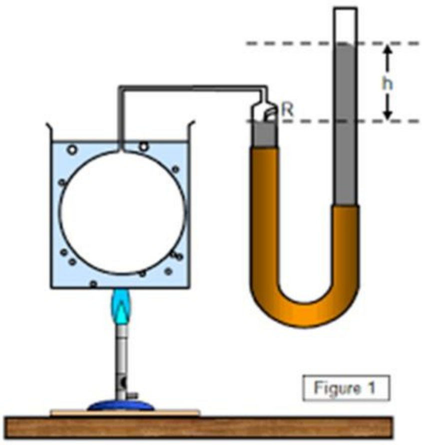
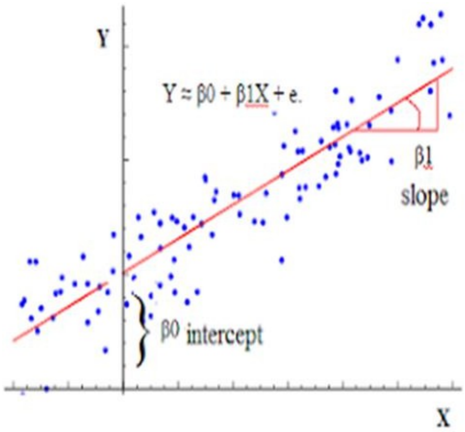
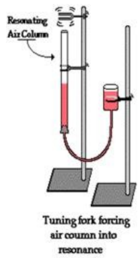
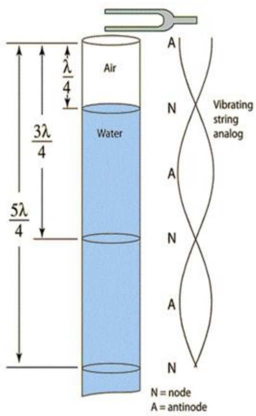
BASIC PHYSICS PRACTICUM I FOR IPA EDUCATION MAJORS









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YOGYAKARTA

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FOREWORD

Praise be to Allah SWT who has bestowed His blessings and grace, so that the author can complete the writing of the Basic Physics I Practicum Manual. Basic Physics Practicum I basically contains some basic experiments on the topics of mechanics, heat, and sound. This practicum guide is expected to be used by students of the Science Education Department in semester I, as a guide to the steps that must be taken to carry out Basic Physics Practicum I.

The author would like to thank various parties for the realization of the Basic Physics I Practicum instructions, to

1. The Dean of FMIPA who has given the author the opportunity to compile this practicum guide.
2. Colleagues who have helped in writing this practicum guide.
3. All parties that we cannot mention one by one, who have helped in writing this practicum guide.

The author realizes that in writing this practicum guide there are still many shortcomings. Therefore, the author expects suggestions and criticism from all parties for the improvement of this practicum guide in the future. Hopefully this practicum guide is useful and makes it easier to carry out Basic Physics Practicum I. Aamiin

Yogyakarta, August 2023

Writing Team

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INTRODUCTION TO IPA MEASUREMENT METHODS

A. Introduction

It is known that the results of observations or measurements of physical quantities must be expressed in numbers. For example, measuring length can be done using various length measuring instruments. If you use an ordinary ruler that has a smallest scale of up to 1 mm, a caliper that can measure up to an accuracy of 0.05 mm or 0.02 mm, or a screw micrometer that has an accuracy of up to 0.01 mm. However, measurement is always followed by uncertainty. For example, the result of measuring a length of 12.52 cm, the number 2 behind is an estimated number not a definite measurement number. Any tool used always has a number that contains uncertainty, in this case due to the limited capabilities of the tools used. Uncertainty in measurement is not only caused by the limitations of the scale that can be read on measuring instruments, but many other sources that cause uncertainty.

B. Source of Uncertainty

Sources of uncertainty can be classified into

1. The existence of the smallest scale value
2. The existence of systematic uncertainty
3. The existence of random uncertainty
4. Observer limitations

C. How to Express Uncertainty in Measurement

In a single measurement (which is done only once), the uncertainty in the results is determined by the ability of the measurer by considering the measuring scale used and the condition of the physical system being studied, but in general the magnitude is equal to **½ the** smallest **scale**. ***Measurement results*** with uncertainty or error are written as

$$x = \bar{x} \pm \Delta x$$

D. Uncertainty in Repeated Measurements

The true value is only obtained if the measurement is repeated or done several times. In a limited number of measurements that are a sample of the population of the quantity, the best value that can be obtained from the sample as something close to the true value whose average can be written

$$\bar{x} = \frac{\sum x_i}{n} = \frac{x_1 + x_2 + \dots\dots\dots x_n}{n}$$

The amount of uncertainty or called the ***absolute error*** that is carried out repeated measurements (*n* times of measurement), formulated

$$\Delta x = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n(n-1)}}$$

E. Mean Number

In writing the measurement result *x* with the error *Δx*, it is possible that the second number already contains uncertainty. Writing the third number and so on is of course no longer meaningful. In writing the measurement results written in 2 numbers means. These results can also be written in other forms or units, such as

$\bar{x} = (0.33 \pm 0.03)$ cm,

$\bar{x} = (0.033 \pm 0.003)$ dm,

$\bar{x} = (0.0033 \pm 0.0003)$ m.

In scientific reports, it is preferred to use one number in front of the comma

$\bar{x} = (3.3 \pm 0.3) \times 10^{-1}$ cm,

$\bar{x} = (3.3 \pm 0.3) \times 10^{-2}$ dm,

$\bar{x} = (3.3 \pm 0.3) \times 10^{-3}$ m.

The number of meaningful numbers used can also be seen from the **relative uncertainties** discussed below.

The rule of thumb used is

Number of significant figures = $1 - \log \frac{\Delta x}{x}$

To $\frac{\Delta x}{x}$ around 10% used 2 numbers means

About 1% used 3 numbers means

About 0.1% used 4 numbers means

The more numbers there are, the smaller the percentage of uncertainty, the more precise the measurement results.

F. Relative Uncertainty and Measurement Precision

The uncertainty written Δx is called the ***absolute uncertainty of*** the magnitude *x*. The size of Δx can describe the ***quality of the measuring instrument,*** but cannot be used to assess the ***quality of the measurement results***.

For example, a rod is measured to be about 1 m long, when measured with an ordinary ruler can give results

$L_A = (1.0000 \pm 0.0005)$ m

If the same instrument is used to measure rod B which is about 10 cm long, the result is written

$L_B = (10.00 \pm 0.05)$ cm

In these two measurements the uncertainty is the same ΔL = 0.05 cm = 0.0005 m but it is clear that the quality of the measurement result L_A is better than L_B .

To be able to provide direct information on the ***quality of measurement***

The so-called measurement accuracy is used ***relative uncertainty.***

Relative uncertainty $= \frac{\Delta x}{x}$

$$\frac{\Delta L_A}{L_A} = \frac{5}{100} = 0,55\%$$

$$\frac{\Delta L_B}{L_B} = \frac{5}{10} = 5\%$$

The smaller the relative uncertainty, the higher the measurement accuracy.

