33rd
INTERNATIONAL
PHYSICS OLYMPIAD
BALI - INDONESIA

EXPERIMENTAL COMPETITION

Thursday, July 25th, 2002

Please read this first:

1. The time available is 5 hours for the experimental competition
2. Use only the pen provided
3. Use only the front side of the paper
4. Begin each part of the problem on a separate sheet
5. For each question, in addition to the ***answer sheets*** where you may write, there is an ***answer form*** where you *must* summarize the results you have obtained. Numerical results should be written with as many digits as are appropriate to the given data.
6. Write on the blank sheet of paper the results of all your measurements and whatever else you consider is required for the solution of question. Please use ***as little text as possible***; express yourself primarily in equations, numbers, figures, and plots.
7. Fill in the boxes at the top of each sheet of paper used by writing your ***Country***, your student number (***Student No***.), the number of the question (***Question No***.), the progressive number of each sheet (***Page No***.), and the total number of blank sheets used for each question (***Total Pages***). Write the question number and the section letter of the part you are answering at the top of each sheet. If you use some blank sheets of paper for notes that you do not wish to be marked, put a large X across the sheet and do not include it in your numbering.
8. At the end of the exam, arrange all sheets for each problem *in the following order*:
    - ❑ Answer form
    - ❑ Used sheets in order
    - ❑ The sheets you do not wish to be marked
    - ❑ Unused sheets and the printed question

   Place the paper inside the envelope and leave everything on your desk.
   You are not allowed to take any sheets of paper and any material used in experiment out of the room .
9. Note that all scales marked on the graph papers and the apparatus for the experiments (e.g. the test tube) are of the same scale unit, but ***not calibrated*** in milimeter.

10. Beware the time consuming process of electrolytic experiment. You are allowed to perform the two problems (problem I and problem II) in any order, even simultaneously.

Use the following symbols in your answer

acceleration of gravity	g	*absolute temperature*	T
gas pressure	P	*frequency*	f
angular frequency	w	*periodicity of oscilation*	T_{osc}
Height	h	*velocity of light*	c
wavelength	l	*refractive index*	n
Mass	m	*gas constant*	R
mechanical work	W	*length*	l
Diameter	d	*electric current*	I
electric charge	q	*electron charge*	e
Boltzmann constant	k_B	*radius*	r
volume of gas	V_g	*voltage*	V

I. Determination of e/k_B Through Electrolysis Process

Background Theory

The electrolysis of water is described by the reaction :

$$H_2O \rightarrow 2H^+ + O^{-2}$$

$$2H^+ + 2e^- \rightarrow H_2\,;\; O^{-2} \rightarrow \frac{1}{2}O_2 + 2e^-$$

The reaction takes place when an electric current is supplied through a pair of electrodes immersed in the water. Assume that both gases produced in the reaction are ideal.

One of the gases produced by the reaction is kept in a test tube marked by arbitrary scale. By knowing the total charge transferred and the volume of the gas in the test tube the quantity e/k_B can be determined, where **e** is the charge of electron and k_B is the Boltzmann constant.

For the purpose mentioned above, this experiment is divided into two parts.

Part A: Calibration of the arbitrary scale on the test tube by using a dynamic method.
This result will be used for part B

Part B: Determination of the physical quantity e/k_B by means of water electrolysis

You are not obliged to carry out the two experiments (part A and part B) in alphabetical order

The following physical quantities are assumed:

- Acceleration of gravity, g = (9.78 ± 0.01) ms^{-2}
- Ratio of internal vs external diameters of the test tube, α = 0.82 ±0.01

The local values of temperature T and pressure P will be provided by the organizer.

List of tools and apparatus given for experiment (part A & B):

- Insulated copper wires of three different diameters:
  1. Brown of larger diameter
  2. Brown of smaller diameter
  3. Blue
- A regulated voltage source (0-60 V, max.1A)
- A plastic container and a bottle of water.
- A block of brass with plastic clamp to keep the electrode in place without damaging the insulation of the wire.
- A digital stopwatch.
- A multimeter (beware of its proper procedure).
- A wooden test tube holder designed to hold the tube vertically.
- A multipurpose pipette

- A vertical stand.
- A bottle of white correction fluid for marking.
- A cutter
- A pair of scissors
- A roll of cellotape
- A steel ball
- A piece of stainless steel plate to be used as electrode.
- A test tube with scales.
- Graph papers.

Note that all scales marked on the graph papers and the apparatus for the experiments (e.g. the test tube) are of the same scale unit, but ***not calibrated*** in millimeter.

EXPERIMENT

Part A: Calibration of the arbitrary scale on the test tube

- Determine a dynamic method capable of translating the arbitrary length scale to a known scale available.
- Write down an expression that relates the measurable quantities from your experiment in terms of the scale printed on the test tube, and sketch the experiment set up.
- Collect and analyze the data from your experiment for the determination and calibration of the unknown length scale.

Part B: Determination of physical quantity e/k_B

- Set up the electrolysis experiment with a proper arrangement of the test tube in order to trap one of the gases produced during the reaction.
- Derive an equation relating the quantities: time t, current I, and water level difference Dh, measured in the experiment.
- Collect and analyze the data from your experiment. For simplicity, you may assume that the gas pressure inside the tube remains constant throughout the experiment.
- Determine the value of e/k_B.

