PRACTICE GUIDE

BASIC PHYSICS

BACHELOR OF PHYSICS PROGRAM
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FOREWORD

The basic physics practice handbook is compiled to be used as a basic physics practice guide. Although it seems simple, this guidebook is an evolution over several years by considering the lecture material and practical skills so that the implementation of the practicum is easy and of high quality.

Before doing the practicum, students must already understand the practice material so that they can plan the data to be taken, using millimeter paper for graphs and stationery or complete drawings.

The complete practice includes assembling tools, making observations and measurements. Meanwhile, the complete report contains data processing and experimental analysis which must be submitted one week after the practice to the basic physics laboratory.

That's our foreword. Hopefully this book is useful and adds knowledge and skills, thank you.

Semarang, September 2023
Basic Physics Laboratory Team

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BASIC PHYSICS PRACTICE RULES

Practice Card
1. Each practitioner will get a practice card determined by the laboratory.
2. Each practitioner is required to bring a practice card when carrying out practice activities.

Introductory Assistance
1. Before all practice activities began, a preliminary assistance was held to get to know the practice tools.
2. All practitioners are required to attend preliminary assistance.
3. There are four things that must be carried out in each experiment: pretest, practice, validation of experimental results and official report.
4. The pretest is carried out before the practice starts in oral or written form, if you do not pass the pretest, you are not allowed to take part in the practice (repeat the pretest).

Validation of Experimental Results
1. The results of the experiment (observation) are presented in the form of a provisional report.
2. The current report is declared valid if there is a signature from the assistant
3. Provisional reports are made in duplicate $n+1$ with n being the number of practitioners in one squad
4. Provisional reports, one sheet is submitted to the laboratory as an archive, while the other sheet is brought by the practitioner to be attached in the official report (official report is made per individual not per group)

White Paper
1. The official report must be made handwritten in the report format provided.
2. The graph is made on a block of millimeter paper.
3. Practitioners who do not submit official reports at the specified time are not allowed to participate in the next practice activities.

Rules of Conduct
1. During the practice, the practitioner is prohibited from leaving the room without permission from the assistant coordinator.
2. During the practice, the practitioner must be at their respective desks
3. During the practice, there are only the necessary stationery on the practice's desk, while all bags and others are placed in the closet provided.
4. During practice activities and collecting reports, it is not allowed to wear t-shirts, all types of sandals, jackets and hats
5. All activities related to the basic physics practice are only carried out in the basic physics laboratory, practitioners are prohibited from providing assistance outside the basic physics laboratory.

Must Attend
1. Each practitioner is required to come to all attendance and practice at the predetermined time.
2. Practitioners who are absent three times without a valid reason will be sanctioned not allowed to continue practicum activities.

ERROR THEORY

Introduction

The purpose of measurement is to know the true value of a quantity measured. This cannot be achieved exactly. The value obtained is always different from the actual value or has a difference even though the difference may be very small. In this regard, it is said that in measurement there are always errors or errors. So the effort in measurement is to obtain the value with the smallest possible error.

Types of Errors

Judging from the cause, errors or errors are divided into three types, namely:

1. **Systematic Errors**
   Systematic errors are errors that are fixed and are caused by:
   a. Tools: wrong tool calibration, e.g. wrong scale division, changing tool conditions and etc.
   b. Observer: The observer's inaccuracy in reading, e.g. reading the scale
   c. Physical condition of the observer: The fissive condition at the time of sealing does not correspond to the time the tool is marked
   d. Observation method: The inaccuracy of the selection of the observation method will affect the observation results

2. **A Chance Error**
   In repeated measurements for the physical quantity that is considered fixed, it turns out to give different results. The errors that occur in this observation are called coincidental errors. The causative factors are:
   a. Estimation errors: Suppose the smallest-scale price estimation by an observer will differ from time to time or by one person to another
   b. Physical conditions change: Suppose as the pressure changes it will affect the temperature measurement of the boiling point of the water
   c. Interference: Suppose mechanical vibration affects the movement of the millimeter needle so that the readable current changes
   d. Definition: Suppose the measurement of the diameter of the pipe, because the cross-section of the pipe is not perfectly round but is considered round, thus affecting the measurement of the diameter

3. **Actions confusion error**
   There are two things wrong with the action in the experiment for the observer
   a. Wrong: E.g. wrong reading of the scale, wrong setting of the condition of the tool, incorrect calculation (e.g. swing 10 times counted 9 times)
   b. Errors in calculations especially in error calculations

Error Calculation

From the description, it can be concluded that errors in measurement are unavoidable, which can only be done to minimize the error to the smallest extent. If errors of action mistakes and systematic errors can be avoided, then what cannot be avoided is accidental errors. To minimize this error, repeated measurements must be made, the more the better. But not all observations can be repeated, in some cases the practitioner can only make observations once. Therefore the error is the smallest half scale (for this can only be done if the situation is really forced).

In calculating errors caused by coincidental errors, there are two things that must be taken into account, namely errors in direct observation and calculation errors (creep errors) as follows:

1. Observation Error

For the quantity obtained directly from measurement (observation), the best value is the average value of the quantity (which is measured repeatedly). Suppose a quantity of x is measured k times with the measured mean value being $x_1, x_2, x_3, \dots, x_k = x_i$, then the best value is $\bar{x}$ i.e. :

$$\bar{x} = \sum_{i=1}^{k} x_i \quad (1)$$

While the difference between measured values and $\bar{x}$ is called the deviation δ which can be written as

$$ðx_i = (x_i - \bar{x}) \quad (2)$$

It can be proven that if what is taken as the best value is $\bar{x}$ of the measured values, then the sum of its squared deviations is the minimum, i.e. $\sum_{i=1}^{k} ð^2 x_i$ is a minimum. To quantitatively show a coincidence error (error), several definitions are defined:

Average standard deviation:

$$S_{\bar{x}} = \sqrt{\frac{\sum_{i=1}^{k} ð^2 x_i}{k(k-1)}} \quad (3)$$

Fractional or relative mean deviation:

$$A = \left(\frac{a}{x}\right) 100\% \quad (4)$$

Fractional or relative standard deviation:

$$S = \left(\frac{S}{x}\right) 100\% \quad (5)$$

The results of the measurements presented are:

$$x = \bar{x} + \Delta x \quad (6)$$

With Δx it can be taken *s/2, s, 2s* or several times *s* depending on the observer. Meanwhile, the relative error is used equation (5).

To express the uncertainty (error) of the measurement of the measurement of the relative error of the equation (4) is used. In the experiment carried out in this basic physics practicum, for Δx is taken equal to S_x (equation (3)) and this Δx is often referred to as an absolute error, While relative or relative errors are of course the same as:

$$\frac{\Delta x}{x} \times 100\% = \frac{S_x}{x} \times 100\% \quad (7)$$

So the final result of the measurement is $\bar{x} + S_{\bar{x}}$, with the relative error equal to equation (7) and the accuracy is 100% minus the relative error.

Example:
A metal rod is measured 10 times with the following results:

Measurement (i)	Measured value x_i (cm)	Deviation $(x_i - \bar{x})$ (cm)	Deviation squared $(x_i - \bar{x})^2$
1	47.51	0.02	0.0004
2	47.49	0.00	0.0000
3	47.48	-0.01	0.0001
4	47.50	0.01	0.0001
5	47.47	-0.02	0.0004
6	47.49	0.00	0.0000
7	47.48	-0.01	0.0001
8	47.46	-0.03	0.0009
9	47.53	0.04	0.0016
10	47.49	0.00	0.0000

Number of measurements $k = 10$

$$\sum_{i=1}^{k} x_i = 474.90; \quad \sum_{i=1}^{k} (ðx_i)^2 = 0.0036$$

So the best value of $\bar{x} = \frac{474.90}{10} = 47.49$ cm

While the standard deviation is average $S_{\bar{x}} = \sqrt{\frac{0.0036}{10(10-1)}} = 0.007$

Therefore the true value of x is $x = \bar{x} \pm S_{\bar{x}} = 47.490 \pm 0.007$ with the following:

$$100\% - \left(\frac{0.007}{47.490}\right) 100\% = 99.986\%$$

Propagation Error

If a physical quantity is not directly measured but is calculated from its elements, suppose the volume of a cube is calculated from its measured sides, velocity is calculated from the distance traveled divided by the time traveled, and so on. In the measurement of the sides of the cube or the distance and travel time, there is clearly an error, so in the calculation of volume and speed there will be errors as well. The errors (errors) that arise from this calculation are called calculation errors or propagation errors. Mathematically, if a quantity is a function of the variables *x, y* and *z*, or *f = f*(*x,y,z*)*,* then the best value is *f = f*(*x,y,z*). While the standard deviation is the average ss the value of uncertainty can be formulated as follows:

$$S_r = \sqrt{\left(\frac{\partial f}{\partial x} s_x\right)^2 + \left(\frac{\partial f}{\partial y} s_y\right)^2 + \left(\frac{\partial f}{\partial z} s_z\right)^2} \tag{8}$$

With *x, y* and *z* as the measured variables and Δ*x,* Δ*y* and Δ*z* as the measurement errors of the variables *x, y* and *z* and *Sr* are the standard deviations for the propagation error. If the measurement is taken only once, the values Δ*x,* Δ*y* and Δ*z* are taken from half the measurement scale. Meanwhile, if the measurements are carried out repeatedly , the values *of x, y* and *z* are taken from the average measurement, then:

$$\bar{x} = \frac{\sum x_i}{n};\ \Delta x = \sqrt{\frac{\sum(x-\bar{x})^2}{n(n-1}} \quad (9)$$

$$\bar{y} = \frac{\sum y_i}{n};\ \Delta y = \sqrt{\frac{\sum(y-\bar{y})^2}{n(n-1}} \quad (10)$$

$$\bar{z} = \frac{\sum z_i}{n};\ \Delta z = \sqrt{\frac{\sum(z-\bar{z})^2}{n(n-1}} \quad (11)$$

With *n* is the number of measurements. So that at the end of the calculation x can be written $x \pm S_r$, where *x* is the result of the calculation while S_r is the value of the propagation error. So that at the end of the entire calculation it can be written as $x_b \pm S_b$ which shows one value that represents the entire calculation result.

