The 28th International Science Olympiad for Young Mathematicians, Physicists and Chemists
November 3, 2015
Physics - Form 11

1. A box was completely submerged into water. Immediately after being released it started moving up with acceleration $a = \frac{1}{4}g$, where g is the gravitational acceleration. When the box stopped moving vertically, the ratio of the volume of it's submerged part and it's total volume was f_1. Finally a liquid that did not dissolve in water was poured onto it. After that only $f_2 = \frac{1}{5}$ of the box was in water, the rest of it was in the second liquid. The density of water is $\rho_w = 1000\,\mathrm{kg/m^3}$.

a) What is the density of the box ρ_b? (*3 points.*)

b) What is the ratio f_1? (*2 points.*)

c) What is the density of the second liquid ρ_l? (*3 points.*)

2. Two small boxes slide frictionlessly on ice in opposite directions. The speed of both of the boxes relative to the ground is $v = 1\,\mathrm{m/s}$. One of the boxes has mass $m_1 = 1\,\mathrm{kg}$, the other $m_2 = 3m_1$. After the boxes collide, they move with speed v relative to each other.

a) What are the speeds of the boxes u_1 and u_2 relative to the ground after the collision? (*5 points.*)

b) How much kinetic energy was lost in the collision? (*3 points.*)

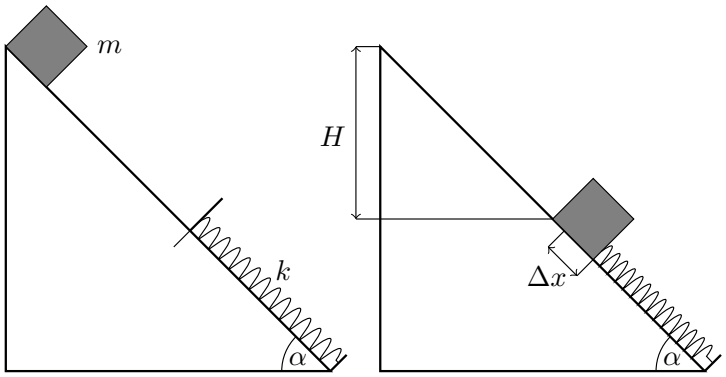
3. In order to find out the internal resistance r and the voltage U of a voltage source it was first connected to a resistor with resistance $R = 280\,\Omega$. The resistor was placed inside an ideal calorimeter that contained $M = 4\,\mathrm{kg}$ of water. It took $t_1 = 810\,\mathrm{s}$ for the temperature of water to increase by $\Delta T = 13.5\,^\circ\mathrm{C}$. After that another resistor with resistance R was added to the circuit in parallel with the previous one. The two resistors together managed to increase the temperature of water by ΔT in $t_2 = 500\,\mathrm{s}$. The specific heat capacity of water is $c = 4200\,\mathrm{J/(kg \cdot K)}$.

a) Find the expression for the internal resistance of the voltage source r as a function of the values provided in the problem and the voltage of the voltage source U. (*5 points.*)

b) Find the voltage U. (*5 points.*)

c) Use the value of U found in the previous question to find the numerical value of the internal resistance r. (*2 points.*)

4. A box with mass $m = 1\,\mathrm{kg}$ was allowed to start sliding on an inclined plane. The box compressed a spring with stiffness $k = 9.8\,\mathrm{N/m}$ and came to rest just when the spring finished expanding for the first time. Whenever the bottom end of the spring was moved lower along the inclined plane after that, the box immediately started to move as well. The coefficient of friction between the box and the inclined plane is $\mu = \frac{1}{2}$ (both static and kinetic), gravitational acceleration is $g = 9.8\,\mathrm{m/s^2}$ and the angle between the inclined plane and the horizontal plane is $\alpha = 45°$. The mass of the spring is very small compared to the mass of the box.



a) By what length Δx was the spring compressed in the final state? (*4 points.*)

b) What is the height difference H of the initial and final positions of the box? (*8 points.*)