G. Uncertainty of quantities that are not directly measurable

If a quantity to be determined is a function of another measured quantity, then that quantity contains the inherited uncertainty of the measured quantity.

Suppose, the quantity to be determined is z which is a function $z = f\,(x, y, ...)$. in this case the function variable is the result of measuring $(x \pm \Delta x)$, $(y \pm \Delta y)$, ...

To obtain the uncertainty of z, Δz, *the* general equation is used.

$$\Delta z = \left[\left(\frac{\partial z}{\partial x}\right)^2 (\Delta x)^2 + \left(\frac{\partial z}{\partial y}\right)^2 (\Delta y)^2 + ... \right]^{\frac{1}{2}} \quad \text{or}$$

$$\Delta z = \sqrt{\left(\frac{\partial z}{\partial x}\right)^2 (\Delta x)^2 + \left(\frac{\partial z}{\partial y}\right)^2 (\Delta y)^2 + ...}$$

Example: Error of equation $z = \dfrac{ab^2 + 2}{c}$

$$\Delta z = \sqrt{\left(\frac{\partial z}{\partial a}\right)^2 (\Delta a)^2 + \left(\frac{\partial z}{\partial b}\right)^2 (\Delta b)^2 + \left(\frac{\partial z}{\partial c}\right)^2 (\Delta c)^2}$$

$$\Delta z = \sqrt{\left(\frac{b^2}{c}\right)^2 (\Delta a)^2 + \left(\frac{2ab}{c}\right)^2 (\Delta b)^2 + \left(\frac{2ab^2 + 2}{2c^2}\right)^2}$$

In the special case, $z = f\,(x, y, ...)$ with unrelated variables $x, y, ...$, the above equation can be simplified into

$$\Delta z = \left|\frac{\partial z}{\partial x}\right| |\Delta x| + \left|\frac{\partial z}{\partial y}\right| |\Delta y| + ...$$

Example: Error of equation $z = \dfrac{ab^2 + 2}{c}$

$$\Delta z = \left(\frac{b^2}{c}\right)\Delta a + \left(\frac{2ab}{c}\right)\Delta b + \left(\frac{ab^2 + 2}{2c^2}\right)\Delta c$$

H. Weighted Average

The weighted average is the best value resulting from a combination of various values produced by different observation methods for one observed physical quantity. The weighted average is used if in an analysis of measurement results to obtain the average value $\bar{x} \pm s_{\bar{x}}$ from $x_1 \pm s_1$, $x_2 \pm s_2$, ..., $x_i \pm s_i$. The conditions that must be met in the analysis are:

1. The values to be averaged must represent the same physical quantity.

2. Each value to be averaged must match each other. This can be tested by looking at their discrepancy (difference in value/BN) from each other.

Suppose: A physical quantity (x) is observed by two different and mutually independent methods, with the respective final results:

Measurement I: $x_1 = x_1 \pm s_1$

Measurement II: $x_2 = x_2 \pm s_2$

The final value of the physical quantity (x) can be calculated from the two results above by calculating the best value which is a combination of x_1 and x_2 . To get the best value of the two measurements compared, it is necessary to see the discrepancy value of x_1 and x_{2l} , with the following equation.

$$BN = l\, x_1 - x_2\, l$$

The requirement for compatibility between two values is determined by BN, i.e. two measured values are said to be mutually compatible if :

$$BN < (s_1 + s_2)$$

The results that fulfill the equation above**,** show that the value of the quantity x produced by measurement 1 corresponds to measurement 2, and is mutually consistent; meaning that both results can be taken into account or compromised to obtain the best value of (x) with the weighted method. In general, for the measurement results of physical quantities with various measurements, and have met the criteria of discrepancy / compatibility with each other with the respective results: x_1 ; x_2 ; x_3 ; $_i$, will have a weighted average value as :

$$\bar{x} = \frac{\sum_{i=1}^{N} w_i\, x_i}{\sum_{i=1}^{N} w_i}$$

$$w_i = 1/s_i^2$$

With its weighted average error is $\frac{1}{s_x^2} = \frac{1}{s_1^2} + \frac{1}{s_2^2} + \frac{1}{s_3^2} + \cdots$

$$s_x^2 = \frac{1}{\sum_{i=1}^{N} 1/s_i^2}$$

$$s_x^2 = \left(\sum_{i=1}^{N} w_i\right)^{-1/2}$$

I. Graphical Method Data Analysis

Every measurement results in errors and uncertainties. Likewise, in every data analysis, the measurement results also give rise to errors. The error value that concerns the value of the graph quantities includes the gradient *b* and the intersection point *a*. The gradient value of the line and the intersection point of the straight line made on the graph are the measurement results of the research data so that the error of the graph appears. This is because the data points on the graph have errors, so the graph line formed from these points must have an error value.

Illustrations related to errors on the graph are presented in Figure 3.4 and Figure 3.5. In Figure 1, the error value is quite large and the overall fluctuation of the points is not visible on the graph line, so the error of the data points on the graph is quite clearly illustrated.

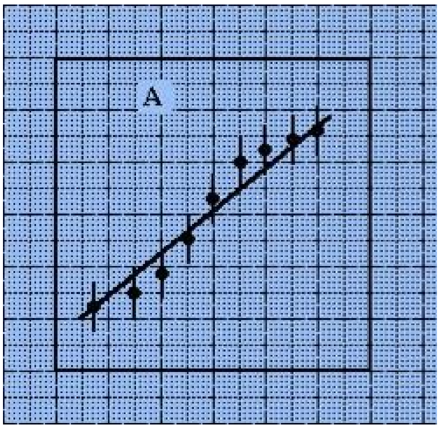


Figure 1. Illustration of Large Graph Error

In Figure 2, the error values of the data points are small, so significant fluctuations in the data are clearly visible on the drawn graph line.

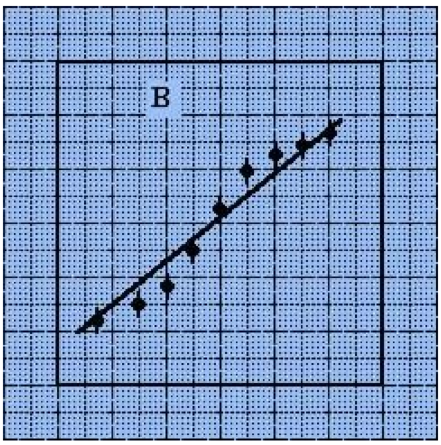
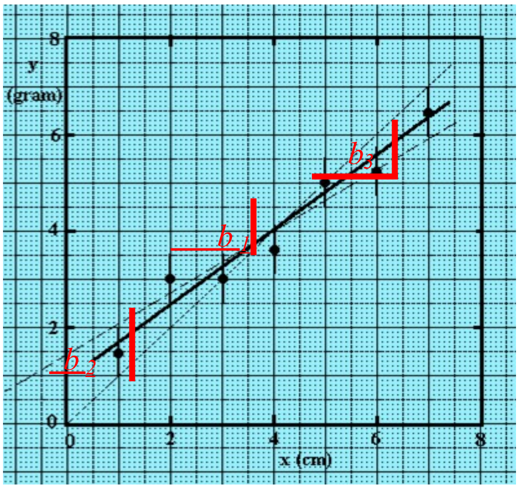


Figure 2. Illustration of Small Graph Error

In data analysis with the graph method, the graph line formed is the flow of data points. Data points on the graph either close or far from the line formed all have errors, so indirectly the graph line formed will also deviate or have a graphical error. An errored data point is depicted by a point that has a bar that is before and after the data point, so that the point can be understood as a point whose value has a range between the maximum and minimum values.

