The 28th International Science Olympiad for Young Mathematicians, Physicists and Chemists
November 3, 2015
Physics - Form 12

1. A small block was allowed to slide into a tube filled with air. The height of the tube is $H_0 = 200.0\,\text{cm}$ and it's cross-sectional area is $S = 1\,\text{cm}^2$. No air was able to pass the block and friction between the block and the tube was negligible. When the block finally stopped, it's lower face was at the height $H_1 = 175.4\,\text{cm}$ from the bottom of the tube. Gravitational acceleration is $g = 9.8\,\text{m/s}^2$, atmospheric pressure is $p_0 = 101\,000\,\text{Pa}$ and the density of the block is $\rho = 19.3\,\text{g/cm}^3$. The tube was not thermally isolated from the environment.

a) What was the mass of the block m? (*3 points.*)

b) What was the height of the block h? (*1 point.*)

c) Later the top of the tube was sealed and a valve at the bottom of the tube was opened. What was the final height H_2 of the lower face of the block from the bottom of the tube after the valve at the bottom of the tube had been opened? (*4 points.*)

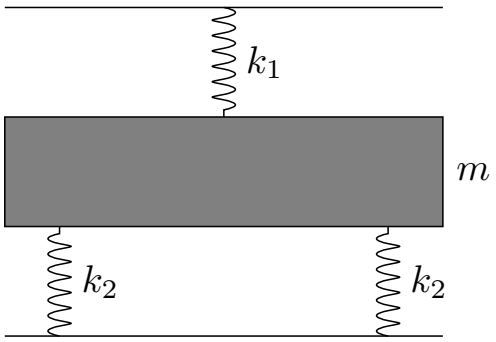
2. An electron is orbiting a small sphere in a homogeneous magnetic field with induction B. The charge of the sphere is $Q = 4.4\,\text{nC}$, electron's orbital radius is $R = 1.2\,\text{m}$ and it's orbital period is $T = 2\,\mu\text{s}$. Coulomb's constant is $k_e = 9.0 \times 10^9\,\text{N} \cdot \text{m}^2/\text{C}^2$, electron mass is $m = 9.1 \times 10^{-31}\,\text{kg}$ and elementary charge is $q = 1.6 \times 10^{-19}\,\text{C}$

a) What would the electron's orbital radius R_E have to be in order for it's orbital period around the charge Q to be T without the presence of a magnetic field? (*3 points.*)

b) How is the magnetic field oriented? (*2 points.*)

c) What is the value of magnetic induction B? (*3 points.*)

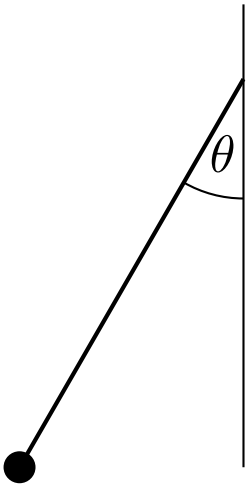
3. A box with mass m is connected with three vertical lightweight springs. The stiffness of the spring above the box is $k_1 = 9.8\,\text{kg/s}^2$, the stiffness of the other springs is $k_2 = 4k_1$. It is known that the box managed to complete exactly 24 more oscillations with all three springs attached during $t = 1\,\text{min}$ than with only the upper spring. Gravitational acceleration is $g = 9.8\,\text{m/s}^2$.



a) What is the mass of the box? (*6 points.*)

b) How much are the springs compressed or extended in the equilibrium position? (*4 points.*)

4. A small ball with mass $m = 1.0\,\text{kg}$ and charge $q = 49\,\text{mC}$ hangs on a string in an electric field with strength $E = 200\,\text{V/m}$. The orientation of the electric field is unknown, but it's vertical component is directed up. The ball is stationary only when the angle between the string and the vertical direction is $\theta = 30°$. Gravitational acceleration is $g = 9.8\,\text{m/s}^2$



a) What is the tension of the string T when the ball is stationary? (*8 points.*)

b) What is the angle α between the electric field strength vectors and the vertical direction? (*6 points.*)