The 34th International Science Olympiad for Young Mathematicians, Physicists and Chemists
November 30, 2021
Physics – Form 11

1. A wind turbine is operating during a windy day. The blades of the turbine are $L = 12\,\mathrm{m}$ long. As an idealised model, assume that the wind turbine converts $\eta = 35\,\%$ of the kinetic energy of the incoming air falling into the range of the blades into electricity. Air density is $\rho = 1{,}2\,\mathrm{kg/m^3}$ and the wind is blowing at $v = 30\,\mathrm{km/h}$ in a direction that's perpendicular to the blades.

a) What is the wind speed right after passing through the propeller blades? *(2 points.)*

b) If the blades are rotating 15 times a minute, how fast is the wind moving with respect to the tips of the turbine blades? *(2 points.)*

c) What is the total power generated by the wind turbine? *(4 points.)*

2. Two cannons, A and B face each-other, some distance apart. Both cannons are primed to shoot out projectiles at different times but with the same speed $v_0 = 100\,\mathrm{m\,s^{-1}}$. The cannons are aimed in such a way that the projectiles collide mid-air. It is known that cannon A is aimed at an angle $\alpha = 30°$, B at $\beta = 60°$ and that the projectiles collide with each-other when A's projectile is at its peak height and B's projectile is on its downward trajectory. The ground is perfectly flat and you may neglect air resistance. Gravitational acceleration is $g = 10\,\mathrm{m/s^2}$ (rounded for convenience).

a) How much time before cannon A must cannon B shoot? *(6 points.)*

b) How far apart are the two cannons? *(2 points.)*

c) Spectacularly, instead of exploding, the projectiles stuck to eachother and fell down as one body. What fraction of the projectiles' kinetic energy is released as heat during the collision? *(4 points.)*

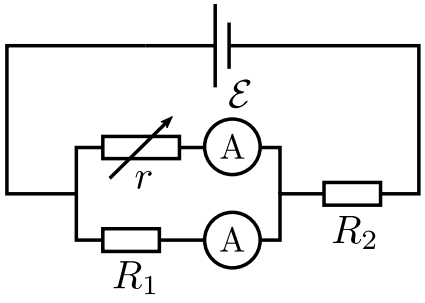
3. An empty bottle is placed in shallow water of depth $h = 4{,}5\,\mathrm{cm}$ and it starts floating. In order to make the bottle not float, rocks were put in the bottle. The minimum amount of rocks needed so that the bottle doesn't float, and sits up-right in the water, was $m = 100\,\mathrm{g}$. In the following, you may treat the bottle as a cylinder of radius $R = 3\,\mathrm{cm}$ and height $H = 20\,\mathrm{cm}$. Water density is $\rho_w = 1000\,\mathrm{kg/m^3}$.

a) What's the empty weight M of the bottle? *(4 points.)*

b) How many rocks are needed to stop the bottle from floating if it were laying on its side? *(6 points.)*

c) How many rocks are needed to weigh the bottle down if it were in deep water? *(2 points.)*

4. A voltage source with some electromotive force $\mathcal{E} = 5\,\mathrm{V}$ is connected to a rheostat r, two unknown resistors R_1 and R_2, and two ideal ammeters, as shown in the figure. When the rheostat is set at $r = 2\,\Omega$, the current in the top branch is measured to be $1\,\mathrm{A}$ which is 2 times bigger than in the bottom branch.



a) What are the values of R_1 and R_2? *(4 points.)*

b) What's the maximal power that can be developed in the circuit by suitably varying the rheostat's resistance? Assume that the rheostat can assume any non-negative resistance. *(4 points.)*