Analysis with the graph method is done by finding the gradient value formed from the straight line formed from the flow of data points. In practice, three lines are made, namely the best line with a gradient of b_1 , then added with two straight lines as the error value of the graph line with a gradient value of b_2 and b_3 . This is done because the data points visually on the graph are described as points that are worth the range between the maximum and minimum values, so the resulting graph line is also the maximum line and minimum line. The illustration is shown in Figure 3.



Line Graph Analysis (Mak-Min) Determination of the error value on the graph as follows.

The average slope value is

$$\bar{b} = \frac{b_1 + b_2 + bb_3}{3}$$

The ratio value is

Δb_1 = $|b_1$ - $b_2|$ and Δb_1 = $|b_1$ - $b_3|$

Thus obtained

$$\Delta b = \frac{|\Delta b_1 + \Delta b_1}{|\,2}$$

The straight line on the graph has the equation *y* = *a* + *bx*, if the intersection point on the *y-axis is* to be found, the value of *x* = *0 is* taken so that the value of *y* = *a is obtained*. so that the following equation is obtained.

$$\bar{a} = \frac{a_1 + a_2 + a_3}{3}$$

The ratio value is

Δa_1 = $|a_1$ - $a_2|$ and Δa_1 = $|a_1$ - $a_3|$

Thus obtained

$$\Delta a = \frac{|\Delta a_1 + \Delta a_1}{|\,2}$$

So the equation *y* = *a* + *bx* becomes

$$y = (a \pm \Delta a) + (b \pm \Delta b)x$$

Graphs as data analysis in all conditions, a researcher should look for the gradient of the line and the intersection with the coordinate axes.

MEASUREMENT METHOD INTRODUCTION ASSIGNMENT

Do the following exercise questions clearly and correctly!

1. The four numbers below are known to an accuracy of about 1%. Write them as (*x* ± Δx*)* :

   x_1 = 1202 $\qquad$ x_3 = 2.05

   $x_2 = \frac{22}{7}$ $\qquad$ x_4 = 25

2. Write down the partial derivatives (∂q/∂x) and (∂q/∂y) of the following three functions.
   a. q(x,y) = x + y
   b. q(x,y) = xy and **c** . q(x,y) = x^2 y^3

   Description: The partial derivative (∂q/∂x) of : q(x,y) is obtained from the differentiation of (q) function (x) with (y) constant as well as the partial derivative (∂q/∂y) of : q(x,y) is obtained from the differentiation of (q) function (y) with (x) constant.

3. A student takes measurements with the following results:

   A = (5 ± 1) cm $\qquad$ t = (3.0 ± 0.5) seconds

   B = (18 ± 2) cm $\qquad$ m = (18 ± 1) gram

   C = (12 ± 1) cm

   Using the existing rules, calculate the values of the following equations, presenting each with its absolute error and relative error models.
   a. (A+2B+3C)
   b. (4A)
   c. (Ct)
   d. (A + B - C)
   e. (B/2)
   f. (mB/t)

4. With the mathematical pendulum formula $T = 2\pi\sqrt{\frac{L}{g}}$, the acceleration of gravity *g is* about was determined in an experiment. The period *T is* measured at several values of the pendulum length *L*. The data obtained are as listed below. Use the graph analysis method to calculate (*g* ± Δg*)*, knowing π =

3,142 exactly.

No.	L (m)	T (secon)
1	0,60	1,56
2	0,70	1,68
3	0,80	1,80
4	0,90	1,90
5	1,00	2,00
6	1,10	2,11
7	1,20	2,20
8	1,30	2,28

5. Measurements of the speed of sound (ϑ) gave results: (334 ± 1) m/s and (336 ± 2) m/s.
    a. Are the two results consistent?
    b. Calculate the best estimate value for (ϑ) and its uncertainty

6. Determine the best estimate value and its uncertainty based on the following 4 measurements:

    (1,4 ± 0,5) ;(1, 2 ± 0,2); (1,0 ± 0,25); **(1 ,** 3 ± 0,2)

PRACTICUM 1. STRAIGHT MOTION

A. Experiment Objective

After conducting this experiment, students are expected to be able to:

1. Measuring the speed of motion of objects in GLB
2. Measuring the acceleration of object motion in GLBB

B. Tools and Materials

1. set of "*Linear Air Tarck* "
2. blower5
3. *Electronic Counter*
4. rope

. load

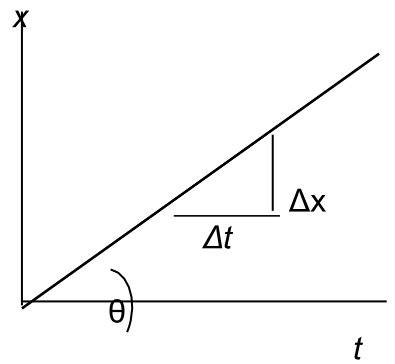
C. Basic Theory

A force acting on an object will cause it to move in a straight line. But if the force is removed, then the object will have the same speed for each time, so it is said to move in a straight line. An object moving in a straight line will apply the equation

$$v = \frac{\Delta x}{\Delta t}$$

Description: With Δx = displacement, and Δt = time interval. The

graph of the relationship between x and t can be depicted as follows



$$\tan\theta = \frac{\Delta x}{\Delta t}$$

θ = angle of inclination

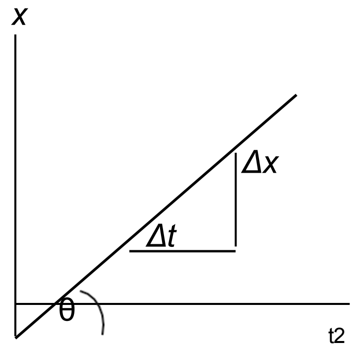
In straight motion, regular changes can be shown in the motion of an object falling from a certain height. In this motion, the speed is always changing at any time, or it can be said that the object has an acceleration of

$$a = \frac{\Delta v}{\Delta t}$$

The relationship between velocity, acceleration and displacement can be formulated as

$$v_t^2 = v_0^2 + 2ax$$

The graph of the relationship between displacement and the change in squared time is as follows



$$\tan\theta = \frac{\Delta x}{\Delta t^2}$$

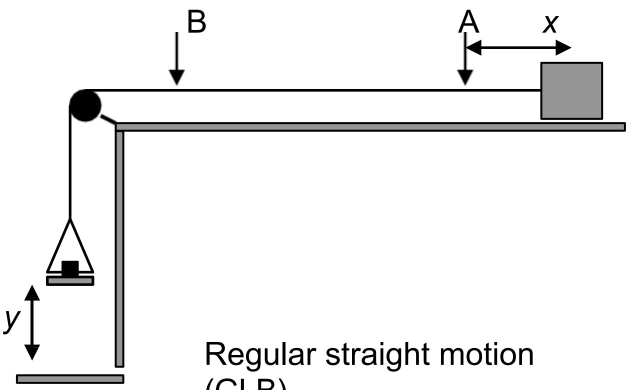
θ = angle of inclination

D. Experiment Steps

1. Preparation

a. Understand first for the introduction of the *electronic counter* function. In this case there are three types of function modes, namely: A; A + B; A + B + C. To determine the time interval traveled, in this experiment select mode A.
+ B, as A stands for input signal and B for output signal.

b. Determine the position of input A and output sensor B that will be used to record the time interval required by the displacement *Δx*.



