

Much Physics - Little Effort

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Introduction

During the WFPPhC-Congress-2012 there was the workshop “Much Physics – Little Effort”. The workshop focused on experiments with rather little effort, but with fruitful insights into important basic concepts of physics.

The participants were asked to work in working groups at several “stations” to carry out these experiments by themselves.

The first experiment was organised in such a way that the participants could take the equipment home.

Experiment 1

This experiment goes back to the former Swedish IPhO-team-leader Hans Uno Bengtsson from the University of Lund. Sadly Hans Uno Bengtsson passed away in May 2007.

I used this experiment to train students for the Physics Olympiads. They also made investigations with different diameters and lengths of the pipe (see fig. 1)

The given parts are optimal.

Material

1 short piece of a plastic pipe with two differently coloured dots on it (see fig. 1)

1 ruler



fig. 1 (produced by Helmuth Mayr)

System

Lay this pipe on the table, so that the two dots are turned upwards. Press one finger on one of the dots. As a reaction the pipe will start to rotate.

To visualize this starting process short video clips are available on the web: **Start-A** (<https://www.dropbox.com/s/75i5855l9teyn1t/Start-A.avi>) and **Start-B** (<https://www.dropbox.com/s/sgvbkdmb0wm3lzu/Start-B.avi>). In this case the pipe does not have two dots with different colours, but instead there is a red “cross” (X) and a black “ring” (O).

(All clips were produced by Engelbert Stütz/Austria)

What to do ?

- Watch carefully what you can see !
- Clarify what’s going on !

Hint

- If you want, you can produce such an object by yourself and take it home.

Solution

One can notice that the pipe rotates around a vertical axis while rolling on its circumference. If you press e.g. the red dot, you can see this red dot four times at the same time.

It is also obvious that one can see just that very dot which has been pressed during the start. The other dot is more or less invisible as long as the speed of the pipe is rather high.

You can watch these movements on the two short videos **pipe-green** (<https://www.dropbox.com/s/gjujmqad3v3pyaf/pipe-green.AVI>) and **pipe-red** (<https://www.dropbox.com/s/93pohr6u7h4mtqi/pipe-red.AVI>).

These two movies are made in slow motion technique. Hence one can see that the “not-pressed dot” rotates much faster than the other one. That means that it is originally so fast that it is more or less invisible.

Due to the fact that the length of the pipe (length = 64 mm) is four times its diameter (diameter = 16 mm) and our eyes show “inertia” one can see four of the pressed dots at the same time.

Comment

Of course you can produce a pipe being e.g. three times or five times longer than its diameter. In these cases you would notice three or five of the pressed dots at the same time, but it can be that these pipes are harder to start.

Experiment 2

Equipment

- 1 Erlenmeyer flask
- 1 stopper with a fixed glass pipe
- 1 syringe
- 1 portion of coloured water
- 1 ruler / tape / calliper
- 3 plastic jugs
- 2 thermometers
- 1 water heater
- 1 adhesive band
- 1 vessel with scale
- material to fix the equipment
- water
- cleaning paper

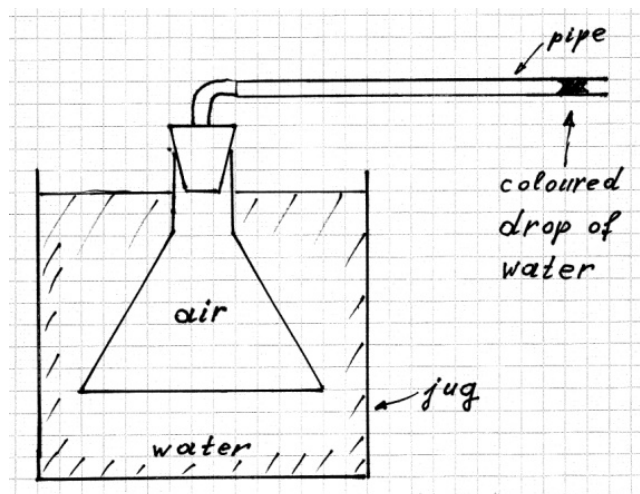


fig. 2 sketch of the system

System

The stopper with the glass pipe is to be put in the Erlenmeyer flask. With the syringe one can put a drop of coloured water in the end of the horizontally orientated glass pipe, so that the air in this system is “jailed”. This equipment can be put in warm or not so warm water being in two plastic jugs. Hence one can assume that the “jailed air” has the temperature of the water.

Hints

- In order to put in the drop of coloured water, it is recommended to hold the glass pipe slightly downwards. After putting in the drop, the pipe has to be placed horizontally as quickly as possible.
- There should be only slight variations in the temperature !
- With pieces of the adhesive band one can show the position of the coloured water drop.
- You can assume that the “jailed air” acts as a perfect gas.
- *If the Erlenmeyer flask gets wet inside, you have to dry it carefully !*

What to do ?

Determine the absolute zero of temperature !