Things to look out for

1. For a single observation, that is, a measurement that is made only once (can only be done if circumstances force it), then as an absolute error it is customary to take the smallest half of the scale.
2. Relative errors, should be written with two important numbers, for example, the result of calculating a relative error of 1.53% is taken to 1.5%.
3. If the direct measurement is meticulous to 4 digits after the comma, then the final result should be a maximum of 3 digits. If it turns out that in the calculation 6 or more numbers are obtained, it must be rounded to 5 numbers after the comma.
4. The decimal number of the error taken is equal to the decimal number of the average price.

GRAPHIC

1. Introduction

Each basic physics practicum is expected to know how to use graphs properly and appropriately, because graphs are very helpful in evaluating data. Its uses are very large, including:

a. It is very helpful through the visual *aid*; that is, by observing the shape of the graph, the observer can already take in a lot of information. By putting on paper the graphs of the magnitude observed during the experiment can be seen with just one glance, where or when there begins to be a difference between the observation and the calculation results.
b. To compare experiments with theories.
c. To show the empirical relationship between two quantities even though people have not had time to investigate how the theoretical relationship between the two experimental quantities is with each other

2. Creating Graphics

What must be considered in making a graph is first which quantity to plot on the vertical axis and which quantity on the horizontal axis. As an agreement, the quantity plotted on the horizontal axis is the magnitude of the cause and on the vertical axis is the magnitude of the effect. Then the appropriate scale must be selected for both axes.

a. Straight line graph (slope graph)

Many experiments have the results of which can be displayed in the form of a graph that follows a straight line equation:

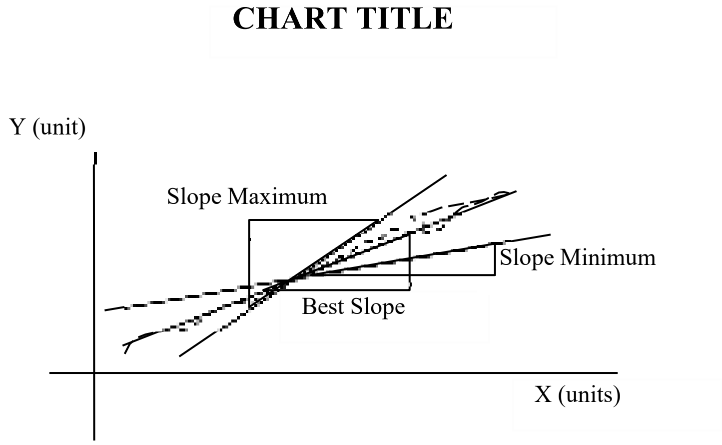
$$y = mx + c \tag{14}$$

With *m* as the line gradient and *c* as the cut-off point constant with respect to the y-axis, the value *m* and *C* is usually used to determine various parameters according to the purpose of the experiment. If the equation that applies in experimental theory can be brought into the equation (14), then it is possible to relate the physical quantity to be searched with the slope (directional tangent) of the graph obtained based on the experimental data. It must be determined that the directly measured quantities will be plotted on the vertical and horizontal axes.

By knowing the slope (gradient) of the graph (*m* in equation (14)) then the value of the physical quantity sought can be obtained. To determine the size of the graph slope the most important thing is to draw the best straight line. The straight lines created should be such that many data points are exposed to the lines. The spread of data points should be as much around the line as possible. From this best line, it can be calculated that the slope is proportional to the physical quantity to be sought. The best slope value (gradient) is found with the equation:

$$m = \frac{\Delta y}{\Delta x} = \frac{(y_2 - y_1)}{(x_2 - x_1)} \tag{15}$$

Where *m* is the slope value, (x_2, x_1) is the last coordinate passed by the slope line, and (x_1, y_1) is the first coordinate that the slope line crosses.



To find slope errors, it is searched by its outermost data points so that the extreme slope values (maximum and minimum) and the slope error values are:

$$\Delta slope = \frac{|slope\ max - slope\ \min\ |}{2} \qquad (16)$$

Thus the best presentation of the slope is the best slope $\pm$ Δslope. Then from the slope value, it is used to find the desired variable value from the experiment carried out.

b. Graphs are not straight lines (analysis graphs)

Not all experiments can be made straight line charts (e.g. K-2 and L-3 etc), so there is no need to force to make a straight line. By including the magnitude in ordinates and abscesses, the form of the graph is only in the form of observations not for calculation. So here the physical meaning of the graph is emphasized, so careful observation is needed to be able to analyze what is observed.

Things to look out for when creating a chart

a. The points should be made circular or otherwise
b. The scale and zero point should be arranged in such a way that the graph is easy to read, meaning that the zero point does not have to be centered cross-axis and the value of the ordinate scale does not have to be the same as the abscess scale.
c. The graph should be given the most complete description including units on the ordinate and abscess scales.
d. If you are not sure about the shape of the graph, then you should draw a curved line (not a broken line) that runs through almost any point.
e. Always try where necessary to interpret the graph, for example linear, exponential relationships and others.

SPRING EXPERIMENT

Purpose of the Experiment
Determine the value of the spring constant.

Necessary tools
A spring, weight, stopwatch, roll bar.

Theoretical basis

If a material can stretch or shrink due to the influence of external forces and can return to its original state if the force acting on it is removed, then it is said to have elastic properties (e.g. Spring). As long as its elasticity limit has not been exceeded then the change in the length of the spring will be proportional to the force acting on it, according to Hooke's law stated as follows:

$$F = -kx \tag{1}$$

Where **F** is the force (N), k is the spring constant (N/m) and **x** is the change in the length of the spring (m).

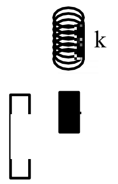


Figure M-1.1a. Spring loading

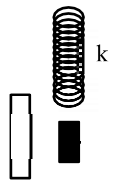


Figure M-1.1b. Spring

When a spring is loaded with a mass m, the force that causes the spring to increase in length is the weight force of that mass, so it applies:

$$mg = kx \tag{2}$$

With g is the acceleration of gravity (m/s2).

In addition to the loading method, the spring constant k can be searched by means of vibration on the spring. An object with a mass m is charged on a spring and deflected from its equilibrium position, then a spring vibration with a vibration period T will occur as follows:

$$T = 2\pi\sqrt{\frac{m}{k}} \tag{3}$$

How it works
Loading Method

1. Determine the weight mass.
2. Put the spring on the stand.
3. Measure the length of the spring without load, and after the load has been applied.
4. Repeat with different load masses.

Vibration (Oscillation) Method

1. Determine the weighting mass.
2. Put the spring on the stand.
3. Pull the load then release it.
4. Note the time it takes for the spring to oscillate.
5. Repeat with different load masses.

Tasks and discussions

1. How do you conclude about the value k obtained from the loading method and the oscillation method?
2. Which is a better way to define k?

STOKES VISCOSIMETER EXPERIMENT

Purpose of the experiment
Determine the viscosity coefficient of the liquid substance.

Necessary tools
Scaled glass pipes, Micrometers of couplers, Marbles of various sizes, Glycerin, Stopwatches, Tweezers, Drip pipettes, Digital balance.

Theoretical basis
A marble moves in a static liquid, then the marble will act as an obstacle force, according to Stokes' magnitude of the force:

$$r = 6\pi\eta r v \tag{1}$$

By η is the viscosity of the liquid substance (Pa.s), v is the velocity of the marbles (m/s), r is the radius of the sphere (m). When the marbles fall vertically, the marbles also act with a force of weight as follows:

$$W = \frac{4}{3}\pi r^3 \rho g \tag{2}$$

3
Where ρ is the density of the marbles (kg/m^3), g is the acceleration of gravity (m/s^2).

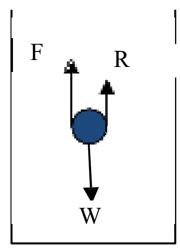


Figure M-2.1. Styles that work on marbles

In addition to the two styles above, there is also a large Archimedes buoyancy force.

$$FA = \frac{4}{3}\pi r^3 \rho_0 g \tag{3}$$

With ρ_0 is the density of the liquid substance (kg/m^3).
The change in the velocity of the marbles is proportional to the impetusal force so that the amount of terminal velocity (vT) will be achieved, which is the state of equilibrium between the gravitational force, the Archimedes buoyancy force and the Stokes drag force, which can be written as:

$$W = R + F_A \tag{4}$$

By substituting equations (1), (2) and (3) to equations (4), the equation is obtained:

$$\eta = \frac{2r}{9V_T}(\rho - \rho_0) \text{ (Prove!)} \quad (5)$$

With *vT* is the terminal speed of the marbles (m/s). Equation (5) applies to *vT* that is not too large so that turbulence currents do not occur. The unit of viscosity in cgs is Poise.

