2012 Bulgarian IPhO Team Selection Test

Short Exam 1

Problem. A thin rod of mass m and length L is placed vertically on a horizontal surface. The acceleration due to gravity is g. The rod is given a tiny lateral push and it starts falling. There is no friction between the rod and the surface. Right before the rod strikes the surface horizontally, find:

(a) The velocity of the centre of mass V_C.

(b) The angular acceleration of the rod ε.

(c) The normal force R.

Theoretical Exam

Problem 1. A point mass oscillates harmonically along a line. The mass passes through a point C of its trajectory in alternating time intervals of 1 s, 2 s, 1 s, 2 s, ... What is the ratio of the distances between C and the endpoints of the trajectory?

Problem 2.

(a) Find the moment of inertia of a rectangle of mass m and sides a and b with respect to an axis passing through its centre of mass perpendicularly to its plane. **(1.0 pt)**

(b) A sheet of size AN is defined as a rectangle of surface area $2^{-N}\,\mathrm{m}^2$ and a ratio of $\sqrt{2}$ between its sides. Calculate the oscillation period of a vertical A4 sheet about a horizontal axis passing perpendicularly to the sheet through the middle of its longer side. Your answer should be accurate to 3 significant figures. **(2.0 pt)**

Problem 3. A particle of mass m and charge q moves under a constant magnetic field B and an alternating electric field $E(t) = E_m \cos(\omega t)$, where $\omega = \frac{qB}{m}$. At time $t = 0$ the particle is at rest at the centre of the coordinate system (Figure 1). Find the classical equations of motion of the particle $x(t)$, $y(t)$, and $z(t)$. Describe the shape of the trajectory.

Hint: The motion along Oy is described by a function of the form $y(t) = At\sin(\omega t)$.

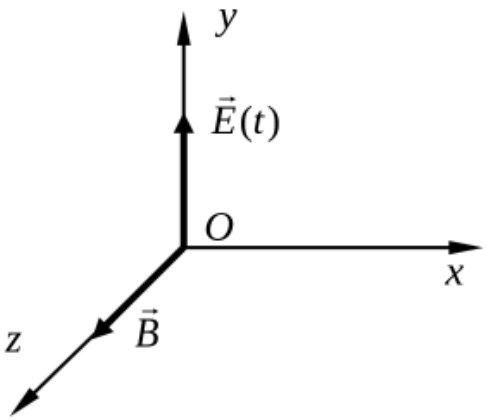

Figure 1

Experimental Exam

Problem 1. Measuring the refractive index of a liquid.

Equipment:
Plastic petri dish (shallow cylindrical dish for cell culture use), unknown liquid, pins, piece of corrugated cardboard, ruler, graph paper, pens (3 colours). See Figure 2.

Figure 2

The aim of this problem is to find the refractive index of an unknown liquid through the appropriate measurements. Do not taste the liquid! Though non-toxic, it has strong laxative properties[1]!

Fill the the petri dish with the liquid and place it on top of the graph paper and the corrugated cardboard. Use the pins to mark the incident and the outgoing rays. Observe the images of the pins through the side of the petri dish. Study the dependence of the angle of deviation φ on the angle of incidence α (Figure 2). These angles are related by

$$\sin\alpha = n\sin\left(\alpha - \frac{\varphi}{2}\right).$$

Assume that the plastic has the same refractive index as the liquid.

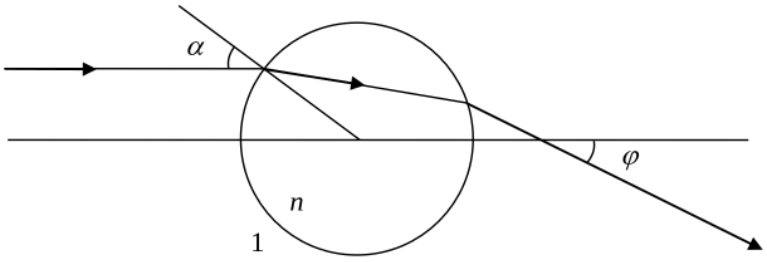

Figure 3

(a) State the parameters that you will be measuring. Take enough useful measurements. Present them in a table and explain how they were obtained. **(6.0 pt)**

(b) State the variables which, when plotted, can easily give you n. **(0.5 pt)**

(c) Plot the relevant graph. **(4.5 pt)**

[1] This turned out to be a lie, as the liquid was just a sugar solution.

(d) Using the graph, determine the refractive index n. **(3.0 pt)**

(e) Estimate your error in finding n. **(1.0 pt)**

Call the examiner in case of any technical difficulties.

Constants:

Acceleration due to gravity g $9.81\,\mathrm{m/s^2}$