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

January 2025
Rudbeckianska upper secondary school
Västerås, Sweden

Physics - Form 10

Question 1. Density of an unknown liquid (10 points)

A spherical shell made of acrylic glass with density $\rho_s = 1.2 \times 10^3\,\mathrm{kg\,m^{-3}}$ contains an unknown liquid. The sphere floats in a container of water at a depth of $h = \frac{3}{2}r_2$. The density of water is $\rho_w = 1 \times 10^3\,\mathrm{kg\,m^{-3}}$ and the internal radius $r_1 = \frac{3}{4}r_2$ where r_2 is the radius of the outer shell, see Figure 1.

(a) Calculate the density ρ_l of the liquid inside the sphere. **Hint:** The volume of a spherical cap of height h is $V = \frac{\pi h^2}{3}(3r - h)$. (6)

(b) Calculate the lowest density of the liquid in the container ρ_c needed for the sphere not to sink. (4)

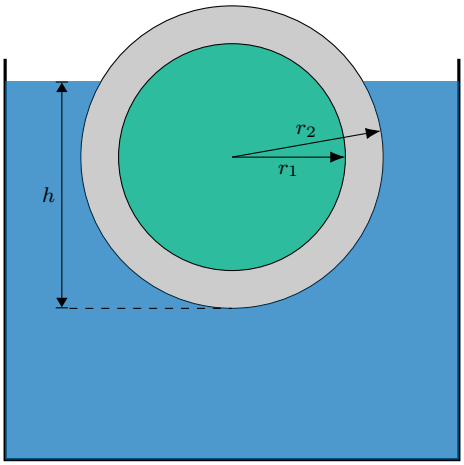

Figure 1: A spherical shell floating in water

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Question 2. Isochoric process of hydrogen gas **(10 points)**

A container is filled with hydrogen gas H_2. The initial pressure of the gas is 200 kPa and the temperature is 600 K. The hydrogen gas is then cooled to a temperature of 375 K. The container can be considered rigid with a volume of $5\,\mathrm{m}^3$.

(a) Calculate the pressure in the tank after the gas has cooled down? (4)

(b) Calculate the amount of heat transfer to the gas? (6)

Hint: The universal gas constant is $R = 4.1\,\mathrm{kJ\,kg^{-1}\,K^{-1}}$ and the specific heat capacity of hydrogen is taken to $c_v = 10.2\,\mathrm{kJ\,kg^{-1}\,K^{-1}}$.

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Question 3. Mid-air collision of golf balls **(10 points)**

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

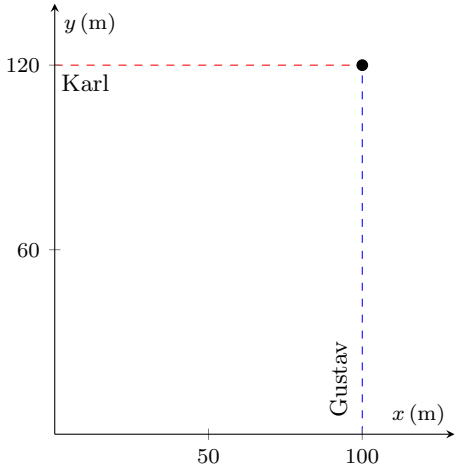

Figure 2: Starting position of Karl and Gustav

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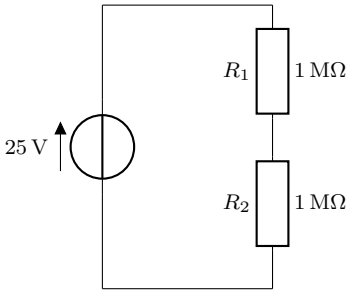
Question 4. Non-ideal electrical meters **(10 points)**

(a) 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)



(b) 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. (4)

(c) An ampere meter with internal resistance $R_{\text{in}} = 10\,\Omega$ can measure current up to $I_{\text{max}} = 20\,\text{mA}$. Suggest a measuring technique that allows current measurements up to 1 A. (4)