The 36th International Science Olympiad

for Young Mathematicians, Physicists and Chemists

PHYSICS

GRADE 12

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Munkkiniemen yhteiskoulu,
Helsinki Finland

Physics Olympiad 2023

Grade 12

1. Electric fields and Coulomb's law

Three small similarly charged balls rest on a horizontal surface, as shown in Figure 1. The charges of the balls are q, $2q$, and q, and the masses are $2m$, m, and $2m$, respectively. The balls are connected by massless unstretchable non-conducting threads of lengths L each, so that the threads form an equilateral triangle. The thread between the balls No. 1 and No. 3 is burned. Determine the maximal velocity of the ball No. 2. Gravitational effects and friction can be neglected.

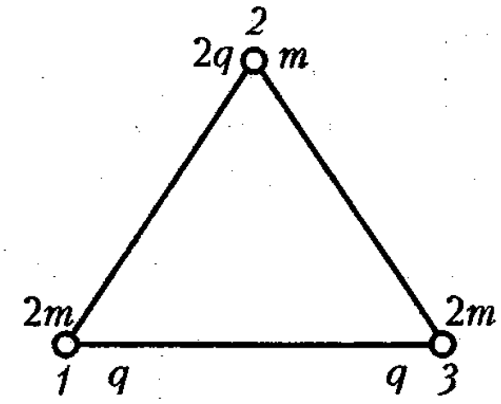

Figure 1: Charged balls.

2. Quantum physics and mechanics

Consider an object of mass m on an inclined plane with static coefficient of friction between the object and the plane equal to $\mu = 0.45$, see Figure 2. The slope of the plane, i.e., the angle the plane makes with the horizontal, is $\theta = 40°$. The object is illuminated with a laser located downhill from the object. The laser beam is parallel to the inclined plane, has wavelength $\lambda = 632$ nm, and power $P = 70$ mW. The power reflection coefficient of the object is $R^2 = 0.75$. What is the maximum mass the object can have if it is to stay static on the surface?

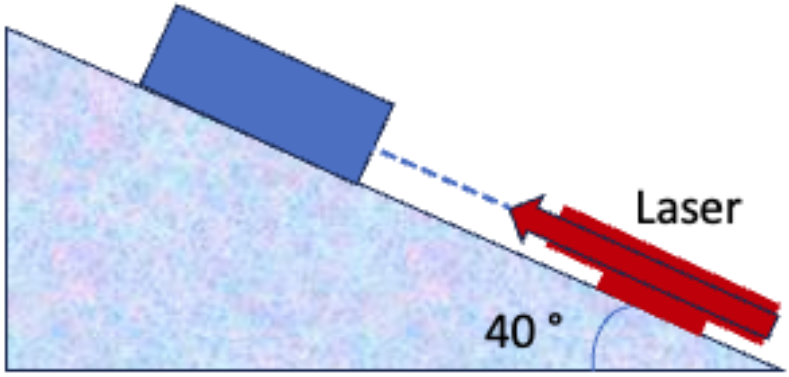

Figure 2: A movable block and the laser.

3. Harmonic oscillations

The system shown in Figure 3 contains a mass m, two ideal springs with the spring constants k_1 and k_2, and three massless frictionless pulleys. An unstretchable massless cable goes around the pulleys, and its ends are attached to the springs. The legs of the cable that are not lying on the pulleys are vertical. The spring axes are also vertical. Determine the maximum amplitude A of the harmonic oscillation of the mass along the vertical axis.

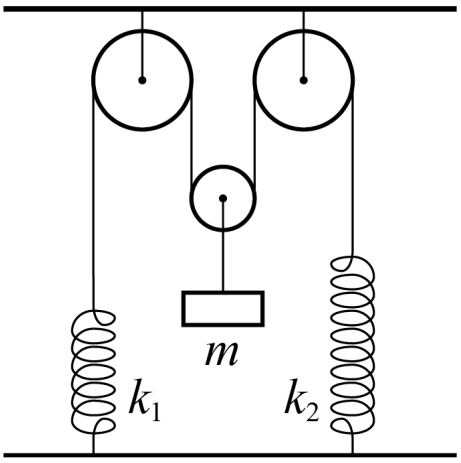

Figure 3: Two springs and the mass.

4. Electric and Magnetic fields

Along the two parallel rails fixed at the angle of $\alpha = 45°$, a jumper can slide, see Figure 4. The jumper remains perpendicular to the rails. The rails are connected with a stationary conductor. The resistance of the jumper is much greater than the resistances of the rails and the conductor. The entire system is placed in a uniform magnetic field of induction **B**. The direction of **B** is perpendicular to the plane formed by the rails. If the direction of the induction is changed to vertical, then the stationary speed of the jumper changes by $k = 0.8$ times. Neglecting the inductance of the circuit, find the friction coefficient μ between the jumper and the rails.

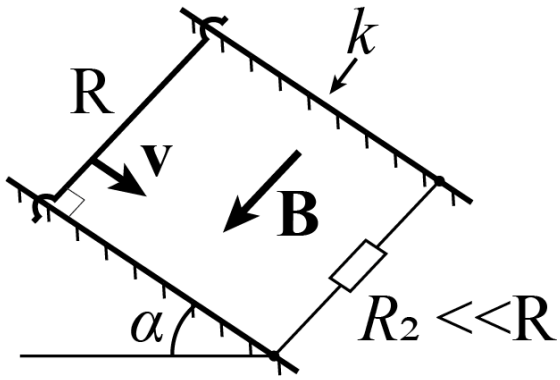

Figure 4: Rails and fields