (and, if possible, formulae). Include a qualitative graph of the current through the resistor as a function of time (let  $t = 0$  be the moment when the resistor is connected). Lastly, describe how the graph you scetched would change if you repeated the procedure with a resistor with higher resistance.

*Note:* The component consisting of the two metal plates is called a *capacitor*.

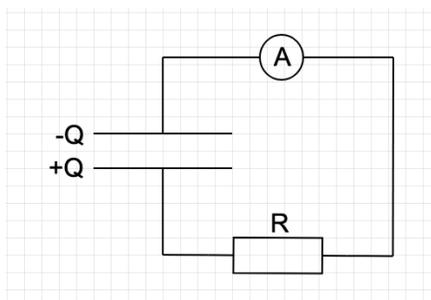
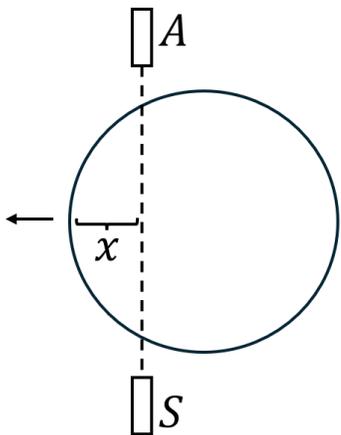


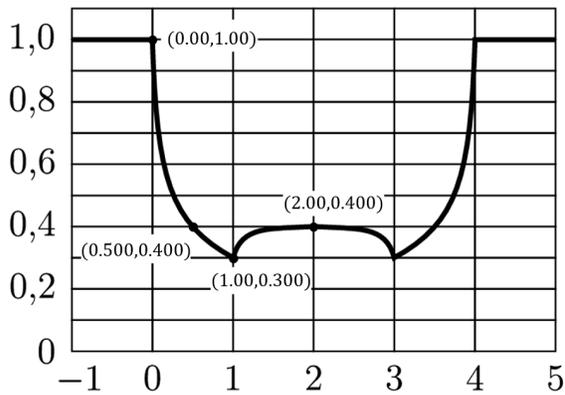
Figure 3: A figure of a circuit with two charged plates and a resistor. The distance between the plates is exaggerated.

**7. Rubidium** Measurements indicate that 27.83% of all rubidium atoms currently on Earth are the radioactive  $^{87}\text{Rb}$  isotope. The rest are the stable  $^{85}\text{Rb}$  isotope. The half-life of  $^{87}\text{Rb}$  is  $4.75 \times 10^{10}$  y, and it decays to strontium, which is stable. Assuming that no rubidium atoms have been formed since, what percentage of rubidium atoms were  $^{87}\text{Rb}$  when our solar system was formed  $4.6 \times 10^9$  y ago?

**8. Criminology** An X-ray device ( $A$ ) emits rays that are detected by a sensor ( $S$ ). Between the X-ray device and the sensor, a cylinder with *thick* walls is placed (in the figure, only the outline of the cylinder is shown). The intensity of the X-ray beam measured by the sensor depends on the position  $x$ , as shown in the graph. Use Figure 4 to determine whether the cylinder contains any (illegal!) material that absorbs X-rays!



(a) A schematic illustration of the setup.



(b) The measured intensity as a function of the position  $x$ . Some points have been added for clarity, and the graph is completely symmetric around  $x = 2$ .

Figure 4: Figures for the problem.

**9. Raindrops** Two spherical raindrops fall from a rain cloud. For one of the raindrops it takes 7 minutes to reach the ground and for the other it takes 4 minutes. Determine the ratio between the radii of the raindrops. Assume that the density of air is constant and that the water drops reach terminal velocity almost immediately.

*Hint:* The air resistance on a falling body is an upward force, whose magnitude is given by  $F = \frac{1}{2}\rho v^2 C_D A$ , where  $\rho$  is the air density,  $A$  is the cross-sectional area of the body (the area one sees if one looks up at the falling body from the ground),  $v$  is speed of the body and  $C_D$  is a constant (that is the same for both raindrops).

**10. Ice and Water** You mix water with mass  $m_w$  and ice with mass  $m_{ice}$  in a container. The diagram shows the final state of the mixture for different initial temperatures  $T_w$  of the water and  $T_{ice}$  of the ice. For points below the curve in the diagram, all the water ends up as ice, and for points above the curve the final state is a mixture of ice and liquid water.

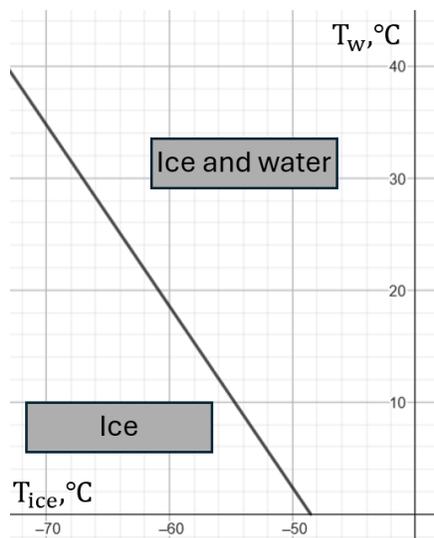


Figure 5: Final state after mixing the ice and the water.

The specific heat capacity of ice at the considered temperature is  $c_{ice} = 1700 \text{ J}/(\text{kgK})$ . The specific heat capacity of water is  $4200 \text{ J}/(\text{kgK})$ , and the latent heat (enthalpy) of fusion of water is  $\lambda = 330 \times 10^3 \text{ J kg}^{-1}$ . Use Figure 5 to determine the ratio  $m_{ice}/m_w$ . Ignore heating of the container and any heat losses to the surroundings.

**11. Speeders** On an infinitely long straight road there is an infinite number of traffic lights. The distance between two consecutive traffic lights is  $L$ . Each traffic light shows red for a time  $T$ , then green for a time  $T$ , and then continues alternating between red and green. At any given time, two consecutive traffic lights always show different colours.

Two cars start at the same time from two traffic lights that are a distance  $2L$  apart, at the moment when the lights have just turned green. The rear car moves with the maximum possible speed that allows it to drive without ever having to slow down. The front car moves with a constant speed  $v > 0$  as long as it can, stops momentarily if it reaches a red light, and resumes motion with speed  $v$  as soon as the light turns green again. Both cars obey the traffic rules, and the traffic lights change colour instantaneously.

*Question:* Will the rear car catch up with the front car? If so, how long does it take? Consider all possible values of  $v$ .

*Comment:* For certain specific values of  $v$  for the front car, it is not entirely clear how long it takes until the cars collide. You may choose yourself how to interpret these limiting cases – it does not matter which convention you use. :)