2006-2007 Physics Olympiad Preparation Program
- University of Toronto -

Every year, POPTOR invites all students to participate in a competition for the best problem created by our contestants. Authors of the best problems are announced and awarded during the POPTOR Weekend. Name your self-made problem as "My Problem", and mail this problem and its solution on a separate sheet of paper along with solutions of the POPTOR problems. You may send us any number of problems, but only self-made and unique will be considered.

Problem Set 1: General

Due October 30, 2006

Since this is the first problem set, a few comments before starting:

- If you want to know what kind of physics you might need to solve these problems, look at the Physics Olympiad syllabus at http://www.jyu.fi/ipho/syllabus.html. You do not need to know the syllabus by heart to do the problems, but you do need to be able to recognize what you need to know, so you can look it up.
- Pay attention to words like "estimate" or "about". They indicate that the expected answer is not exact because either the input data is not precisely known or because approximations or simplifying assumptions are necessary. Much of real physics is learning how to turn insoluble exact problems into soluble approximations.
- "*Nothing ventured, nothing gained*": Whether you finish a problem or not, please make sure your reasoning and analysis are clear. If you write down nothing, it is easy for us to mark – we just give you zero – but pretty boring. Your basic ideas may be right even if you make a mistake or get stuck. You may be on the way to your own Great Discovery!

Problem 1

A small bead with mass M is attached to a very light string hung from a ceiling. The string can be torn by a force exceeding the value of 10 Mg where g is acceleration due to gravity. The bead on the string may ocsillate harmonically with a period T_0. A student decides to perform another experiment. He takes the attached bead aside from its equilibrium and pushes it in such a way that the bead performs a full revolution in a horizontal plane.
What is the time of one revolution of the bead that can be calculated with the data, given above? Is this time a maximum or a minimum value of all possible?

Problem 2

A sample of an ideal gas is in a vertical cylinder fitted with a piston. As 5.79 kJ of energy is transferred to the gas by heat to raise its temperature, the weight on the piston is adjusted so that the state of the gas changes from point A to point B along the semicircle, shown in fig. 2.1.
Find the change in internal energy of the gas.

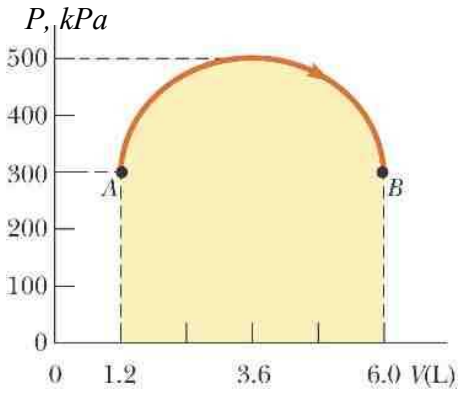

Fig.2.1

Problem 3

A possible means for making an airplane invisible to radar is to coat the plane with an antireflective polymer. Radar waves have a wavelength of 3.00 cm and the index of refraction of the polymer is $n = 1.50$.
How thick would you make the coating?

Problem 4

An oceanographer is studying how the ion concentration in sea water depends on depth. She does this by lowering into the water a pair of concentric metallic cylinders (Fig.4.1) at the end of a cable and taking data to determine the resistance between these electrodes as a function of depth. The water between the two cylinders forms a cylindrical shell of inner radius r_a, outer radius r_b, and length L much larger than r_b. The scientist applies a potential difference ΔV between the inner and outer surfaces, producing an outward radial current I. Let ρ represent the resistivity of the water.
(a) Express the resistivity of the water in terms of the measured quantities L, r_a, r_b, ΔV, and I.
(b) Estimate roughly the relationship between the resistivity of the water and the ion concentration in it.

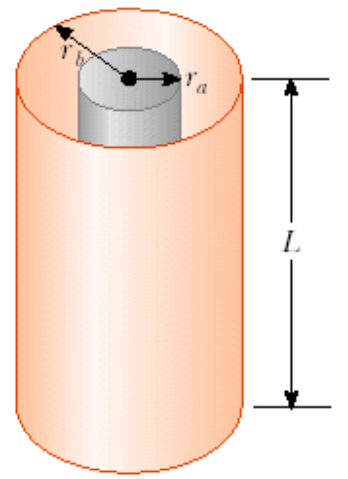

Fig.4.1

Problem 5

Student's determination of the half-life of ^{137}Ba *in an experiment of the first-year Physics laboratory*.

The radioactive barium isotope ^{137}Ba has a relatively short half-life and can be easily extracted from a solution containing its parent cesium (^{137}Cs). This barium isotope is commonly used in an undergraduate laboratory exercise for demonstrating the radioactive decay law. Undergraduate student using modest experimental equipment took the data, presented in fig.5.1. Along the vertical axis, the student plotted *lnR* that was a natural logarithm of a decay rate, or activity, *R*. *R* is the rate of change of the number of nuclei of a parent isotop due to the decay (a conversion into the other isotop).
Determine the half-life for the decay of ^{137}Ba using the sudent's data.

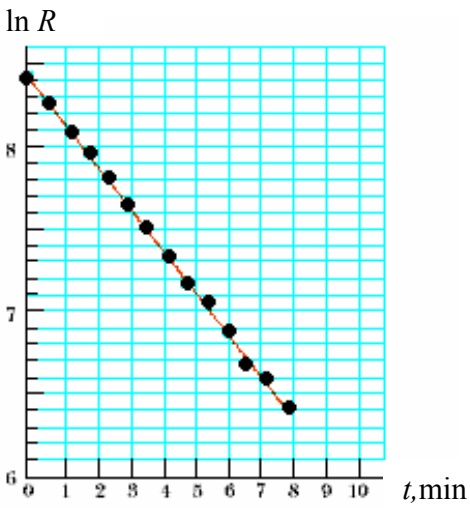

Fig.5.1