How It Works

1. Measure the mass and volume of the marbles to obtain the density of the marbles.
2. Measure the mass and volume of glycerin to obtain the density of glycerin.
3. Drop the marbles on the glycerin surface and measure the travel time of the marbles to a certain depth.
4. Repeat the experiment with variations in depth and marbles of different sizes.

Tasks and discussions

1. Calculate the value of the liquid η based on equation (5) and by using a graph!
2. Compare the results of η values on marbles of different sizes, is there a difference? Analyze!

MOMENT OF INERTIA EXPERIMENT

Purpose of the experiment

Determine the moment of inertia of an object and compare the moment of inertia between the principle of geometry and the oscillation of torque.

Tools used

Inertial moment tool, Solid ball, Solid cylinder, Hollow cylinder, Wooden disc, Solid cone, Time counter, Light gate, Roll crossbar, Digital balance.

Theoretical basis of geometric shapes

A point of mass with a mass *m* is at a distance *r* from the axis of rotation hence the moment of inertia (*I*) is

$$I = \sum mr^2 \tag{1}$$

For a continuous object, the moment of inertia with respect to a rotating axis can be obtained by dividing the object over the elements with a mass *dm* that are at a distance *r* from that rotating axis, so that it can be stated:

$$I = \int R^2 DM \tag{2}$$

Suppose for a solid ball with a mass *m*, and a radius of *r* , then the moment of inertia with respect to the axis of rotation that passes through the center of the solid ball is:

$$I = \frac{2}{5} mr^2 \tag{3}$$

While a solid cylinder with a radius of *r* and a period of *m*, the moment of inertia Against the axis that passes through the center of the cylinder is:

$$I = \frac{1}{2} mr^2 \text{ (Prove!)} \tag{4}$$

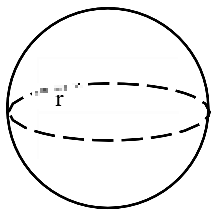


Figure M-5.1. Solid balls

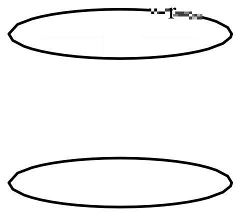


Figure M-5.2. Solid cylinder

The moment of inertia can also be searched by means of torque oscillation. The object is placed on the moment of inertia device then the object is deflected and the length of its oscillation time is calculated. To calculate the moment of inertia on the tool the following equation is used:

$$I_0 = \frac{k}{4\pi^2} T0_2 \quad (5)$$

If an object that is attached to the device of the moment of inertia and is dialected, then the oscillation period is as follows

$$T_2 = \frac{4\pi^2 I + I_0}{k} \quad (6)$$

the moment of inertia of an object attached to the moment of inertia device can be known by the equation:

$$I = \frac{T_2 - 1}{T_{02}} I_0 \text{ (Prove!)} \quad (7)$$

With k being the spring constant on the tool moment of inertia, I is the moment of inertia of the object, I_0 is the moment of inertia of the tool, T is the oscillation period of the object, and T_0 is the oscillation period of the tool moment of inertia.

How Geometric Shapes work

Measure the diameter and weight of the mass of each object and calculate its moment of inertia.

Torque Swing

1. Prepare a moment of inertia tool with a light gate.
2. Swing the inertial moment tool without objects (objects) at an angle of 90o.
3. Set the timer in *cycle* mode and set the oscillation count 10 times.
4. Record the time shown by the timer.
5. Repeat the timekeeping with different variations of objects.

Tasks and discussions

1. Determine the value of the moment of inertia *I* for solid balls, solid cylinders, hollow cylinders, wooden discs, and solid cones against the position of the rotating axis whose direction is different from the geometric and torsional oscillations!
2. Compare the results you get from both methods. Is there a difference?

ATWOOD AIRCRAFT EXPERIMENT

Purpose of the Experiment

Understand the concept of GLB and GLBB and determine the acceleration of the earth's gravity *g*.

Necessary tools

Two masses m_1 and m_2, Extra load, Rope, Pulley, Scaled pole, Time counter, Light gate , Load stopper with hole.

Theoretical basis

The Atwood machine consists of two masses m_1 and m_2, which are connected by ropes. If $m_1 > m_2$. Then these two masses begin to move with an acceleration *a*:

$$a = \frac{|m_1 - m_2|}{m_1 + m_2} g \quad \text{(Prove!)} \qquad (1)$$

Equation (1) assumes that the pulley mass is zero and there is no friction. If the influence of the pulley is taken into account then equation (1) becomes:

$$a = \frac{|m_1 - m_2|}{m_1 + m_2 + R_2} g \quad \text{(Prove!)} \qquad (2)$$

With *I* is the moment of inertia of the pulley, *R* is the radius of the pulley.

The second correction is the influence of friction, assuming the frictional force (*Fges*) is constant then acceleration *a* becomes:

$$a = \frac{|m_1 - m_2| g - F_{ges}}{m_1 + m_2 + R_2} \quad \text{(Prove!)} \qquad (3)$$

Note that the two corrections make the acceleration *a* smaller than that given in equation (1). In this experiment, equation (3) was investigated and determined g.

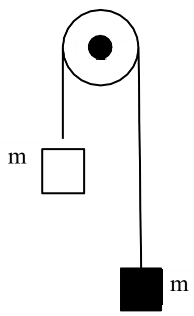


Figure M-6.1. Illustration of Adwood Aircraft

How it works

GLB Experiment

1. Set the position of the mass m_2 at a certain height and place the perforated load bearer below the mass of m_2.
2. Add an additional load to m_2.
3. Set the distance of the first light gate with the second light gate.
4. Set the time counter on the timing function 2.
5. Remove the retainer on the load m_1 and record the travel time that the mass m_2 experiences from the first light gate to the second light gate.
6. Repeat the experiment by varying the distance between the first light gate and the second light gate.

GLBB Experiment

1. Set the position of the mass m_2 at a certain height and place the first light gate just below the mass of m_2.
2. Add an additional load to m_2.
3. Set the distance of the first light gate with the second light gate.
4. Set the time counter on the timing function 2.
5. Remove the retainer on the load m_1 and record the travel time that the mass m_2 experiences from the first light gate to the second light gate.
6. Repeat the experiment by varying the distance between the first light gate and the second light gate.

Tasks and discussions

1. State the velocity value in the GLB experiment as well as the velocity and acceleration values in the GLBB experiment graphically and then analyze it.
2. Determine the value of gravitational acceleration *g* using a graph and compare it with the results of the calculation of the experimental data.

WATER FLOW IN CAPILLARY PIPES EXPERIMENT

Purpose of the experiment
Determine the half-time of the exponential deterioration of water flow in capillary pipes.

Necessary tools
100 ml measuring cup, Capillary pipe, Calipers, Water containers, roll bars, Burettes.

Theoretical basis

A capillary pipe is connected to a tap burette, with a bar and the water level in the burette is measured. If the height of the water in the burette h, the reduction of the height of the water in the burette Δh, then for the interval of flow Δt is fulfilled that:

$$\Delta h \sim \Delta t \tag{1}$$

Water discharge flowing laminar through capillary pipes:

$$Q = \frac{\Delta V}{\Delta t} = \frac{\pi r 4 \Delta P}{8 \eta L} \tag{2}$$

With ΔV is the volume of water flowing through the capillary pipe during the flow time Δt, and Δt is the flow time interval, r is the radius of the capillary pipe, ΔP is the pressure difference between the two ends of the capillary pipe, L is the length of the capillary pipe and η is the viscosity. For the flow of water in the burette:

$$Q = A \frac{\Delta h}{\Delta t} \tag{3}$$

With A is the cross-sectional area of the burette
By substituting equations (2) and (3) it is obtained:

$$\Delta h = \frac{\pi r 4 \Delta P}{8 \eta A L} \Delta t \tag{4}$$

Pressure difference between the two ends of the ΔP capillary tube:

Since $\Delta h \sim \Delta P$, then $-\Delta h \sim h$, with a negative sign indicates a reduction in height h. so that from equations (4) and (5) it is obtained:

$$\Delta h = \frac{\pi r 4 \rho g h \Delta t}{8 \eta A L} \quad \text{or} \quad dh = -\lambda h dt \tag{5}$$

With λ is called the decay setting The solution of equation (5) is

$$h = h_0 e^{-\lambda t} \tag{6}$$

With *h0* is the height of the water level in the burette at the time $t = 0$, and t is the flow time.

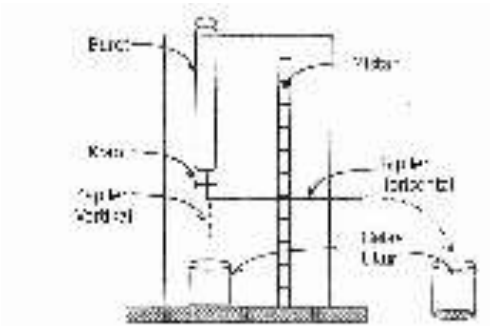


Figure M-7.1. Scheme of the water flow device in a capillary pipe

How it works

1. Fill the burette with water and measure h_0 , which is the height of the water level from the end of the capillary pipe
2. Open the tap on the burette and measure the water level level every 10 seconds of flow.
3. Do this for capillary pipes of various lengths with the same cross-sectional diameter and also for capillary pipes of various sizes with the same cross-sectional diameter.
4. All experiments were performed with vertical and horizontal capillary pipe positions.

Tasks and discussions

1. Create a graph h vs t to get λ
2. What is meant by half-time and determine half-time graphically.
3. If the water density is 1 g/cm^3, determine the viscosity price from the λ value obtained from the above experiment and compare it with the reference.

