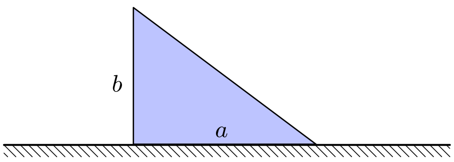
Physics Olympiad Selection Competition

Round 1, 26th February 2024, 15:00-18:00

In the competition, no tools other than a non-graphing calculator, writing and drawing utensils can be used (e.g. no books, notebooks, internet etc.). The solutions to the tasks must be handwritten on paper, each task should start on a new page. The first page should include the competitor's name, grade, the names of the preparing teachers, and the name of the school. It is important to strive for a clear layout, readable handwriting, explanation of the physical basis of the solutions, as well as using clear wording.

Each task is worth the same number of points. The competition lasts for 3 hours. The solutions must be sent in a single pdf document to the email address `iphoteamhun@gmail.com` by 6:00 PM on the day of the competition (February 26, 2024). Late submissions will not be accepted. The pdf document can be created, for example, with a mobile application or scanner.

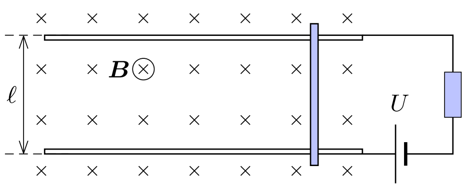
F1. On a horizontal plane, a right-angled triangular wedge is fixed as shown in the *figure*. The lengths of the triangle's legs are $a = 40$ cm, $b = 30$ cm. From the horizontal plane, a small grasshopper wants to leap off to the left of the wedge, pass over it, and land on the horizontal plane on the right side of the wedge. Neglect air drag and use $g = 9{,}8\ \mathrm{m/s^2}$.



a) What is the minimum speed at which this can be done if the grasshopper can freely choose the point of takeoff?

b) How far from the left side of the wedge should the grasshopper jump with the minimum speed?

F2. A conducting rod of mass m shown in the *figure* can slide without friction on the horizontal rails, which are at a distance ℓ from each other. The system is placed in a homogeneous magnetic field B perpendicular to the frame. We connect an ideal voltage source of voltage U and a resistance R between the rails, neglecting the resistance of the other elements of the system.



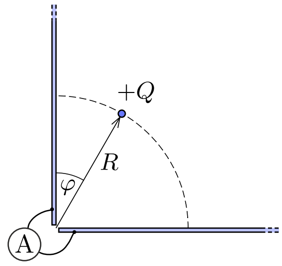
a) Find the speed of the sliding rod as a function of time if the rod is started from rest.

b) Express the time dependence of the speed of the rod started from rest in case when the resistance R is replaced by an inductance L. Assume that initially no current flows in the system.

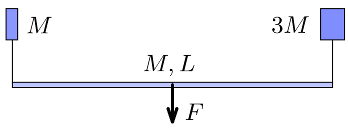
F3. Two large metallic plates of same size are held close to each other at right angle (see the *figure*). In the corner formed by the plates a point charge $+Q$ is placed at distance R from the edge of the corner. The two plates are connected by an ideal ammeter.

a) Find the magnitude and direction of the force acting on the charge if $\varphi = 45°$.

b) The charge is moved with constant speed v along a circular trajectory of radius R (indicated by dashed arc in the figure). Find the reading of the ammeter as a function of angle φ.



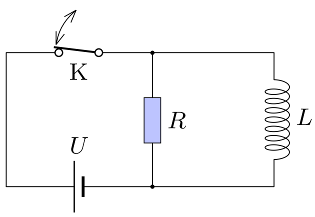
F4. On a horizontal, smooth table, a thin, homogeneous rod of length L and mass M is lying. At each end of the rod, two small objects of mass M and $3M$ are attached with a string as shown in the *figure*. The moment of inertia of the rod about its center is $mL^2/12$.



a) Suddenly, the middle of the rod is pulled with a force F perpendicular to the length of the rod. What is the initial acceleration of the middle of the rod?

b) From what distance from the center of the rod should we start pulling the rod with a force F perpendicular to the rod, so that the string attached to the mass M does not become tense in the moment following the start?

F5. From an ideal battery with voltage U, an ideal coil with inductance L, a resistance R, and the switch K, we have assembled the circuit shown in the *figure*. Initially, the switch is kept open for a long time, then suddenly we start switching periodically: we close the switch for time τ, then keep it open for time 2τ, then close it again for time τ, and so on. It is known that $\tau \ll L/R$.



After a long time, what will be the time-average of the power delivered by the resistance R?