Regular straight motion
(GLB)

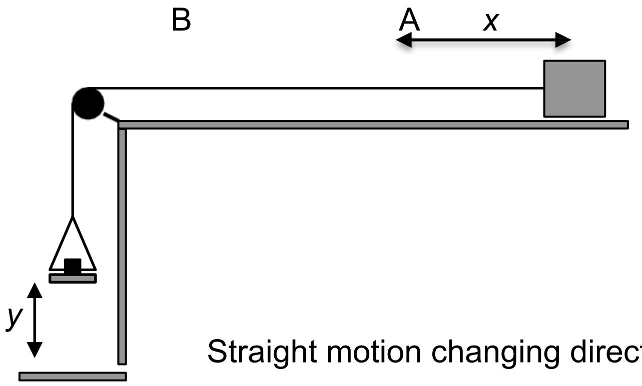
2. Measurement

a. ***Regular straight motion (GLB)***, arrange the device as shown above. In this case the distance *x is* longer than *y*, so that after the object passes through the input sensor A there is no longer an acting force (attractive force) so that the object will move in a straight line. Measure the time interval Δt

every change in distance AB. Graph Δx against Δt, and calculate the slope as the speed of the object's motion.

$$v = \frac{\Delta x}{\Delta t}$$

b. In ***straight line motion (GLBB),*** arrange the apparatus as shown below.



Straight motion changing direction (GLBB)

In this case, the distance *y* is longer than *x,* so that after the object passes through the input sensor A there is still an acting force (attractive force) so that the object will move straight and change regularly. At

This experiment uses the equation $\Delta x = \frac{1}{2} a \Delta t^2$, by measuring the interval time Δt for each change in distance AB, and graph Δx against Δt^2 . From the slope of the graph, you can determine the acceleration of the object.

E. Task/Question

1. Graph the difference between displacement and time lapse for regular straight motion.
2. Determine the initial velocity of the object in regular straight motion at each load you choose.
3. Graph the displacement with the square of the time interval in perpendicular motion.
4. Determine the amount of acceleration in a straight line motion.

EXPERIMENT 2. PEGAS FORCE CONSTANTANT (k)

A. Purpose of the Experiment

After carrying out this practicum students can :

1. Describe the effect of force on objects
2. Determining the force constant of a spring

B. Tools and Materials

The tools you will use include:

- Spring	- Ruler	- Stopwatch
- Load	- Balance Sheet	- Statip

C. Basic Theory

The impact of the force acting on an object, among others: the occurrence of changes in the motion of objects or changes in the shape of objects. Based on the nature of flexibility / elasticity is known two kinds of objects, namely:

a. ***Plastic objects***: objects that when subjected to force will change their shape but the change in shape remains even though the force has been removed. Examples of this kind of object include: clay, plasticine.

b. ***Elastic objects***: objects that when subjected to a force will change their shape, but when the force is removed the object will return to its original state. Examples: rubber, spring.

In everyday life there are many equipment using **springs**, for example: balance sheets, shock absorbers (both for motorcycles and cars), spring beds, and many more. In each equipment the function / role of the spring is different, but almost all equipment is related to the elasticity of the spring. The response of a spring to a force is indicated by a change in the length of the spring.

The relationship between load and spring length increase was proposed by Hooke. In this experiment, you will find out the characteristics of a spring's response to force by determining the spring force constant.

Constantan spring force

The crimp modulus is a quantity that describes the crimp properties of a particular material, but does not indicate directly the effect of force on the change in shape experienced by a rod, cable or spring (per) made from a particular material.

The relationship between force (F), Young's modulus (Y), cross-sectional area (A), initial length (L_o) and the change in length (strain) that occurs (ΔL) on a rod subjected to a force is :

$$F = \frac{YA}{L0}\Delta L \qquad \text{(please prove it...!)}$$

On a spring, $\frac{A}{Lo}$ is expressed as a single constant **k** and changes length ΔL is expressed by Δx then

$$\mathbf{F = k}\ \Delta x$$

The equation states that the increase in length of a suspended object is directly proportional to the amount of force pulling on it. This statement is **Hooke's Law.**

When a vine-shaped spring (per) is stretched, the change in shape of the spring wire is a combination of pulling, bending and twisting, but the overall increase in length of the spring is directly proportional to the force pulling on it. This means that the above equation still applies with the constant ratio k not being a function of the modulus of curvature.

The constant k is called the spring force constant or spring stiffness coefficient.

The units of k are newton/meter; dyne/cm; lb/ft.

Hooke's law states that the amount of force that results in a change in the shape (length) of a spring is proportional to the change in length that occurs, provided that the limit is not exceeded.

The restoring force is the force that will return the spring (object) to its original shape, determined by :

F = - k Δx

in this case the minus sign (-) states that the direction of the force and the direction of the deviation (x) are in opposite directions.

F = - k Δx

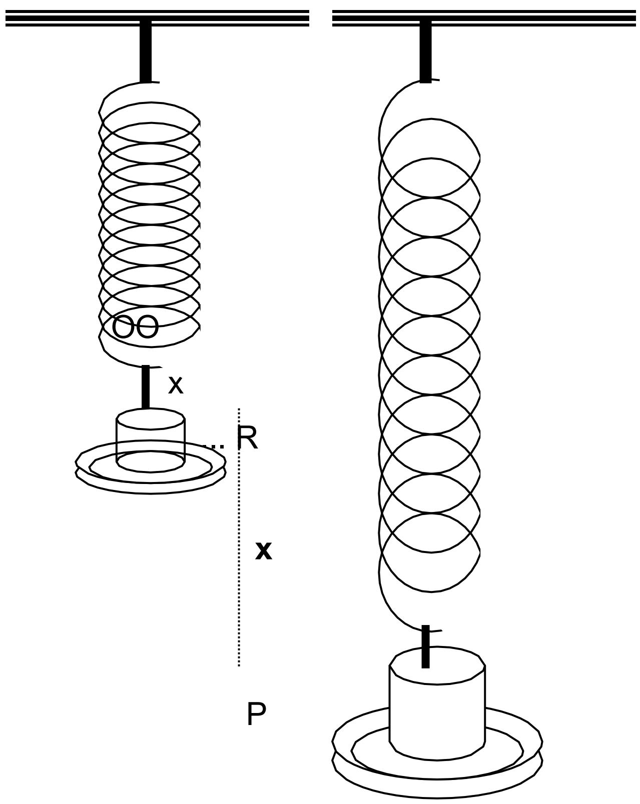


Figure 1. Spring

Figure 1 depicts an object suspended from a spring, equilibrium point at R, after a second (larger) load is applied.

spring increase length as far as RP, or as far as Δx position equilibrium. The resultant force acting on the body (at R) is only the restoring bouncy force F = - k Δx

Based on Newton's law: F = mg, then:

$$- k \Delta x = m g \quad \Rightarrow \quad k = - (mg/\Delta x)$$

in this case m is the mass of the object.