RESONANCE TUBE EXPERIMENT

Purpose of the experiment
Determine the speed of sound using a resonance tube.

Necessary tools
The resonance tube is equipped with piston, Sound level meter, Connecting cable, Audio frequency generator.

Theoretical basis

From the image M-8.1 it is shown that sound waves propagate down the tube and are reflected at the water-air boundary, and stationary vibrations will be generated from the interference of the incoming and reflecting waves. The air-water boundary of the tube is a knot and the open end of the tube is the stomach.

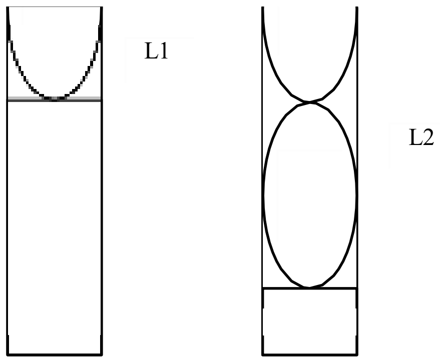


Figure M-8.1. Difference in air column height when resonant

From the M-8.1 image it is obtained that:

$$L1 + e = \frac{\lambda}{4} \text{ (first resonance)} \quad (1)$$

$$L2 + e = \frac{3\lambda}{4} \text{ (second resonance)} \quad (2)$$

With L1 is the length of the tube when the first resonance occurs. L2 is the length of the tube when the second resonance is correct, *e* is the correction at the end of the tube, and λ is the wavelength of the tone. By eliminating eqations (2) and (1) it is obtained

$$L2 - L1 = \frac{\lambda}{2} \quad (3)$$

If *c* is the speed of sound in the air and *f* is the pitch frequency, then there is a relationship:

$$c = \lambda f \quad (4)$$

Substitution of equation (3) to equation (4) so that

$$c = 2f(L2 - L1) \tag{5}$$

How it works

1. Measure the temperature of the room before starting the experiment.
2. Set the position of the resonance tube and make sure the piston position is at the end of the tube.
3. Connect the resonance tube to the audio frequency generator (AFG) and sound level meter (SLV).
4. Set the frequency and frequency multiplier on the AFG.
5. Turn on the SLV then pull the piston slowly, and observe the needle deviation on the SLV.
6. If there is a loud noise and the SLV shows maximum deviation, record the position of the piston from the end of the tube as L1.
7. Pull the piston back until the needle on the SLV deviates to the maximum, and record the position of the piston from the end of the tube as L2.
8. Repeat the experiment at different frequencies.

Tasks and discussions

1. Determine the correction value e of the end of the tube calculated from equations (1) and (2)

$$e = \frac{1}{2}\,(L2 - 3L1)\ \text{(Prove!)}$$

2. Compare sound speeds through calculations and graphs, analyze!

MATHEMATICAL PENDULUM EXPERIMENT

Purpose of the experiment
Determining the acceleration of the Earth's gravity

Required tools
Stopwatch, Measuring bar, Mathematical pendulum tool.

Theoretical basis

Gravity is a natural phenomenon or phenomenon, which is an event of attraction between two masses. While what is meant by gravitational acceleration *g* is the gravitational force per unit mass. According to Newton the force of gravity is:

$$F = \frac{Gm_1m_2}{r_2} \tag{1}$$

Where *G* is the gravitational constant, m_1 and m_2 is the mass of the object and *r* is the distance between the two masses. The value of *G* was determined by Cavendish using a punter balance, and this experiment was known as "Weighing the Earth", because knowing *G* the mass of the earth could be calculated with equations

$$F = G\frac{mM}{R_2} = mg_0 \rightarrow M = g_0\frac{R_2}{G} \tag{2}$$

With *M* being the mass of the earth, *R* is the radius of the earth and g_0 is the magnitude of the gravitational acceleration on the earth's surface. At a distance $r = h + R$ from the center of the earth, the weight of an object with a mass *m* is:

$$mg = G\frac{mM}{r^2} \rightarrow gr^2 = GM \tag{3}$$

For $r=R$ (on the earth's surface) then $g = g_0$, so

$$mg_0 = G\frac{mM}{R} \rightarrow g_0R = GM \tag{4}$$

Substitution of equations (3) and (4) will result in an equation

$$g = g_0\left(1 - 2\frac{h}{R}\right) \text{ (Prove !)} \tag{5}$$

To measure *g, a* pendulum swing is used swinging on a long mass of no thread *L*. When the angular deviation is small, the cross *m* can be considered straight, so that

$$\sin \sin \alpha = \frac{x}{l} \tag{6}$$

With x is the pendulum deviation. A force that returns m to a state of equilibrium

$$F = -mg \sin \sin \alpha \tag{7}$$

$$m\frac{d^2x}{dt^2} = -mg\frac{x}{l} \tag{8}$$

$$\frac{d^2x}{dt^2} + \frac{g}{l}x = 0 \tag{9}$$

General form of harmonized vibration differential equation

$$\frac{d^2x}{dt^2} + \omega^2 x = 0 \tag{10}$$

Or

$$\omega^2 = \frac{g}{l} \rightarrow \omega = \sqrt{\frac{g}{l}} \tag{11}$$

Or the system (object with mass m) oscillates with the period:

$$T = 2\pi\sqrt{\frac{l}{g}} \tag{12}$$

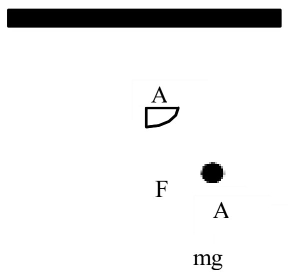


Figure M-11.1. Swing Matematis Gang

how it works

1. Tie the pendulum at the end of the rope and measure the length of the rope
2. Swing the pendulum with a small angle of swing
3. Record the time it takes for multiple swings (More is better)
4. Repeat the experiment with different rope lengths

Tasks and discussions

Determine the value of the acceleration of the earth's gravity by means of a mathematical pendulum swing through a graph!

SURFACE TENSION EXPERIMENT

Purpose of the experiment
Determining the magnitude of the surface tension of a liquid

Required tools
Burets, Cups, Capillary pipes, Manometers, Erlemeyer, Soap.

Theoretical basis

The occurrence of surface tension is caused by the cohesion force between one molecule of a liquid against another molecule. In this experiment, the maximum pressure method of the bubble was used whose arrangement of the tools is as shown in Figure M.13.1

The price of the surface tension of the aquadest can be determined by equalizing the pressures acting on the vessel and the manometer M. By lowering the water from the burette into the Erlenmeyer E bottle, the air pressure in the capillary pipe C becomes large. If at the end of the capillary pipe there is an air bubble with the radius R, then on the surface of this bubble the pressures from above = P and from the bottom consist of: hydrostatic pressure ($\rho_2 g h_2$), air pressure (PB) and surface tension pressure (2S/R) (Prove!). In equilibrium the pressure P is equal to the pressure at point N and at the manometer M, i.e.: hydrostatic pressure (ρ1gh1) and pressure air (*PB),* so it can be written:

$$P = \rho_1 g h_1 + P_B = \frac{2S}{R} + \rho_2 g h_2 \quad (1)$$

The pressure P will be maximum if R is the minimum, i.e. equal to the radius of the capillary pipe = r. then at the time *of* $R = r$ the equation is obtained

$$P_{max} = \rho_1 g h_1 + P_B = \frac{2S}{R} + \rho_2 g h_2 \quad (2)$$

$$S = \frac{1}{2} gr(\rho_1 h_1 + \rho_2 h_2) \quad (3)$$

For soapy water, you get the same

$$S = \frac{1}{2} gr(\rho_1 h_1 + \rho_2 h_2) \quad (3)$$

$$S = \frac{1}{4} gr(\rho_1 h_1 + \rho_2 h_2) \text{ (Prove!)} \quad (4)$$

With h_2 is the difference in the surface height of the liquid in the capillary pipe/beaker B, h_1 is the difference in the surface height of the liquid in the manometer, $\rho 1$ is the density of the liquid in the manometer and ρ_2 is the density of the liquid in the cup cup.

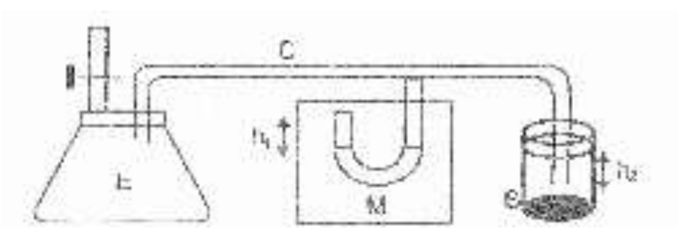


Figure M-13.1. Schematic of the tool for determining the surface tension by the maximum pressure method of air bubbles

How it works

1. Make the surface of the liquid inside the M manometer pipe the same height.
2. Capillary pipe C is dipped *as deep as h2* into cup B beaker.
3. Drip water from the burette into the erlemeyer E tube, the liquid in one of the manometer legs will rise.
4. Observe on the manometer: the maximum pressure reached is characterized by the bursting of air bubbles coming out of the capillary pipe and the surface of the manometer fluid drops again.
5. Measure the highest surface difference in the manometer.
6. Determine the tightness of the liquid in the manometer and in the cup glass.
7. Measure the radius of the capillary pipe and calculate the surface tension for aquadest and soapy water.

