



The 37th Science Olympiad for Young Mathematicians, Physicists and Chemists



January 2025
Rudbeckianska upper secondary school
Västerås, Sweden

Physics - Form 11

Question 1. Passive solar house

(10 points)

A house uses solar energy to heat 50 glass containers to 80 °C during the day. Each glass container is filled with 20 L of water. The house loses heat at an average rate of 50 000 kJ h⁻¹ during a 10 h long winter night. A thermostat-controlled 15 kW back-up electric heater turns on whenever necessary to keep the house at a constant temperature of 22 °C.

- (a) How long did the electric heater run at night? (7)
- (b) How long would the electric heater need to run if the house did not have solar heating? (3)

Hint: The specific heat capacity of water is $c_v = 4.18 \text{ kJ kg}^{-1}$.



The 37th Science Olympiad for Young Mathematicians, Physicists and Chemists



January 2025
Rudbeckianska upper secondary school
Västerås, Sweden

Question 2. Force between boxes

(10 points)

Two boxes are placed on an inclined plane. The mass of box A is $m_A = 25$ kg and box B has mass $m_B = 15$ kg. The friction coefficient between the surface of the inclined plane and the boxes is for box A $\mu_A = 0.7$, and for box B $\mu_B = 0.3$. What is the force between the two boxes right after they are released? **Hint:** Assume that they move together down the slope and set $g = 9.82$ ms⁻².

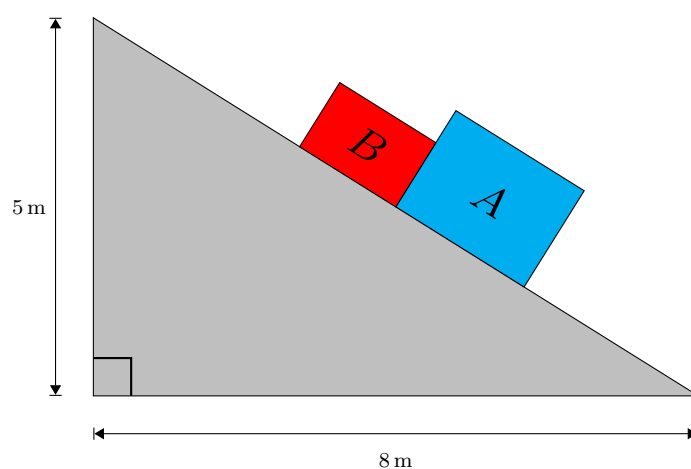


Figure 1: The problem setup and the geometry for the two inclined plane and the two boxes A and B .



The 37th Science Olympiad for Young Mathematicians, Physicists and Chemists



January 2025
Rudbeckianska upper secondary school
Västerås, Sweden

Question 3. Mid-air collision of golf balls

(10 points)

Karl and Gustav play golf on neighboring holes. The golf course is designed in such a way that the fairways of the holes intersect, see Figure 3. Karl hits his golf ball at an angle $\theta_K = 30^\circ$ and an initial velocity v_K . Gustav hits his golf ball at the same time at an angle θ_G and an initial velocity v_G . The golf balls collide at the apex of Gustav's trajectory. **Hint:** The gravitational constant is $g = 9.82 \text{ m s}^{-2}$.

- Find Gustav's launch angle θ_G and the initial velocities v_K and v_G . (3)
- Where does the golf balls land? **Hint:** Assume that the collision is perfectly inelastic, and that the golf balls have the same mass m . (2)
- How long are the balls in the air after the collision? (2)
- What is the change of kinetic energy due to the collision? (3)

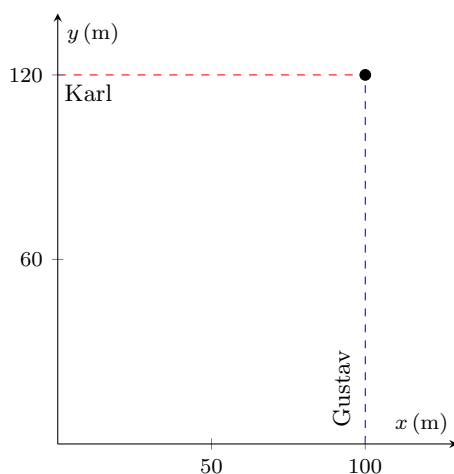


Figure 3: Starting position of Karl and Gustav



The 37th Science Olympiad for Young Mathematicians, Physicists and Chemists

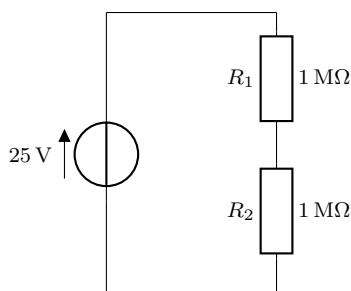


January 2025
Rudbeckianska upper secondary school
Västerås, Sweden

Question 4. Non-ideal electrical sources and meters

(10 points)

- (a) The voltage across the terminals of a black box is measured to $U_m = 25\text{ V}$ and the current to $I_m = 7.5\text{ mA}$. The measurements are made with an ideal voltmeter and an ideal ampere meter. The black box can be modeled, equivalently, as either a voltage source with voltage U_T and internal resistance R_T or as a current source with current I_N and internal resistance R_N . Calculate U_T, R_T, I_N, R_N and draw the equivalent circuits. (4)
- (b) The voltage over the resistor R_2 is measured with a non-ideal voltmeter with internal resistance $R_{\text{in}} = 10\text{ M}\Omega$. What voltage does the voltmeter display? (2)



- (c) A voltmeter with internal resistance $R_{\text{in}} = 100\text{ k}\Omega$ can measure voltages up to $U_{\text{max}} = 2\text{ V}$. Suggest a measuring technique that allows voltage measurements up to 230 V . (2)
- (d) An ampere meter with internal resistance $R_{\text{in}} = 10\text{ }\Omega$ can measure current up to $I_{\text{max}} = 20\text{ mA}$. Suggest a measuring technique that allows current measurements up to 1 A . (2)