Solution

It is obvious that the pressure of the “jailed” air is constant. Hence the volume of the “jailed” air will be higher at a higher temperature, and visa versa. If the jailed air were a perfect gas, its volume would be zero at 0 K.

$$\text{From } p \cdot V = N \cdot k \cdot T \quad \text{we get} \quad \frac{V}{T} = \frac{N \cdot k}{p}$$

$$\text{Hence} \quad \frac{V_1}{T_1} = \frac{V_2}{T_2} \quad \text{that means:} \quad \frac{V_1}{T_1} \approx \frac{V_2}{T_2} \approx \frac{V_{\text{total}}}{T_0}$$

Put the Erlenmeyer flask into the warmer water (its temperature is measured by a thermometer) and wait some minutes so that the air inside has about the same temperature as the warmer water. Then – following the hints – put the drop of coloured water into the end of the pipe by use of the syringe. Use a short bit of the adhesive band to show the position of the coloured drop. After that take the whole apparatus out of the warmer water and put it in the not so warm water, whose temperature is also measured by use of a thermometer: (The difference of the temperatures should be about 5°C to 10°C in maximum; otherwise the drop will go into the flask). Hence the coloured drop will move in another position, which can also be shown by another bit of the adhesive band.

The easiest way to measure the necessary volumes is to fill the system completely with water and to fill it into the vessel with the scale.

Having done this it is easy to calculate the temperature T_0 .

Comment

The goal of this experiment is definitely not an exact value of 0 K, furthermore students should understand that there is a deepest temperature which can be estimated with rather simple equipment.

Carefully done, one can get results in the range of about - 250°C to about - 300°C.

Experiment 3

This experiment is a part of the experimental problem of the IPhO-1982/Germany. One can find the whole optical experiment including the solution of the IPhO-1982 in Germany at the IPhO-home-page

http://ipho.phy.ntnu.edu.tw/problems-and-solutions_3.html#1982

Equipment

- 1 convergent lens
- 1 plan mirror
- 1 pencil
- 1 ruler / tape / calliper
- material to fix the components

What to do ?

Determine the focal length of this lens as accurately as it can be !

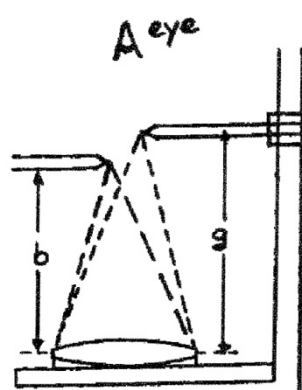
Solution

This solution is part of the official solution of the whole problem, one can find at the IPhO-home-page given above.

For the determination of the focal length f_L , place the lens on the mirror and with the clamp fix the pencil on the supporting base. Lens and mirror are then moved around until the vertically downward looking eye sees the pencil and its image side by side.

In order to have object and image in focus at the same time, they must be placed at an equal distance to the eye. In this case object distance and image distance are the same and the magnification factor is 1.

It may be proved quite accurately, whether magnification 1 has in fact been obtained, if one concentrates on parallax shifts between object and image when moving the eye: only when the distances are equal do the pencil-tips point at each other all the time.



The light rays pass the lens twice because they are reflected by the mirror. Therefore the optical mapping under consideration corresponds to a mapping with two lenses placed directly one after another:

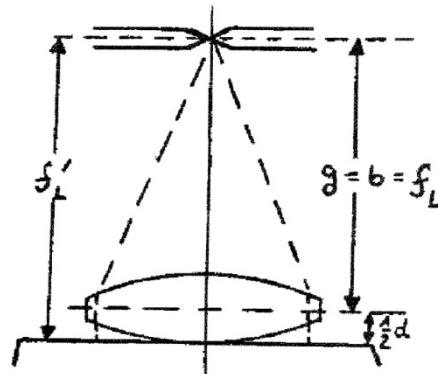
$$\frac{1}{g} + \frac{1}{b} = \frac{1}{f} \quad \text{where} \quad \frac{1}{f} = \frac{1}{f_L} + \frac{1}{f_L}$$

i.e. the effective focal length is just half the focal length of the lens. Thus we find for magnification 1:

$$g = b \quad \text{and} \quad \frac{2}{g} = \frac{2}{f_L} \quad \text{i.e.} \quad f_L = g$$

A different derivation for $f_L = g = b$:

For a mapping of magnification 1 the light rays emerging from a point on the optical axis are reflected into themselves. Therefore these rays have to hit the mirror at right angle and so the distance g equals the focal length f_L of the lens in this case.



The distance between pencil point and mirror has to be determined with an accuracy, which enables one to state f_L with a maximum error of $\pm 1\%$. This is accomplished either by averaging several measurements or by stating an uncertainty interval, which is found through the appearance of parallax.

Half the thickness of the lens has to be subtracted from the distance between pencil point and mirror:

$$f_L = f_L^* - \frac{d}{2}$$

The given lens had a thickness $d = 4 \pm 0,2$ mm

The nominal value of the focal length of the given lens is $f_L = 100$ mm.

Comment

I used this part of the problem successfully very often in order to train optics.

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