Tasks and discussions

Based on equations (3) and (4) for aquadest and soap solution respectively, an equation can be made containing the magnitude *S*, which shows the relationship between the measured quantities directly from each other. Determine the value *S* of the graph and compare the results obtained from equations (3) and (4) with those obtained from the graph.

REVERSIBLE PENDULUM EXPERIMENT

Purpose of the experiment

Determining the acceleration of gravity using a reversible pendulum (physical pendulum)

Necessary tools

Tripods, Support poles, Light gates, Reversible pendulums, Pendulum holders, Timers, Measuring bars, Screwdrivers.

Theoretical basis

Figure M.15.1 shows a rigid object hanging on its horizontal axis through the O point. The object will experience its recovery force moments as great as:

$$\tau pem = -Mgh \sin \sin \theta \quad (1)$$

Since θ is small then

$$-Mgh \sin \sin \theta \approx -Mgh\theta \quad (2)$$

The equation of motion of an object can be written as

$$-Mgh\theta = I \frac{d^2\Theta}{dt^2} \text{ (Prove!)} \quad (3)$$

With I is the moment of inertia of the object with respect to the O axis.

Motion of objects is harmonious motion and has a period of

$$T = 2\pi \sqrt{\frac{I}{Mgh}} \quad (4)$$

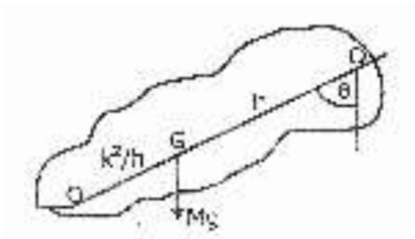


Figure M-15.1 Illustration of the Physical Pendulum

Using the parallel axis theorem, the moment of inertia Ig is the moment of inertia facing the center point of mass, so that

$$I = I_g + Mh^2 \quad (5)$$

With

$$Ig = Mk^2 \text{ (Prove!)} \quad (6)$$

And *k* is the radius of rotation.
Equation (4) can be rewritten

$$T = 2\sqrt{\frac{k_2 + h_2}{gh}} \quad (7)$$

The mathematical swing period is:

$$T = 2\pi\sqrt{\frac{l}{g}} \quad (8)$$

The period of a rigid body equal to the oscillation period of a mathematical pendulum with the length of the physical pendulum is

$$I = h + \frac{k_2}{h} \quad (9)$$

The solution of equation (9) is:

$$H_2 + HK + K^2 = 0; H_1 + H_2 = l \text{ and } H_1 - H_2 = k \quad (10)$$

The k_2/h *distance* is measured along the axis of the O' point which is the center of oscillation. The period O' is the same as the period O so that the center of suspense and oscillation is interchangeable, so that the gravitational acceleration of the physical pendulum is:

$$g = \frac{4\pi^2 l}{T^2} \quad (11)$$

Where *g* is the gravitational force, *T* is the period of swing, and *l* is the length of the rod Overall.

How it works

1. Set the distance between load A and blade 1, the distance between blade 1 and load B, and the distance between blade 1 and blade 2.
2. Place the pendulum on the pendulum holder with the position of blade 1 as a focus.
3. Set the timer on the function cycle and set the number of oscillations.
4. Deflect the pendulum and record the time indicated by the timer.
5. Turn the pendulum back, so that the focus is on blade 2 and repeat steps 3 and 4.
6. Repeat the experiment with the variation of the distance between the blades 1 and the

different pendulum B.

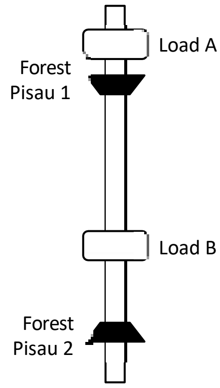


Figure M-15.2. Reversible Pendulum

Tasks and discussions

1. Calculate the value of g using equation (11) from the experiment data that was assembled.
2. Make a graph of T (period) against y (load distance B to the focus) for each focus (blade 1 and blade 2). Look for the intersection of the two graphs (if they don't intersect, look for the nearest point). Calculate the value of g from the intersection point.

COEFFICIENT OF LONG EXPANSION EXPERIMENT

Purpose of the experiment

Determining the coefficient of expansion of the length of the metal

Necessary tools

A set of Length expansion coefficients, Thermometer, Caliper, Measuring bar.

Theoretical basis

The length expansion of a solid object can be expressed with the equation:

$$LT = L_0(1 + \alpha T) \tag{1}$$

With LT is the length of the object at temperature T, L_0 is the length of the object at temperature 0, and α is the coefficient of expansion of the length of the material. At temperature $T1$ the length of an object is expressed by the equation

$$LT_1 = L_0(1 + \alpha T_1) \tag{2}$$

From equations (1) and (2) it is obtained:

$$\alpha = \frac{LT_1 - LT}{L_0(T_1 - T)} = \frac{\Delta L}{L_0 \Delta T} \tag{3}$$

So α can be reduced if the increase in the length of the heating from temperature T to T_1 and the length L is measurable. In this experiment, the metal rod was heated from room temperature until the water boiled. Since the length of the wire at 0^{O}C ($L0$) is not much different from the length at room temperature, L_0 is replaced by LT. So:

$$\alpha = \frac{LT_1 - LT}{LT(T_1 - T)} = \frac{\Delta L}{LT \Delta T} \tag{4}$$

Because the increase in bar length $\Delta L = L_{T1} - L_T$ is very small, careful measurements were made using the Mussschenbroeck tool. In this tool, the left end of the B rod is clamped to the left stand D, the right end is installed pressing the wheel (r-radius) of the j-scale pointing needle. When the water in the vessel is heated to a boil, the water vapor will heat the rod so that the rod will increase in length.

This increase in length will cause the wheel to rotate and the scale pointing needle will deviate and point to the scale s, and this increase in length ΔL is proportional to the magnitude of the deviation on the scale, namely:

$$\Delta L = \frac{rS}{R} \tag{5}$$

Where r is the radius of the wheel, R is the length of the pointing needle and s is the difference of the designated scale needles at T_1 and T temperatures. Equation (5) we substitute equation (4) and obtain:

$$\alpha = \frac{rs}{RLT\Delta T} \quad (6)$$

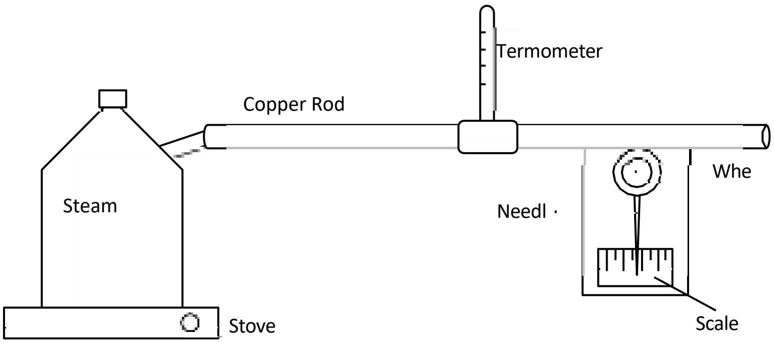


Figure K-1.1. Scheme of the Length expansion coefficient tool

How it works

1. At room temperature *T*, measure the length of the rod L_0. At this temperature, make a scale that is pointed to the needle at 0 (right in the middle of the scale).
2. Measure the length of the needle (R) using the bar and the spokes (r) using the caliper.
3. Place the thermometer in the place provided (on the wheel) and turn on the electric stove.
4. Increase the temperature of the stem by running moisture into the stem until the temperature is T_1 and the stem will increase in length. Observe the scale indicated by the needle.
5. Switch off the electric stove when the rod reaches temperature T_1
6. Observe and record the number indicated by the needle on the scale of each temperature drop in the rod.

Tasks and discussions

1. Prove the equation (5)
2. Calculate the coefficient of expansion of the length of the supplied alogam rod
3. Is it possible that α value is graphically determined? Explain!
4. Calculate what % of errors occurred on replacing L_0 with *LT?*

MELTS HEAT EXPERIMENT

Purpose of the experiment

Determining the melting heat of the ice

Tools used

Calorimeter and Stirrer, Thermometer, Balance, Stopwatch.

Theoretical basis

The state (phase) of a substance consists of 3 types, namely solid, liquid and gas. Substances under certain temperature and pressure conditions undergo all three phases. The phase transition from one phase to another is accompanied by the release or absorption of heat without any change in temperature.

The heat absorbed by a unit of mass of matter in a solid form that melts (melts) without a change in temperature is defined as melting heat. The amount of heat Q required to melt the mass m at a constant temperature with L stating that the melting heat of the substance is:

$$Q = mL \quad (1)$$

To determine the melting heat of a substance (ice), the calorimeter method can be used, which is to put ice (mass me) into a calorimeter containing water (mass ma). If the calorimeter is equipped with a stirrer, a thermometer and has a water price m_kC_k (m_k: calorimeter mass along with stirrer and thermometer and C_k: heat capacity of the calorimeter type), then when the two substances (water and ice) are mixed, there will be heat transfer.