D. Trial Step

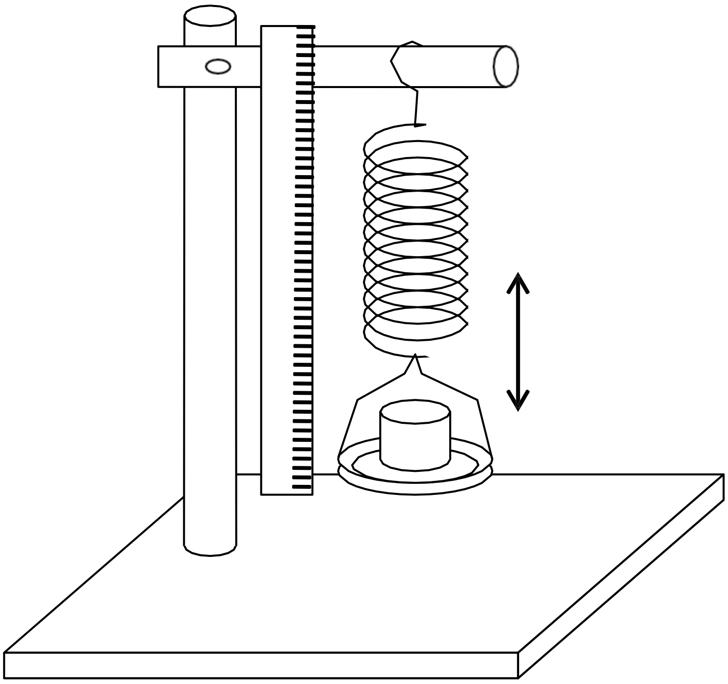


Figure 2. Tool circuit

a. Arrange the tools as shown
b. Make a table of observations from the experiment you are going to do. (as table 1)
c. Put enough weight on the spring (as little as possible) so that the spring is upright but try not to stretch the spring with the weight.
d. Add to the spring with a weight whose mass you already know (m).
e. Record the increase in length that occurs (Δx)
f. Repeat steps c and d for the other weights 10 times
g. Record your observations in the table you have made (table 1).
h. Repeat the above steps with another spring.

E. Tasks and Questions

1. Determine the spring constant k based on your observation table (calculation)
2. Determine the spring constant k based on the graph of the relationship between Δx and
   m in this case m is the horizontal axis (independent variable) and x is the vertical axis (dependent variable).
3. Compare the results of the spring force constant you obtained using Hooke's law method with the two ways of analysis

No.	*Data processing method*	*Spring 1*	*Spring 2*
1	Directly		
2	Graphically		

What is your final conclusion?

Notes: In data processing, you need to know that the acceleration of gravity in Yogyakarta is g = 980 ms^{-2} .

PRACTICUM 3. DENSITY OF SUBSTANCES

A. Experiment Objective

After conducting the experiment, students are expected to:

1. determine the density of a solid by measuring the mass and volume of the object
2. determine the density of a liquid using the concept of hydrostatic pressure.

B. Tools and Materials

1. balance arm
2. ruler, caliper
3. Measuring cup
4. liquids (water, methylated spirits, salt water)
5. solids (metals)
6. Y-pipe (Hare tool), beakerglass.

C. Basic Theory

In nature, there are three types of substances, including solid, liquid and gas. What distinguishes the properties of substances, one of which is density. Density is the mass per unit volume. The density of a substance is formulated as

$$\rho = \frac{m}{V}$$

Description:

ρ= density (kg/m^3 , g/cm^3)

m = mass (kg, g)

V = volume (m^3 , cm^3)

A liquid having density ρ with height *h*, will have hydrostatic pressure equal to

$$p = \rho g h$$

If two liquids are put in a Y pipe (by sucking), the heights of the two liquids may be different, depending on the

the density of the liquid. The smaller the density of the liquid, the higher the liquid in the pipe.

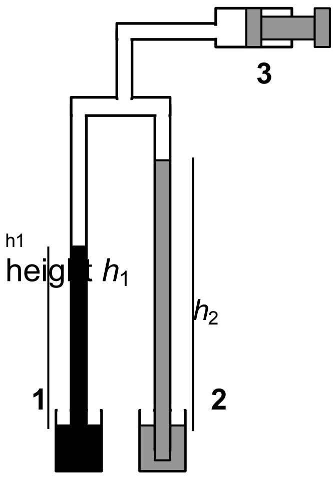
D. Experiment Step

Activity 1

1. Take a solid object of regular shape
2. Measure the length, width and height with a caliper or screw micrometer.
3. Weigh the solid with a balance sheet.
4. Measure the volume of the solid with a measuring cup filled with water.
5. Record the measurement results in the table.
6. Repeat the measurement for other solids.

Activity 2

Density of Liquid



1. Put water in glass cup 1, and the liquid to be found for density (spiritus) in glass cup 2.
2. Suck in both liquids using sucker 3 to high (pulling gently so that the two liquids do not mix).
3. Measure the and h_2 (*h* measured from the surface liquid inside the bekerglass until the surface liquid inside the glass pipe).
4. Repeat for different liquid heights with depressing the pump little by little.
5. Repeat steps 1 to 4 for another liquid, (salt solution).
6. Mass density liquid can be searched with the equation

$$\rho_1 h_1 = \rho_2 h_2$$

Description: ρ_1 = density of water (1 g/cm^3).

E. Activity

Observation Table 1

No.	Substance Name	Shape	*p* (cm)	*l* (cm)	*t* (cm)	*m* (g)
1.	....	....	....	....	....	....

No.	Substance Name	V (cm)^3	*m* (g)
	....	....	....

Activity 2

No.	Substance Name	h_1 (cm)	h_2 (cm)
	....	....	....

F. Task/Question

1. Find the density of each substance.
2. Draw conclusions from your results.

PRACTICUM 4. BOYLE'S LAW

A. Objective:

After conducting this experiment, students are expected to find the relationship between pressure and volume at a fixed temperature.