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ANSWER FORM

PART A

1. State the method of your choice and sketch the experimental set up of the method: **[*0.5 pts*]**

2. Write down the expression relating the measurable quantities in your chosen method: **[*0.5 pts*]. State all the approximations used in obtaining this expression [1.0 pts].**

3. Collect and organize the data in the following orders : physical quantities, values, units **[*1.0 pts*]**

4. Indicate the quality of the calibration by showing the plot relating two independently measured quantities and mark the range of validity. **[*0.5 pts*]**

5. Determine the smallest unit of the arbitrary scale in term of mm and its estimated error induced in the measurements. **[*1.5 pts*]**

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PART B

1. Sketch of the experimental set up. **[*1.0 pts*]**

2. Derive the following expression:

$$I\,\Delta t = \frac{\mathrm{e}}{\mathrm{k_B}} \frac{2P(pr^2)}{T} \Delta \mathrm{h}$$ **[*1.5 pts*]**

3. Collect and organize the data in the following format : physical quantities (value, units) **[*1.0 pts*]**

4. Determine the value of ***e/k_B*** and its estimated error **[*1.5 pts*]**

II. OPTICAL BLACK BOX

Description

In this problem, the students have to identify the unknown optical components inside the cubic box. The box is sealed and has only two narrow openings protected by red plastic covering. The components should be identified by means of optical phenomena observed in the experiment. Ignore the small thickness effect of the plastic covering layer.

A line going through the centers of the slits is defined as the axis of the box. Apart from the red plastic coverings, there are three (might be identical or different) elements from the following list:

- Mirror, either plane or spherical
- Lens, either positive or negative
- Transparent plate having parallel flat surfaces (so called plane-parallel plate)
- Prism
- Diffraction grating.

The transparent components are made of material with a refractive index of 1.47 at the wavelength used.

Apparatus available:

- A laser pointer with a wavelength of 670 nm. **CAUTION: DO NOT LOOK DIRECTLY INTO THE LASER BEAM.**
- An optical rail
- A platform for the cube, movable along the optical rail
- A screen which can be attached to the end of the rail, and detached from it for other measurements.
- A sheet of graph paper which can be pasted on the screen by cellotape.
- A vertical stand equipped with a universal clamp and a test tube with arbitrary scales, which are also used in the Problem I.

Note that all scales marked on the graph papers and the apparatus for the experiments are of the same scale unit, but ***not calibrated*** in millimeter.

The Problem

Identify each of the three components and give its respective specification:

Possible type of component	Specification required
mirror	radius of curvature, angle between the mirror axis and the axis of the box
lens*	positive or negative, its focal length, and its position inside the box
plane-parallel plate	thickness, the angle between the plate and the axis of the box
prism	apex angle, the angle between one of its deflecting sides and the axis of the box
diffraction grating*	line spacing, direction of the lines, and its position inside the box

- implies that its plane is at right angle to the axis of the box

Express your final answers for the specification parameters of each component (e.g. focal length, radius of curvature) in terms of millimeter, micrometer or the scale of graph paper.

You don't have to determine the accuracy of the results.

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ANSWER FORM

1. Write down the types of the optical components inside the box :

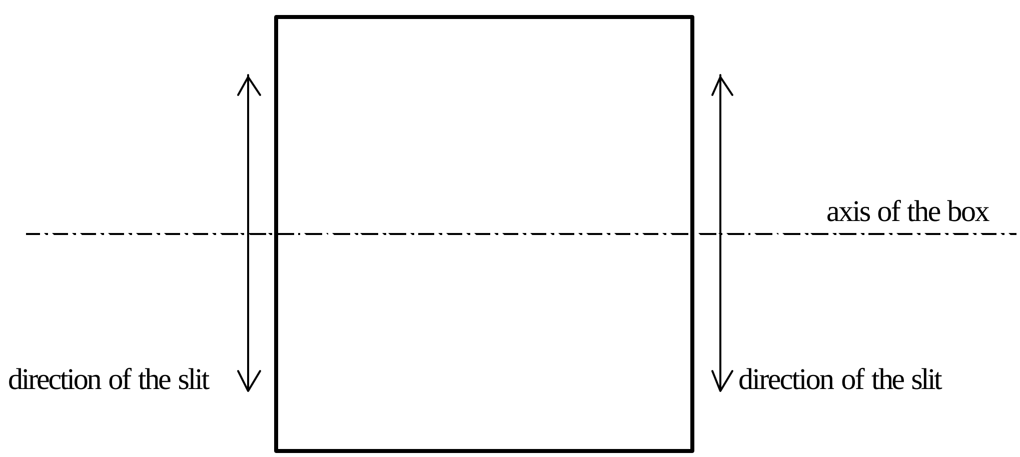
   no.1. ……………………………………………… **[*0.5 pts*]**

   no.2.. ……………………………………………… **[*0.5 pts*]**

   no.3. ……………………………………………… **[*0.5 pts*]**

2. The cross section of the box is given in the figure below. Add a sketch in the figure to show how the three components are positioned inside the box. In your sketch, denote each component with its code number in answer 1 .

   [*0.5 pts* for each correct position**]**



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3. Add detailed information with additional sketches regarding arrangement of the optical components in answer 2, such as the angle, the distance of the component from the slit, and the orientation or direction of the components. **[*1.0 pts*]**

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4. Summarize the observed data **[*0.5 pts*]**, determine the specification of the optical component no.1 by deriving the appropriate formula with the help of drawing **[*1.0 pts*],** calculate the specifications in question and enter your answer in the box below **[*0.5 pts*]**.

Name of component no.1	Specification

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5. Summarize the observed data **[*0.5 pts*]**, determine the specification of the optical component no.2 by deriving the appropriate formula with the help of drawing **[*1.0 pts*],** calculate the specifications in question and enter your answer in the box below **[*0.5 pts*]**.

Name of component no.2	Specification

Country	Student No.	Experiment No.	Page No.	Total Pages

6. Summarize the observed data **[*0.5 pts*]**, determine the specification of the optical component no.3 by deriving the appropriate formula with the help of drawing **[*1.0 pts*],** calculate the specifications in question and enter your answer in the box below **[*0.5 pts*]**.

Name of component no.3	Specification