The water in the calorimeter will release the heat, the heat will be received by the calorimeter and the ice inside. Ice that receives heat from water will begin to melt slowly and raise its temperature towards the point of thermal equilibrium (T_c). The amount of heat released by water and calorimeter is

$$Q_{air} = m_a C_a (T_a - T_C) \quad (2)$$

$$Q_{calorimeter} = m_k C_k (T_a - T_C) \quad (3)$$

With ma is the mass of water, C_a is the heat of the water type, mk is the mass of the calorimeter along withThe stirrer, C_k is the density of the calorimeter, T_a is the initial temperature of the water, and Tc is the mixed temperature (the point of thermal equilibrium). Meanwhile, the heat needed for ice to increase its temperature to 0^oC is

$$Q_{es} = m_e c_e (0 - T_e) \quad (3)$$

With me being the mass of ice, C_e is the heat of the ice type, and Te is the initial temperature of the ice. Then the heat needed for ice to melt all the ice is

$$Q_{lebur=} m_e L \quad (4)$$

With L is the melting heat (latent) of ice. Then the heat required to raise the temperature of water (which comes from ice) from 0o C to the mixture temperature is.

$$Q_{air\ es} = m_e c_a (T_C - 0) \quad (5)$$

Then to determine the value of the melting heat of a substance (ice) using the Black Principle principle, where water and calorimeter are the heat release while ice is the heat receiver so that the following equation is obtained:

$$L = \frac{[m_a C_a - m_k C_k](T_a - T_c) - m_e C_e(-T_e) - m_e C_a(T_c)}{m_e} \text{ (Prove!)} \quad (7)$$

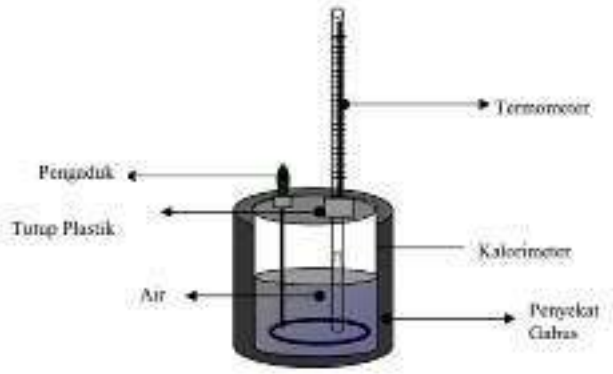


Figure K-2.1. Set up the Melting Heat tool

How it works

1. Weigh the calorimeter + the stirrer to determine the mass of the calorimeter.
2. Add hot water to the calorimeter and then weigh it again to get the water mass.
3. Measure the water temperature in the calorimeter as well as the ice temperature in the thermos.
4. Place the ice in a calorimeter filled with water and a stirrer, stirring and observe the temperature on the thermometer every 15 seconds until the ice has melted completely.
5. If the temperature of the calorimeter is equal to the temperature of the melted ice, then the minimum temperature will be reached and this minimum temperature is the final temperature of T_c.
6. Continue to observe every 15 seconds until a few minutes after the minimum temperature is reached.

Tasks and discussions

1. Calculate the melting heat of ice
2. Create a graph between temperature and time. Analyze the graph!

WATER COOLING EXPERIMENT

Purpose of the experiment
Determine the cooling constant of water and determine the effect of cross-sectional area on the rate of water cooling.

Necessary tools
3 pieces of erlemeyer pumpkins (100, 250 and 500 ml), 3 pieces of thermometer, stopwatch.

Theoretical basis

Newton's law regarding cooling states that the speed of heat transfer of an object to the environment is proportional to the difference in temperature of the object with its environment.

If an object in the form of a liquid has a temperature hotter than the ambient temperature, it will cool due to heat transfer. A hypothesis states that the rate of temperature decrease *dT/dt* (the decrease in temperature per unit of time) will be proportional to the temperature difference between the liquid and its environment, according to the equation:

$$\frac{Dt}{Dt} = \alpha(T - T_0) \qquad (1)$$

With α is a setting, T is the temperature of the liquid and T_0 is the ambient temperature. Then, the cooling rate of water can be calculated using the equation:

$$Q = A(T - T_0) \qquad (2)$$

With Q is the cooling rate of water (calories/second), and A is the cross-sectional area (m^2)

How it works
1. Measure the cross-sectional diameter of each erlemeyer.
2. Fill each erlemeyer pumpkin with 100 ml of hot water.
3. Record the initial temperature of each erlemeyer pumpkin.
4. Observe the change in water temperature in each erlemeyer flask simultaneously for each interval of several minutes.

Tasks and discussions
1. Check with experiments whether the hypothesis in theory is true or not!
2. In your opinion, the value of α depends on what factors?
3. Describe the results of your experiment observations!
4. Based on equation 1, a linear equation can be compiled that states the relationship between the difference in water temperature and the environment over time. Select the appropriate variables to plot on the x-axis graph!

JOULE'S LAW EXPERIMENT

Purpose of the experiment

Determine the relationship between electric power and heat power (heat) and determine the thermal equivalent of electricity.

Necessary tools

Calorimeters and stirrers, Heating wires, Thermometers, Shear resistance, Amperemeters, *Power supply*.

Theoretical basis

Electrical energy can be turned into panad, for example in the wire of the heating element if it is current, heat will arise. If the heat from the wire is transmitted to the liquid, there will be heat transfer from the wire to the liquid. According to the Black Principle, the amount of heat generated by electric current is equal to the amount of heat absorbed by the liquid along with its place and equipment.

According to Joule's law, the amount of heat generated by an electric current is:

$$Q = I^2Rt \text{ Joule} \quad (1)$$

With Q is the heat generated by the electric current, I is the electric current, R is the resistance of the heating wire and t is the heating time.

While the heat absorbed by the water, the calorimeter and the stirrer are

$$Q = (m_a c_a + m_k c_k)(T_a - T_m) \text{ calorie} \quad (2)$$

With m_a is the mass of water, c_a is the heat of the water type, m_k is the mass of the calorimeter, c_a is the calorimeter type heat, T_a is the final temperature and T_m is the initial temperature

By equalizing equations (1) and (2) obtained

$$Q = I^2Rt\ Joule = (m_a c_a + m_k c_k)(T_a - T_m)\ kalori \quad (3)$$

Or

$$1\ joule = [(m_a\ c_a + m_k\ c_k)(T_a - T_m)] / (I^2Rt)\ calorie \quad (4)$$

Equation (3) is the equivalent number of mechanical heat – electricity.

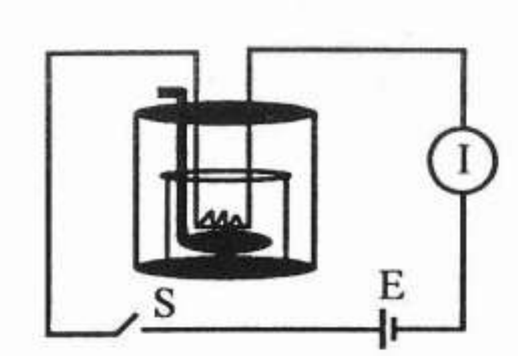


Figure L-2.1. Set up the Joule Law tool

Procedure

1. Weigh the empty calorimeter.
2. Fill the calorimeter with water until the heating element is immersed, then weigh the calorimeter

again.
3. Cool the water together with the calorimeter to below room temperature.
4. Arrange the experiment as shown in Figure L-2.1.
5. Set the current with the variable resistor so that the electric current is approximately 2 A.
6. Start the experiment by recording the initial temperature T_m and note the temperature rise at each time interval.
7. When the desired final temperature T_a is reached, turn off the electric current.

Tasks and Discussions
1. Calculate the electrical equivalent of heat using Eq. (4).
2. Determine the electrical equivalent of heat graphically from Eq. (4) by selecting the directly measured quantities as the vertical and horizontal axes of the graph.
3. Compare the results obtained from the two methods above and analyze them.
4. In the experiment, $T_a - T_k = T_k - T_m$ must be satisfied. Why?
5. What is the electrical equivalent of heat?

INCANDESCENT LAMP CHARACTER EXPERIMENT

Purpose of the experiment

1. Understand Ohm's law in incandescent lamps and interpret electrical charts
2. Interpret graphs of the relationship between installed voltage vs flowing current, installed voltage vs internal resistance and installed voltage vs absorbed power

Tools used

Transformer, Voltmeter, Amperemeter, Crocodile Clip, Incandescent lamp.

Theoretical basis

The potential difference between the two ends of a conductor is proportional to the strength of the flowing current and the magnitude of the conductor's resistance. This is known as Ohm's law and is mathematically written

$$V = IR \tag{1}$$

With V is the potential difference, I is the strong current and R is the conductive resistance.

A conductor *wire* R that is passed by an electric current I then there is a lost electrical energy (dissipated) in the conductor. The amount of energy dissipated each second is called electrical power, formulated as:

$$P = VI = I^2R \tag{2}$$

Where P is the electric power

To find out the incandescent character of Ohm's law was obtained by taking *measurements* V and I simultaneously. Measurements *of* V and I using voltmeters and amperemeters are carried out simultaneously with two possibilities as shown in chart (1) and chart (2).

Circuit (1)   *Circuit (2)*

Circuit (1)

In this chart there is an error in the amperemeter because the measured electric current is the amount of current passing through the lamp and voltmeter. The magnitude of the error is formulated as:

$$(R_L / R_V) \times 100\% \tag{3}$$

With R_L is the resistance of the lamp and R_V is the resistance of the voltmeter

Circuit (2)

In this circuit, there is a voltmeter error because the measured voltage is the sum of the lamp voltage and the ammeter voltage. The magnitude of the error is:

$$(R_A / R_L) \times 100\% \tag{4}$$

With RA is the amperemeter resistance

Because of the two possible measurements, all have errors, the chart with the smallest error is chosen.