B. Tools and Materials

1. Boyle's law tool set
2. barometer
3. thermometer

C. Basic Theory

A gas at a certain volume, pressure, and temperature can undergo three processes, including isothermic (fixed temperature), isochoric (fixed volume), and isobaric (fixed pressure) processes. A gas at volume *V*, if pressed at a fixed temperature (isothermic) then vomele will decrease and the gas pressure will increase, the relationship between pressure and volume of gas at a fixed temperature, Boyle's law will apply.

$$pV = C$$

$$p_1V_1 = p_2V_2$$

The instrument used to measure outside air pressure is a barometer. At an air pressure of 1 atmosphere (atm), the height of mercury in the pipe is 76 cm. While the tool used to measure gas pressure in a room is called a manometer. There are two manometers, namely closed manometers, and open manometers

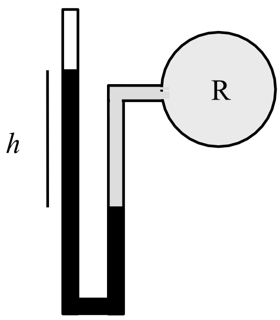


Figure a Closed manometer

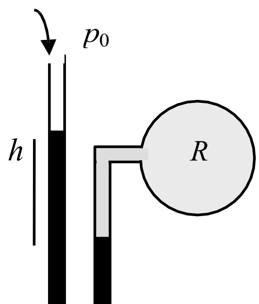


Figure Manometer open

The room pressure R in a closed manometer is

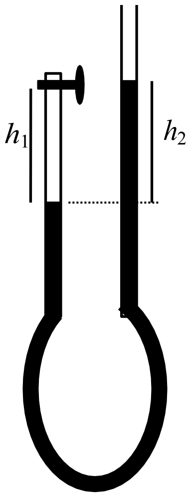
$$p = h \text{ cm Hg}$$

While the room pressure R on the manometer is open:

$$p = p_0 + h \text{ cm Hg}$$

D. Experiment Steps

Tool Schematic



1. Set the right pipe so that the mercury level of the right and left pipes are the same, and measure the height of the air column on the left pipe (h_1).
2. Raise the right pipe, measure the height of the air column (h_1) and the difference in the height of the mercury surface between left and right (h).$_2$
3. Repeat step 2 by raising or lowering the right pipe several times.
4. Measure the outside air pressure (p_0), and room temperature (T).

E. Trial Data

No.	p_0 (cm Hg)	h_1 (cm)	h_2 (cm)	T(^{o} C)
1.	....	....	....	....

F. Tasks

Graph the relationship between p and V, and draw conclusions from your experiment.

PRACTICUM 5. *GAY LUSSAC'*S LAW & GAS THERMOMETER

A. Destination

After conducting this experiment, students are expected to find the relationship between temperature and pressure of a gas at a fixed volume and its application as a gas thermometer.

B. Tools and Materials

1. gas thermometer tool set
2. beakerglass
3. thermometer
4. heater (bunsen)
5. barometer

C. Basic Theory

The process of changing the state of a gas at a fixed volume has been formulated by *Gay Lussac*, and is formulated as

$$\frac{p}{C} = \overline{T}$$

Description:

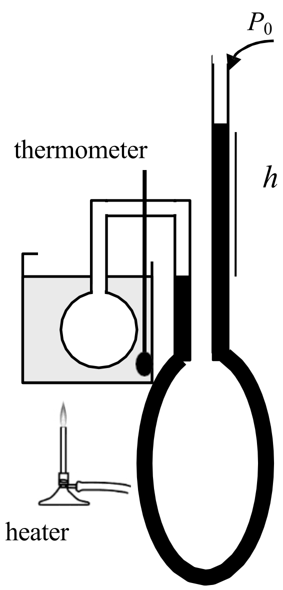
p =
pressure *T*
=
temperatur
e

If a room filled with gas is heated at a fixed volume, the pressure will rise. With this principle can be used to measure a substance. We already know that to determine a substance a thermometer is used. In liquid thermometers, in principle, two reference points are used, namely the lowest point and the highest point. In the Celsius thermometer, the lowest reference point is used ice melting point and given a scale of 0, while the highest point is used water boiling point and given a scale of 100. But the gas thermometer does not require two reference points, but only one reference point, namely the triple point of water, which is around 0 C.^{o}

When a chamber of volume *V is* heated, the volume and pressure of the gas in the chamber will increase. If the volume of the gas is kept constant, the pressure will rise. The relationship between the pressure *p* and the temperature (*T*) of the gas is the *Gay Lussac* equation, and this principle is used in the principle of a gas thermometer.

D. Experiment Step

Schematic of the device



1. Insert the glass ball into the beakerglass has been filled with water, also insert the thermometer.
2. Set the right pipe so that the mercury level is the same level as the mercury level in the left pipe. (if necessary, use ice)
3. Heat the water (turn on the Bunsen) while adjusting the right pipe so that the mercury level on the left pipe remains at the starting position (there is a difference in mercury height *h*).
4. Repeat the experiment by continuing to heat the water and keeping the mercury level in the left pipe fixed and recording *h*.

E. Trial Data

No.	p_0 (cm Hg)	*h* (cm)	*T* (K)
	....	....	....

F. Tasks

1. Graph the relationship between temperature (*T*) and pressure (*p*).
2. Graph the relationship between temperature (*T*) and gas pressure (*1/p*).
3. Draw conclusions from the results of your experiment.

EXPERIMENT 6. ELECTRICAL HEAT EQUIVALENCE

A. Experiment Objective

After conducting the experiment, students are expected to be able to :

1. Determining the magnitude of energy heat/calor that received calorimeter based on Black's principle
2. Determine the equivalence value (heat - electricity).

B. Tools and Materials

1. electric calorimeter
2. *power supply* (DC power supply).
3. *stopwatch*.
4. Thermometer

C. Basic Theory

In this experiment, the released electrical energy will be received by water and calorimeter. Based on Blak's principle that the heat / heat released is equal to the heat / heat received, the electrical energy released will be received by the water in the calorimeter and the calorimeter (including the stirrer) itself, so there will be heat changes in water and calorimeter. The amount of heat required to raise the temperature of a substance is expressed by the equation:

$$Q = mc(T - T_a)$$

m: mass of substance (g)
c: specific heat of substance (cal/g^o C) *T*: initial temperature of substance (^{o} C) T_a : final temperature of substance (^{o} C)
Q: amount of heat required (cal)

In this experiment we are dealing with two forms of energy, namely heat energy and electrical energy. The electrical energy produced by a power supply on a resistor is expressed by the equation:

$$W = VIt$$

Description:

V : voltage (volts)
I : electric current (Ampere)
t : time/length of electricity flow (secon)
W : electrical energy (joules)

The value of electric heat equality can be expressed by the equation

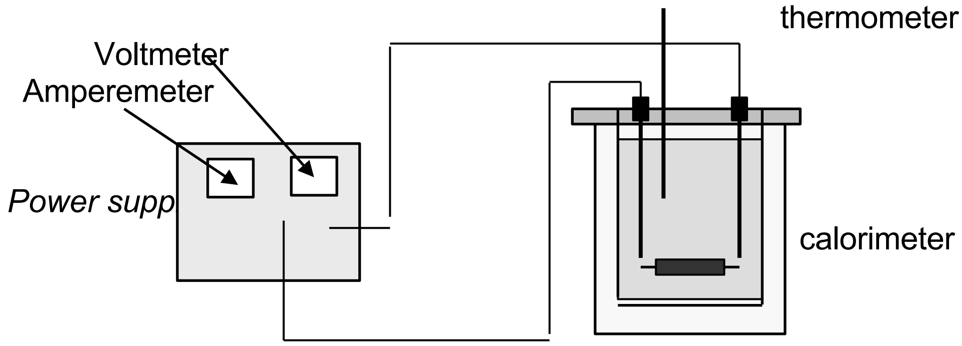
$$\gamma = \frac{VIt}{(mmck + maca)(T1 - T2)}$$

