2010 Bulgarian IPhO Team Selection Test

Short Exam 1

Problem. An axially symmetric body (e.g. a hoop, a cylinder, or a ball) of mass m, radius r, and moment of inertia I has zero initial velocity and an initial angular velocity ω_0. The body is placed at the base of an incline, as shown on Figure 1. The coefficient of friction between the body and the incline is k. The acceleration due to gravity is g.

(a) For what values of k will the body go up? **(0.5 pt)**

(b) Assume k is such that the body starts moving along the incline.
What is the distance L_1 the body has moved until the slipping stops? **(1.25 pt)**
What is the velocity of the body V_1 at that instant? **(0.5 pt)**

(c) What additional distance L_2 does the body move until it stops? **(1.0 pt)**
We place three bodies at the base of the plane – a hoop, a cylinder, and a ball (with moments of inertia mr^2, $\frac{1}{2}mr^2$ and $\frac{2}{5}mr^2$). The bodies are given identical initial angular velocities. Which body will rise up the most, and which the least? **(0.25 pt)**

(d) What is the velocity V_2 of the body when it returns to the base of the incline? **(1.25 pt)**
Calculate V_2 for a hoop with $k = \sqrt{3}/2$ and $\alpha = 30°$. **(0.25 pt)**

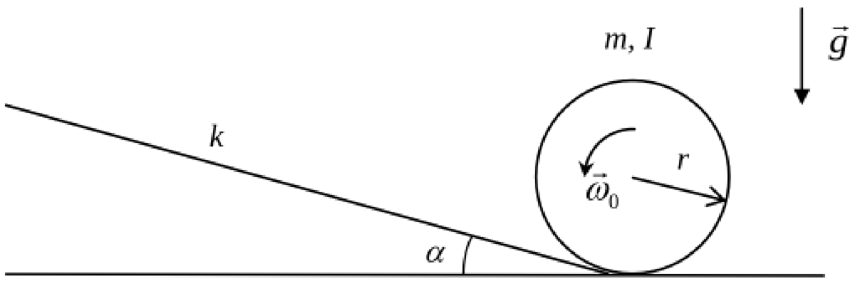

Figure 1

Theoretical Exam

Problem 1. Assume the Earth rotates around the Sun in a circular orbit of radius $r_0 = 1\,\mathrm{au}$ with velocity $v_0 = 30\,\mathrm{km/s}$ and period $T_0 = 1\,\mathrm{yr}$. Halley's comet has an orbital period of $T_1 = 76\,\mathrm{yr}$ and its closest approach to the Sun is at a distance $r_{\mathrm{min}} = 0.59\,\mathrm{au}$.

(a) Find the maximum distance between the comet and the Sun r_{max}. **(1.0 pt)**

(b) Find the minimum and maximum velocities of the comet, v_{min} and v_{max}. **(2.0 pt)**

Your formulae should only include the data in the problem statement, and your numerical values should be in the same units.

Problem 2. A metal puck of mass m has an outer radius b and an inner radius a.

(a) Find the moment of inertia of the puck about an axis perpendicular to the puck and passing through its centre of mass. **(1.0 pt)**

(b) The puck is tied on a very thin string and is left to oscillate around its equilibrium position. Find the oscillation period T. The acceleration due to gravity is g. **(2.0 pt)**

Problem 3. A neutron at rest decays into an electron, an electron antineutrino, and a proton at rest, $n \to p + e^- + \tilde{\nu}_e$. The neutrino is assumed massless.

(a) Find the momentum of the electron p_e and calculate it. **(2.0 pt)**

(b) Find the velocity of the electron v_e and calculate it. **(1.0 pt)**

Experimental Exam

Problem 1. N-resistor black box.

Equipment:
Sealed paper box with a closed circuit (Figure 2), multimeter, ruler, graph paper. The circuit consists of N identical resistors in series, each of resistance R_0. You can only access the terminals of 12 adjacent resistors.

Figure 2

The aim of this problem is to find the resistance R_0 and the number of resistors in the box N.

(a) Find a formula for the resistance $R(k)$ of the circuit when measuring between terminals which are k resistors away from each other. **(1.0 pt)**

(b) Describe a method for finding the resistance R_0 and the number of resistors N by plotting a series of measurements. **(1.0 pt)**

(c) Take the necessary measurements. Present them in a table and explain how they were obtained. **(3.0 pt)**

(d) State the variables which, when plotted, can easily give you R_0 and N. **(1.0 pt)**

(e) Plot the relevant graph. **(4.0 pt)**

(f) Using the graph, determine R_0. **(1.5 pt)**
Likewise, determine N. **(2.5 pt)**

(g) Estimate your error in finding R_0. **(0.5 pt)**
Estimate your error in finding N. **(0.5 pt)**

Call the examiner in case of any technical difficulties.

Note: If there is evidence that the box has been unsealed or that the circuit has been interrupted, you will be disqualified.

Constants:

Elementary charge	e	1.6×10^{-19} C
Electron mass	m_e	$0.000\,91 \times 10^{-27}$ kg
Neutron mass	m_n	$1.674\,95 \times 10^{-27}$ kg
Proton mass	m_p	$1.672\,65 \times 10^{-27}$ kg