Because both possible arrangements contain errors, the circuit with the smaller error is chosen. If R_L < R_A, then Circuit (1) is selected, but if R_L > R_A, then Circuit (2) is selected. By considering that the internal source resistance can be neglected, the following formula is obtained:

$$R_L = V' / (I' - V'/R_V) \quad or \quad R_A = (V'' / I'') - R_L \qquad (5)$$

where V is the source voltage without load, V′ is the voltage in Circuit (1), V″ is the voltage in Circuit (2), I is the current without voltmeter, I′ is the current in Circuit (1), and I″ is the current in Circuit (2).

Procedure

1. Arrange Circuit (1) and activate the transformer after obtaining approval from the assistant.
2. Record the transformer voltage, voltmeter voltage, and current on the ammeter for each voltage change.
3. Repeat the experiment by turning the variac from high voltage to low voltage.
4. Replace the circuit with Circuit (2) and repeat the same procedure.
5. Repeat the experiment above for lamps with different power ratings.

Tasks and discussions

1. Choose the circuit that has the smaller error using Eq. (5).
2. Make graphs of V vs I, V vs R, and V vs P using the data from the circuit with the smaller error.
3. Make logarithmic graphs of log V vs log I, log V vs log R, and log V vs log P to determine the heat exponent in an incandescent lamp.
4. Analyze the graphs obtained.

CURRENT AND VOLTAGE IN TUNGSTEN FILAMENT LAMPS EXPERIMENT

Purpose of the experiment

Investigate the relationship between the current passing through the tungsten filament lamp and the potential used

Tools used

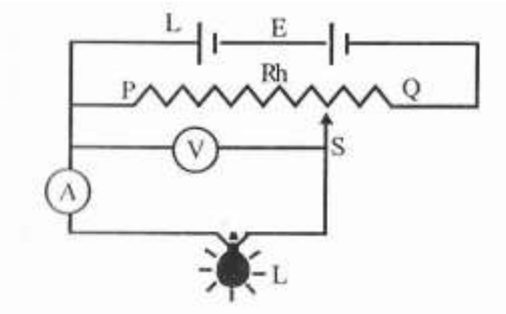
Crocodile pin, Amperemeter, Voltmeter, Filament lamp.

Theoretical basis

The relationship between the obtained current *I* and the voltage used *V* is given by the equation:

$$I = kV^n \qquad (1)$$

Where *k* is a constant and *n* is a constant of lamps



Picture. L-4.1

Procedure

1. Arrange the circuit as shown in Figure L-4.1.
2. Adjust the resistance so that readable values of V and I are obtained from the voltmeter and ammeter.
3. Record the values of V and I.
4. Repeat the experiment using different filament lamps.

Tasks and discussions

1. Calculate *the values of k* and *n* from the graph and analyze
2. Prove the equation (1)
3. From the above experiment, there is an influence of shear resistance to determine the values *of k* and *n*.

WHEATSTONE BRIDGE EXPERIMENT

Purpose of the experiment

Determine the value of an unknown prisoner, and determine the correction of the end of the Wheatstone bridge.

Tools used

Wheatstone bridge range, Metal pen, Measuring bar, Galvanometer, Unknown resistance, Known resistance, *Power supply*.

Theoretical basis

Determining the value of an unknown prisoner

ABCD is a diagram of a wheatstone bridge network. At the equilibrium point, G will indicate the number zero, then the current in the circuit is shown as follows.

$$I_1R_1 = I_2R_3 \text{ and } I_1R_2 = I_2R_4 \quad (1)$$

From equation (1) it is obtained

$$R_1/R_2 = R_3/R_4 \quad (2)$$

R3 is the resistance on the wire that is *L1 long* and *R4* is the resistance on the wire that is *L2 long*. Since the size of the resistance is proportional to the length of the wire, then:

$$R_1/R_2 = L_1/L_2 \quad (3)$$

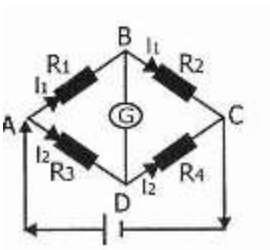


Figure L-8.1a

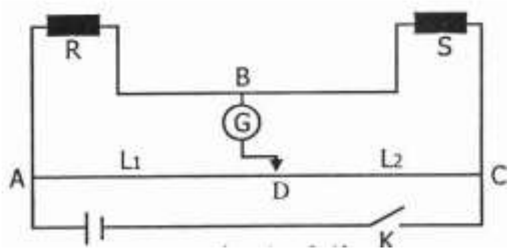


Figure L-8.1b

Determining the Wheatstone bridge end correction

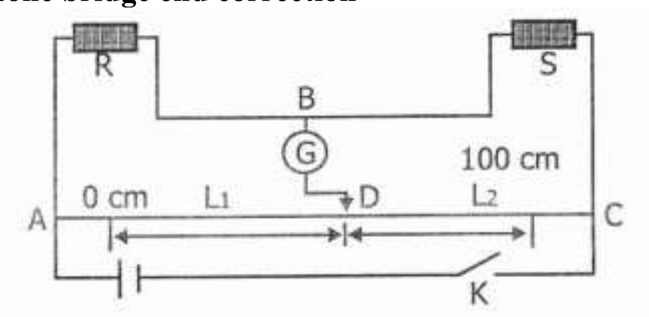


Figure L-8.2

The equilibrium of the Wheatstone bridge at L_1 is given by the equation

$$\frac{R}{S} = \frac{x + L_1}{y + (100 - L_1)} \quad (4)$$

R and S are then determined and the new equilibrium at L_2 is determined

$$\frac{S}{R} = \frac{x + L_2}{y + (100 - L_2)} \quad (5)$$

The subtraction of equation (4) from equation (5) is obtained

$$L_2 - L_1 = x\left(\frac{R}{S} - \frac{S}{R}\right) + \frac{SL_1}{R} - \frac{RL_2}{S} \qquad (6)$$

So

$$x = \frac{RL_2 - SL_1}{S - R} \qquad (7)$$

And

$$y = \frac{SL_2 - RL_1}{S - R} - 100 \qquad (8)$$

Based on equations (7) and (8), the correction values of the Wheatstone bridge are x and y.

How it works

Determining the value of a prisoner

Slide the metal pen along the wire until you get the equilibrium point at D (G=0), measure the length *of L1* and *L2*, turn *R* and *S* to determine the new equilibrium point, measure *L1* and *L2*, average *L1* and *L2*, and *L2* and *L1*

Determining the Wheatstone bridge end correction

Slide the metal pen on a series of Wheatstone bridges with a 100 cm long wire until you get the equilibrium point D (G=0). Measure *the length of L1* and *L2*. Conduct an experiment for 5 prisoners (*R* and *S*).

CONVERGENT AND DIVERGENT LENSES EXPERIMENT

Experiment Objectives:

Determine the focus and strength of the lens.

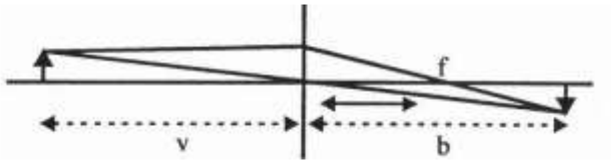
Tools used

Converged lenses, divergent lenses, shadow-catching layers, lights.

Basic Theory:

The relationship between the distance between objects *v* and the distance of shadow *b* is expressed by the equation:

$$\frac{1}{f} = \frac{1}{b} + \frac{1}{v} \quad (1)$$



With *f* = lens firing point distance

Equation (1) can be written as follows:

:

$$\frac{1}{b} = \frac{1}{f} - \frac{1}{v} \rightarrow y = \frac{1}{f} - x \quad (2)$$

In this experiment, it will be examined that there is an area from B1 to B_2 where the shadow is still sharp. The position of shadow B is located in the middle of this district.

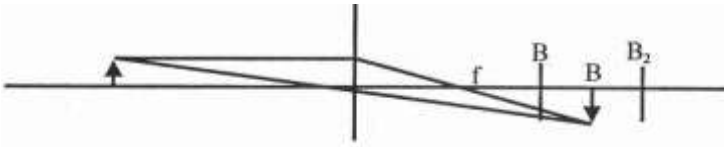


Figure O-1.1a. Position from shadow B.

By observing the boundaries of B1 and B_2, the position of point B can be obtained. By using equation (2), the focus value and strength of the lens (P) can be determined.

In addition to the above method, lens focus can be found through two types of lens positions that may be between objects and shadows that are formed

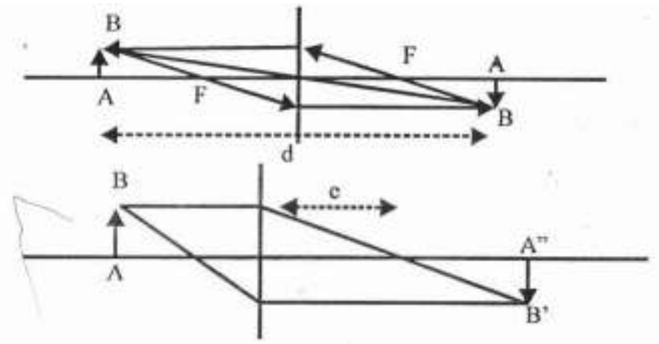


Figure O-1.1b. Two possible lens positions in the region d

If the object and the shadow are at a fixed distance and the value is greater than 4 times the distance of the lens's point of fire, then there are two kinds of possible lens positions between the object and the shadow, which produce the shadow being magnified and reduced.