Description:

V : voltage (volts)
I : electric current (Ampere)
t : time/length of electricity flow (secon)
m_k : mass of empty calorimeter and stirrer (grams)
c_k : specific heat of calorimeter (cal/gr^o C)
m_a : mass of water in the calorimeter (grams)
c_a : specific heat of water (cal/gr^o C) T_1 : initial temperature of substance (^{o} C) T_2 : final temperature of substance (^{o} C)

D. Experiment procedure

a. Circuit Schematic



b. Experiment Steps

1. Install the electrical circuit as shown above and notify the supervisor/assistant first to check before the power supply is turned on.
2. Weigh the empty calorimeter (inner vessel) and the stirrer. Record the mass of the empty calorimeter.
3. Put enough water in the calorimeter (the coil filament is submerged all or more than half) and weigh again. Record the mass of water in the calorimeter.
4. Install the calorimeter and set the current and voltage on the *power supply* for a certain *I* and *V* price (current *I* and *V are* directly read on the *power supply*).

The ammeter and voltmeter are included in the *power supply*), thus no external ammeter and voltmeter are used.

5. Turn on the *power supply* switch at the same time as starting the timer (*stopwatch*). Stir the water slowly.
6. Record the water temperature every few minutes, until the desired water temperature is reached.

E. Data Tabulation

No.	m_k (grams)	m_a (grams)	V (volts)	I (A)	t (minutes)	T (^{o} C)
	....	....	....	....	....	....
					....	....
					....	....
					....	....
					....	....
					....	....
					....	....
					....	....
					....	....
					....	....
					....	....
					....	....

F. Task/Question

1. Determine the value/number of the heat-electric equivalence
2. Do discussion on results experiment You then draw a conclusion.

PRACTICUM 7. ROPE WAVES (MELDE)

A. Destination

After conducting this experiment, students are expected to be able to:

1. Shows the waveform of a string
2. Determine the speed of a wave on a string

B. Tools and Materials

1. Melde device
2. scale
3. load

C. Basic Theory

If a string is vibrated at one end, a traveling wave is formed. If one end of the rope is vibrated and the other end is made fixed, there will be interference of the incident wave with the reflected wave, so that it will form a stationary wave. The tool that can show the existence of stationary waves on a rope is the **Melde experiment**. The speed of propagation of a stationary wave on a rope is formulated as

$$v = \sqrt{\frac{F}{\mu}}$$

Description:

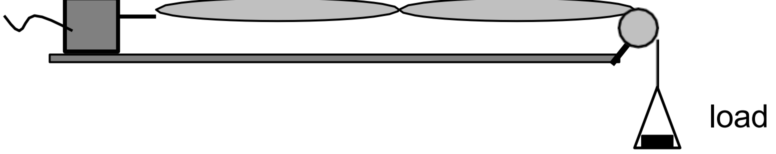
v = wave speed (m/s)
F = tensile force (N)
μ = mass/length rope density (g/cm; kg/m). $\mu = \frac{m}{L}$

The magnitude of the wave propagation rate can generally be written as

$$v = f\lambda \quad \text{or} \quad v = \frac{\lambda}{T}$$

Description:

v = wave propagation speed
f = frequency
λ = wavelength
T = period



D. Experiment Steps

1. Prepare the necessary equipment.
2. Measure the length of the rope (*L*) and measure μ or *m/L*.
3. Connect the Melde device to an ac power source.
4. Give load on place load so that at rope forming stationary wave pattern.
5. Count the number of stomachs that occur.
6. Repeat for another number of bellies, adjusting the amount of rope tension force.
7. The vibration frequency is considered equal to 50 Hz.

E. Task/Question

1. Determine the speed of propagation of rope waves at various voltages.
2. Draw conclusions from the results of your experiment.

EXPERIMENT 8. RESONANCE IN AN AIR COLUMN

A. Experiment Objective

After conducting the experiment, students are expected to be able to :

1. Indicates the occurrence of resonance in the air column.
2. Measuring the rate of sound in the air.

B. Tools and Materials

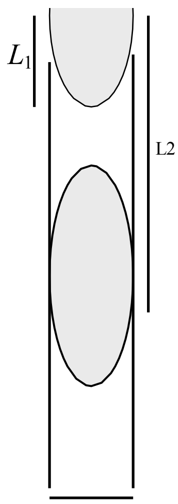
1. glass tube
2. water
3. amplifier
4. speaker
5. scale
6. AFG
7. water reservoir

C. Basic Theory

If sound enters the air column and then hits the water surface, the sound waves will be interfered with the incident wave and the reflected wave. The interference can be called resonance between the incident sound wave and the reflected sound wave. The occurrence of resonance is characterized by the occurrence of loud sound. At the time of resonance will apply:

First resonance

$$L_1 = \frac{1}{4}\lambda + k$$



Second resonance

$$L_2 = \frac{3}{4}\lambda + k$$

If the length is subtracted, the following applies

$$L2 - L1 = \frac{1}{2}\lambda$$

In general, it can be formulated

$$\lambda = 2(L_n - L_{n-1})$$

In this case

n = number of resonances λ = wavelength (cm, m)

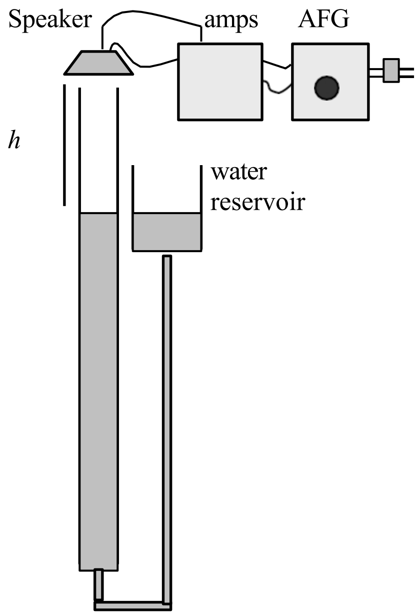
L_n = *nth* air column length (cm, m)

Knowing the wavelength of sound and the frequency (from the AFG), the rate of sound in the air at the temperature being measured can be determined.

$$v = f\lambda$$

Description: f = frequency (Hz)

D. Experiment Steps



1. Arrange the apparatus as shown in the side image.
2. Turn on the AFG and amplifier.
3. Determine the frequency of the sound source (AFG), for example 400 Hz. And set the intensity of the sound so that it is very low (not loud).
4. Lower the water tendon until the loudest sound is heard, then confirm the position of resonance by raising or lowering slightly at the position of resonance. (Note L_1 : when the first resonance occurs).
5. Continue lowering the water tendon until the second resonance occurs. (Note L_2 : when the 2nd resonance occurs).
6. Repeat steps 3 to 5 for the other frequencies.
7. Measure the room temperature.

