

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 $\alpha = 30^\circ$. (0.25 pt)

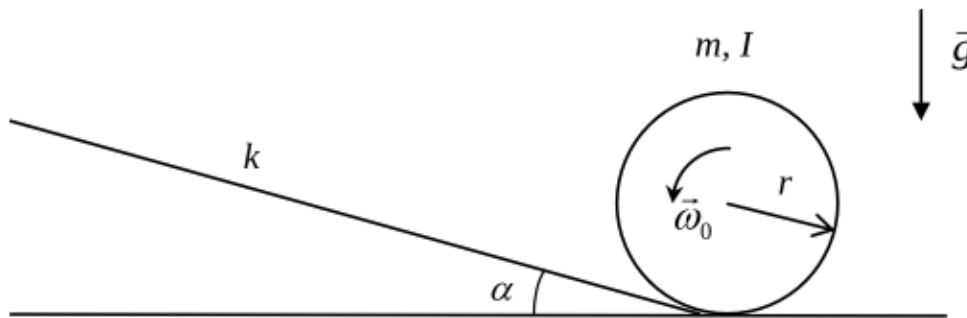


Figure 1

*The problem is worth 5 points.
Time: 60 minutes.*

Theoretical Exam

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

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

*Each problem is worth 3 points.
Time: 5 hours.*

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.

Each problem is worth 15 points.

Time: 5 hours.