If the distance between the object and the fixed shadow is expressed by *d* and the distance between the two lenses, i.e. the distance between the first and second positions, is c, then the point of fire of the lens can be calculated based on the equation:

$$f = \frac{d^2 - c^2}{4d} \tag{3}$$

For a negative lens, to obtain a true shadow on the screen, the object must be a virtual object. This virtual object can be obtained with the help of a positive lens, i.e. the true shadow by the positive lensf will be a virtual shadow for the negative lens.

How It Works:

1. Positive Lens

- **How to Graph**
  1. Set the position of objects, lenses and screens in a straight line position on the optical bench where the position of the object and lens is fixed.
  2. Swipe the screen until you get a sharp shadow that is in positions *b1* and *b2*.
  3. By observing the shadows that occur for various prices *v, a variable* price b will *be obtained* so that the graph can be made.
- **Using Equations (3)**
  1. Set the distance of the object and the screen (*d*) is made larger by 4 times the focal point of the lens.
  2. By looking for two types of lens positions that can form sharp, enlarged and reduced, the distance between the two types of lens positions can be determined (way) so that *the values f* and *p* can be calculated.

b. Negative Lens

- **How to Graph**
  1. To obtain the true shadow of the negative lens, a virtual object is required obtained from the true shadow of the positive lens
  2. By knowing the distance between positive and negative lenses as well as true and positive shadows, it can be determined the distance of the negative lens's virtual objects.
  3. By sliding the screen, a sharp shadow is obtained, which is the true shadow of the negative lens. (Note: Negative lenses have *f* and *b* negative).

Question:

1. From the results of the experiment, what is the angle of inclination of the graph.
2. Theoretically, you would expect how much the slope of the graph would be.

PHOTOMETER EXPERIMENT

Determining the strength of the lamp and its efficiency

Tools used

Standard lamps, Test lamps, Bows, Bar bars, Galvanometers, Photometers.

Dasar theory:

The strength of the light source can be determined with a device called a photometer. The principle is to compare the intensity of standard lighting and the lamp that will be sought.

The working principle of this tool is shown in the image below:

Figure O-2.1. Working principle of photometer

Each side of the sensor (VU Display) is illuminated by P1 and P2 sources. The position of the sensor (VU) is set until there is an equilibrium of the pointing needle (the pointing needle is right in the middle of the VU scale) and the distance of the source 1 and 2 to the sensor (*R1* and *R2*) is measured. Because it is equally bright on both sides of the sensor, then

$$E1 = E2 \qquad (1)$$

With *E1* being a strong light source 1, *E2* being a strong illumination source 2. As a result of the occurrence of equation (1), the following is obtained:

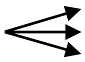
$$I_1/R_1^2 = I_2 / R_2^2$$
$$I_1 / I_2 = R_1^2 / R_2^2 \qquad (2)$$

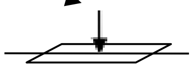
With *I1* being a strong light source 1, *I2* being a strong light source 2. If the strength of one light is known, then the strength of the other light source can be calculated based on equation (2). While efficiency is defined as the ratio between the flux of light (*E*), and the flux of radiation (*P*), which can be written as follows:

Efficiency = E/P (3)

The unit of efficiency is lumen/watt and the unit of strength of light is lumen/steradial or wax. Below are some definitions that have to do with light:

 = Source: Strong Light/ *Lumenous Intensity* (*I*) → $I = \frac{F}{\omega}$ Wax

 = Space: Arus cahaya / *Lumeneous Flux* (*F*) → $F = 4\pi I$ lumen

 =Surface: Strong Illumination/ *Illumenance* (*E*) → $E = \frac{F}{A}$ lux

Light brightness (B) → $B = \frac{I}{\pi R2}$ Lambert

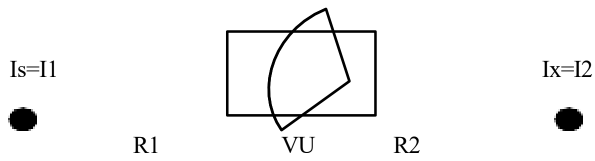


Figure O-2.2. Photometer tool scheme

How It Works

1. Set the standard light, the light to be searched and the photometer is inline on the scale optic bench, provided that both lights are kept fixed while the photometer is shifted.
2. Slide the photometer so that a balanced state (the needle shows in the middle of the scale) is obtained, then the *distance R1* and *R2 can be* obtained.
3. Repeat the experiment for standard lamp positions at 0^o, 30^o, 60^o, and 90^o from the vertical line, while unknown lamps have light strength in vertical positions (for different lamp positions different prices R1 *and* R2 *will be obtained*, so that light strength can be obtained graphically based on equation (2)).

Tasks and discussions

1. Calculate the power of the lamp light with equation (2) and through the fork!
2. Analyze the two results and how the position of the standard lamp angle affects the desired results

BIAS INDEX EXPERIMENT

Purpose of the Experiment

Determine the refractive index of the liquid using the ABBE refractometer.

Necessary tools

Refraktometer ABBE, Pipet, Tisue.

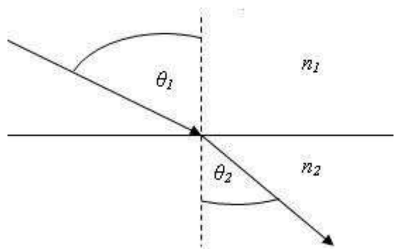
Theoretical basis

The refractive index of the medium is defined as the comparison between the speed of light in a vacuum and the speed of light in the medium, mathematically the refractive index is written as:

$$n = \frac{c}{v} \quad (1)$$

Where *c* is the speed of light in a vacuum (3 108 $^{ms-1}$), *v* is the speed of light in medium and *n* is the refractive index of medium. The writing of the refractive index is usually accompanied by the wavelength, if it is not accompanied by the writing of the wavelength, then the refractive index in question is the refractive index of the wavelength of the sodium vapor ray 5890 Å.

If the light comes from medium 1 with a refractive index *n1* and the speed of light *v1* goes to medium 2 with a refractive index *n2* and a light speed *v2* then it applies:



$$n_1/n_2 = v_2/v_1 \quad (2)$$

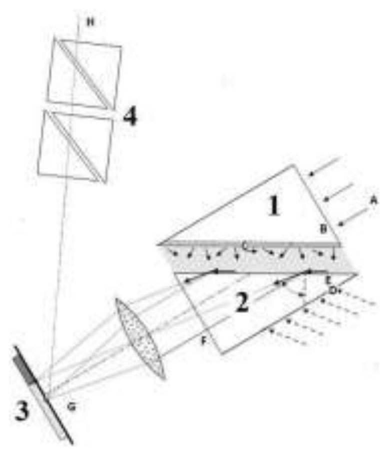
According to Snelius's law of refraction:

$$sin\ \theta_1/sin\ \theta_2 = v_1/v_2 \quad (3)$$

The consequences occur:

$$n1\ sin\ sin\ \theta 1 = n2\ sin\ sin\ \theta 2 \quad (4)$$

The components of the optical apparatus on the ABBE refractometer are:



1. Prism Irradiation Assistant (PP).
2. Prism measurement (PU).
3. Flat mirror.
4. Two achromatic prism arrays.

In the experiment, the substance under investigation has refractive index n and is placed or dropped between the surfaces of PP and PU. The path of the rays in the refractometer follows the ABCDEFGH line. The AB rays from the outside enter the PU and are refracted according to the BC line. The position of the PP is arranged in such a way that at point C the rays are refracted to coincide with the prism plane on which the substance being investigated is placed.

If the PU refractive index is N, then when the CD ray reaches point D at the critical angle β, it follows that:

$$n \sin 90° = N \sin \beta \qquad (5)$$

If the angle of the beam at point E is i and the angle of the ray is r, then:

$$\beta = \alpha - i \qquad (6)$$

With α as the refracting angle of the PU, the result is:

$$n = N \sin(\alpha - i) \qquad (7)$$

Using trigonometric rules, the following is obtained:

$$n = N(\sin \alpha \cdot \cos i - \cos \alpha \cdot \sin i) \qquad (8)$$

At point E, the law of refraction applies:

$$N \sin i = \sin r, or \sin i = (\sin r)/N \qquad (9)$$

Using the rule of trigonometry, the following is obtained:

$$\cos i = (1/N)\sqrt{(N^2 - \sin^2 r)} \qquad (10)$$

By substituting the values of cos i and sin i into Eq. (8), the refractive index of the substance is obtained:

$$n = \sin \alpha \cdot \sqrt{(N^2 - \sin^2 r)} - \cos \alpha \cdot \sin r \qquad (11)$$

For each refractometer, the values of N and α are fixed, so there is only a relationship between n and r. When the magnitude of angle r is observed, the refractive index of the substance can be calculated. The ABBE 60 refractometer is calibrated, so that the readable scale directly shows the value of n corresponding to the angle r in question..

Gambar O-6.1. Refractometer ABBE 60

How It Works

1. Orient the instrument so that the prism box faces away from the observer and points toward the light source.
2. Open the prism box by removing the lock on the right side, then place a few drops of the substance to be investigated into the prism box.
3. Observe through the T1 binoculars while rotating the achromatic prism with the P1 control until white light is obtained without dispersion.
4. After obtaining white light, determine the critical angle of the substance using the P2 control by aligning the boundary between dark and light with the intersection of the crosshair seen in the T1 binoculars.
5. Observe the refractive index of the substance shown in the T2 binoculars.
6. When finished, clean the prism surface that has been in contact with the substance using tissue paper until it is clean, and repeat the experiment with a different material.

Assignment

1. Plot the relationship between solution concentration and refractive index.
2. Plot the relationship between substance temperature and refractive index.