E. Tabulation of Observation Data

No.	Frequency f (Hz)	L_1 (cm)	
1.	....	....	....
2.	....	....	....

Room temperature: .... C°

F. Tasks

Determine the rate of sound in air at a given temperature/room.

LITERATURE

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APPENDIX

Appendix 1. Physical quantity constants

1. Density of Some Substances

Material	ρ (g/cm)^3	Material	ρ (g/cm)^3
Water	1,00	Glycerin	1,26
Aluminum	2,7	Brass	8,6
Steel	7,8	Silver	10,5
Benzene	0,90	Platinum	21,4
Iron	7,8	Raksa	13,6
Gold	19,3	Copper	8,9
Es	0,92	Black tin	11,3
Ethyl alcohol	0,81		

2. Density and volume of water

t C^o	ρ (g/cm)^3	v (cm^3 /g)
0	0,9998	1,0002
4	1,0000	1,0000
10	0,9997	1,0003
20	0,9982	1,0018
50	0,9881	1,0121
75	0,9749	1,0258
100	0,9584	1,0434

3. Specific Heat of Substance

Metal	Specific Heat *c* (cal/g C)^o	Temperature Region (^{o} C)
Aluminum	0,217	17 - 100
Beryllium	0,470	20 - 100
Iron	0,113	18 - 100
Silver	0,056	15 - 100
Raksa	0,033	0 - 100
Copper	0,093	15 - 100
Lead	0,0031	20 - 100

Source: (Sears, 1985)

4. Vapor Pressure or Boiling point of Water

T_d (^{o} C)	Vapor Pressure (cm Hg)
0	0,458
5	0,651
10	0,894
15	1,267
20	1,75
40	5,51
60	14,9
80	35,5
100	76
120	149
140	271

160	463
180	751
200	1.165
220	1.739

Source: (Sears, 1985)

Practicum Report Format

EXPERIMENT REPORT

An experiment or research report should include the following components:

- Experiment Title/Topic
- Purpose of the Experiment
- Basic Theory / Hypothesis
- Experiment Method
- Data Analysis Discussion
- Conclusion
- Suggestions (if any)
- Bibliography

The report should not be too long, the writing style should be short and clear, not long-winded as this will only irritate the reader. The length of the report should be tailored to the content of the experiment; it may be long due to the number of sample observations that need to be discussed, or the depth of the discussion.

Experiment Title/Topic

The title should be brief as it is an identification of the report. For example, for an experiment to check Ohm's Law, it is sufficient to write the title 'Ohm's **Law',** and not '**Proving Ohm's Law with direct current'**. The second title is too long, a more detailed explanation of the title can be given in the introduction or introduction to the report.

Purpose of the Experiment

In the objective section, it is explained specifically what the purpose of our experiment is. Taking the title of the experiment above, "Ohm's Law", the objective might take the form of:

1. Examination of Ohm's Law $V = R\,I$ on a Cu wire;
2. Formula relationship check: Serial and Parallel Resistance $R_{seri} = R_1 + R_2$

   $$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

So just like the title; the purpose of the experiment is also quite "short, but clear", which is better and more interesting.

Theoretical Basis and Hypothesis

- **Basic Theory:**

  In the theory section, a brief but complete description of the experimental theory is given. The description will be clearer if accompanied by pictures, circuits, diagrams, and so on, this is to make it easier to understand the material to be worked on. If there are several important formulas, they should be numbered sequentially. Formulas that must be proven, we give the proof, if necessary by mentioning the reference book.

  The theory in the practical instruction should contain an explanation of the theory, which is adapted and complemented by materials taken from the reference book; this will make it easier for practitioners to explore further and add insight when discussing the results of their experimental analysis.

- **Hypothesis:**

  Hypothesis is a scientific conjecture based on observable symptoms, and its truth will only be revealed if the results of the analysis of observational data show a match. Hypotheses can be in the form of predictions of mathematical function relationships that connect physical quantities to one another, as well as "statements", which are sentences that explain something scientific and based on clear scientific laws.

Experiment Method

- **Equipment:**

The equipment used may be briefly described. First, about its accuracy. Especially tools that play an important role in the experiment, describe in detail in an effort to reduce the incidence of systematic errors and observation errors caused by these tools, this is very important because the main tool in data collection. Give a brief description of how the measurements were carried out, so that others who read enough can replicate well without any doubt of the procedure. The resulting data is recorded along with the uncertainty and units of the observed quantities. This data should not be processed, but presented in an attractive form, for example in tabulation. Number them sequentially if more than one list is required.

- **Experiment Design and Procedure**

A sequence of steps explaining the procedure for obtaining observational data. This must be described in detail and sequentially, especially regarding numerical issues that must be observed in the measurement. Sometimes it needs attention words, for example: wait 5 minutes then mix the following ingredients ....; etc.

Data Analysis

- Data Processing:

Data processing or calculations are carried out and reported directly without much comment, mention the form of the formula on which the observation is based, and the related data and calculation results are directly entered into the report. Describe the method of calculating the uncertainty or error of your measurement. The final result which is the result of the presentation of the value and its error is written clearly, with the right meaningful numbers, so that the experiment can be assessed accurately and can be accounted for.

In the preliminary calculation (before the final), all calculation numbers should be included (do not round). Only at the end of the final calculation, we determine the number of important numbers (this needs to pay attention to the measurement error value).

If the final results are obtained using the graphical method, the calculations are carried out using graphs, so a correct graphical drawing (meeting the rules of graphical analysis) is required. The scale value on the graph plays a role in the analysis, so careful installation of the scale will greatly affect the analysis results.

- **Observation Chart:**

Observation graphs become a very important part if data analysis is carried out using graphic methods. In this case, the graph is not just a data display, but really a phenomenon of the observed symptoms to be analyzed, so the way to draw the graph must be correct, fulfilling the rules of graph analysis.

Discussion:

The discussion is a response from the observer to examine whether the results are in line with scientific expectations; or whether there are deviations. If it turns out to be appropriate but has not achieved high accuracy, it is necessary to explain the weak points, and why it cannot be achieved well or perfectly. What are the obstacles to achieving it. Conversely, if the results obtained deviate far from scientific expectations, it must be able to indicate the source of the error, and the efforts that have been made to overcome the source of the deficiency. This way, the reader is not disappointed and still appreciates us for conducting experiments, and does not think that the mistakes we make are because we are stupid; but because we are hampered by the limitations of the existing equipment. So that when we get a better / more accurate / sophisticated tool, our problems can be overcome.

Conclusion

The conclusion contains some information that contains :

1. Did your experiment achieve its goal?
2. Show your results and how much accuracy did you achieve?
3. Point out your strengths and weaknesses
4. Compare with reference values (if any); and provide a description if there is a large discrepancy.

Suggestions

In this case, respond to your results in detail. For example, you may suggest improvements to the experiment, both in terms of the measurement method and the equipment used. Or we can suggest the next measurement or experiment that is held as a follow-up. The point is that the suggestions we make are steps to improve the experiments we do so that in the future they can be continued to obtain more perfect values.