The 28th International Science Olympiad for Young Mathematicians, Physicists and Chemists
November 3, 2015
Physics solutions - Form 10

1. a) The total resistance of the circuit is $R_t = R_1 + \frac{R_2 R_3}{R_2+R_3} = \frac{11}{5}\,\Omega$ (*1 point*), so the current through the ammeter is $I_1 = \frac{U}{R_t} = 5\,\text{A}$ (*1 point*).

b) Because the ammeter, which has no resistance, is now connected in parallel with two of the resistors, the presence of those resistors no longer influences the circuit (*2 points*). The total resistance of the circuit must be equal to the resistance of the one resistor that is connected to the ammeter in series. $I_2 = \frac{U}{R_1} = 11\,\text{A}$ (*2 points*).

2. a) The distance covered by the first motorcyclist while he was accelerating was $s_a = \frac{a_1\left(\frac{t}{2}\right)^2}{2} = \frac{a_1 t^2}{8}$ (*1 point*). His final speed was $v_1 = \frac{a_1 t}{2}$ (*1 point*), so while moving with a constant speed he covered the distance $s_c = v_1 \frac{t}{2} = \frac{a_1 t^2}{4}$ (*1 point*). Obviously $s = s_a + s_c = \frac{a_1 t^2}{8} + \frac{a_1 t^2}{4} = \frac{3}{8} a_1 t^2$ (*1 point*), from which we get $a_1 = \frac{8s}{3t^2} = 1\frac{7}{9}\,\text{m/s}^2$ (*1 point*).

b) Let the time during which the second motorcyclist accelerated be t_a and the time during which he moved with constant speed be t_c. First half of the motorcyclist's movement is described by the equation $\frac{s}{2} = \frac{a_2 t_a^2}{2}$ (*1 point*). After he finished accelerating he had the speed $v_2 = a_2 t_a$, so the distance covered with constant speed must be $\frac{s}{2} = v t_c = a_2 t_a t_c$ (*1 point*). Now we can see that $a_2 t_a t_c = \frac{a_2 t_a^2}{2}$ and $t_c = \frac{t_a}{2}$ (*1 point*). Since $t_a + t_c = t$, we get $t_a = \frac{2}{3} t$ (*1 point*). By substituting this to the first equation we get $a_2 = \frac{9s}{4t^2} = 1\frac{1}{2}\,\text{m/s}^2$ (*1 point*).

3. a) The cone is pulled down by gravity ($F_g = Mg$, where g is the gravitational acceleration) and pushed up by buoyancy ($F_b = \frac{\pi r_w^2 h_w}{3} \rho_w g$) (*1 point*). The equality of these forces can be written as $M = \frac{\pi r_w^2 h_w}{3} \rho_w$ (*1 point*). Because the submerged part of the cone is similar to the cone as a whole $\left(\frac{r_w}{h_w} = \frac{R}{H}\right)$, we can write $r_w = \frac{R}{H} h_w = 8.5\,\text{cm}$ (*1 point*). The mass of the cone is therefore $M = \frac{\pi R^2 h_w^3}{3H^2} \rho_w = 2.57\,\text{kg}$ (*1 point*).

b) The density of the cone is the ratio of the mass of the cone and it's volume. $\rho_c = \frac{3M}{\pi R^2 H} = \frac{h_w^3}{H^3} \rho_w = 614\,\text{kg/m}^3$ (*2 points*).

c) While answering the previous question we showed that $\rho_c = \frac{h_w^3}{H^3} \rho_w$. Analogously we can write for the unknown liquid $\rho_c = \frac{h_u^3}{H^3} \rho_u$ (*2 points*), from which we obtain $\rho_u = \frac{H^3}{h_u^3} \rho_c = \frac{h_w^3}{h_u^3} \rho_w = 789\,\text{kg/m}^3$ (*2 points*).

4. a) The mass of ice can be found by examining what happened when hot water was poured into the calorimeter for the second time. Equalizing the heat given by the hot water and absorbed by the cold water, some of which was poured in earlier and some of which was the result of the ice melting, gives us $c_w M_2 (T_w - T_2) = c_w (M_0 + M_1)(T_2 - T_1)$ (*4 points*), which can be rewritten in the form $\frac{M_0 + M_1}{M_2} = \frac{T_w - T_2}{T_2 - T_1}$ or $M_0 = \frac{T_w - T_2}{T_2 - T_1} M_2 - M_1 = 2.5\,\text{kg}$ (*3 points*).

b) Now that we know the amount of ice we can find it's initial temperature from what happened to it after hot water was first added. Heat lost by hot water was $Q = c_w M_1 (T_w - T_1)$ (*1 point*). Raising the temperature of freshly molten water to T_1 takes $Q_1 = c_w M_0 (T_1 - T_m)$ (*1 point*). Melting ice took $Q_2 = L M_0$ (*1 point*). The initial temperature of ice was therefore $T_0 = T_m - \frac{Q - Q_1 - Q_2}{c_i M_0} = T_m - \frac{c_w M_1 (T_w - T_1)}{c_i M_0} + \frac{c_w (T_1 - T_m) + L}{c_i} \approx -12\,^\circ\text{C}$ (*4 points*).