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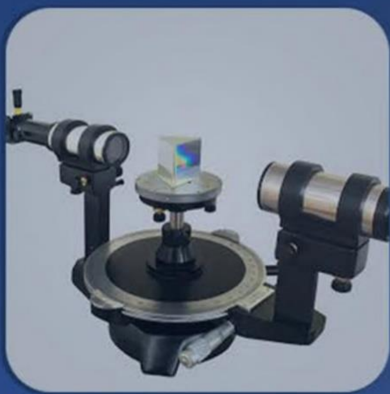
LECTURER TEAM



FUNDAMENTAL PHYSICS II

PRACTICAL GUIDEBOOK

PHYSICS STUDY PROGRAM
FACULTY OF NATURAL SCIENCE AND MATHEMATIC
UNIVERSITAS NEGERI JAKARTA
2018

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PREFACE

Alhamdulillah, we pray for the presence of Allah SWT. This expression of gratitude was accompanied by the completion of improvements to the Fundamental Physics II practicum guidebook, which had not been revised since 2006.

This practical guidebook basically refers to the syllabus for the Fundamental Physics II course for the Optical-Wave and Electric-Magnetic chapters. However, this guidebook is still far from perfect.

In general, this book is divided into two main parts, namely the chapter on optics, which consists of modules: refractive index, mirrors, lens properties and image defects, microscopes, spectrometers, polarimeters, and oscilloscopes. Meanwhile, the next chapter is about electricity, which consists of three modules: alternating current, the nature of incandescent lamps, and transformers. Apart from that, this practical guidebook also includes a discussion of statistical methods in data processing. This is intended so that students understand how to carry out a more comprehensive analysis of practicum data by calculating uncertainty factors in measurements. Important figures are also presented so that students understand how to write quantitative results from the practicum that has been carried out.

In writing this Fundamental Physics II practicum guidebook, we would like to thank all parties who helped with improvements. Special thanks go to the Head of the Physics Department, Mr. Prof. Dr. Agus Setyo Budi, and to Dr. Esmar Budi, Hadi Nasbey, M.Si, Iwan Sugihartono, M.Si, and the entire team of Fundamental Physics lecturers in the academic community of the Physics Department, FMIPA, Jakarta State University. We also do not forget to express our thanks to Sifa Alfiyah, the assistant lecturer, who helped in the process of making improvements to this practical guidebook.

Finally, we hope that this Fundamental Physics II practicum guide book will be useful for all students who are taking the Fundamental Physics II Practicum course.

Jakarta, September 2018

Fundamental Physics Lecturer Team

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CODE OF CONDUCT

1. Prerequisites for practicum
    a. Wear a designated laboratory coat
    b. Wear neat clothes (collared shirt/shirt, pants/long skirt) and wear shoes
    c. Using identifiers
    d. Bring a neatly bound preliminary report
    e. Prepare yourself with the material to be practiced
    f. Pass preliminary tests (if any)
2. Presence
    a. Practice must be present 15 minutes before practicum begins
    b. Late practice is declared to have failed to participate in practicum
    c. Practitioners who do not attend the practicum due to illness are required to show an official certificate from a doctor
3. Practicum Implementation
    a. In the laboratory, the practice must be calm, orderly, polite, neatly dressed, and wear laboratory coats. Bags, hats, and other items not related to practicum are stored in lockers.
    b. The practitioner must understand what will be practiced
    c. Practice must obtain data in accordance with what is practiced
    d. Practitioners must prepare equipment (assisted by assistants) and tidy up equipment that has been used again as before
    e. Practice must maintain order, personal safety, and equipment used
    f. Practitioners are prohibited from smoking, bringing food and drinks, disturbing other groups, and leaving the laboratory without the permission of the assistant or person in charge of the practicum.
    g. After the practicum is completed, the practice is mandatory:
        i. Ask for the signature of the person in charge of practicum or assistant on observation data paper
        ii. Re-request a preliminary report that has been assessed
        iii. Ask your assistant for a final assignment
4. Assessment
    a. Practicum values are determined from:
        - Preliminary tests (if any)
        - Preliminary report
        - Activities during practicum (work value)
        - Final practicum report
        - Presentation of practicum results (if any)
    b. Practicum graduation is determined based on the average score of practicum and attendance (compulsory practicum participation is 100%)
5. Sanctions
    a. Practices that follow the practicum are carried out in the first week starting after all practicums are completed.
    b. Practitioners who did not participate in practicum 3 times and did not follow up were declared not to have passed.
    c. Practitioners are required to replace damaged or lost equipment during practicum with the same equipment or a fine of Rp. 250,000 before participating in practicum the following week.

Observation Data Sheet Fundamental Physics Practicum

Study Program. Physics FMIPA State University of Jakarta

STATISTICAL METHODS IN DATA PROCESSING

1. Least Square Method

The *Least Square* method is a widely used method to see the linear tendency of an observation data. For example, there are a number of observational data:

$$\begin{aligned} x &\rightarrow x_1, x_2, x_3, \ldots, x_n \\ y &\rightarrow y_1, y_2, y_3, \ldots, y_n \end{aligned} \tag{1}$$

The linear relationship between data y_i and x_i is

$$y = a + bx \tag{2}$$

with:

a = intersection (*intercept) of the* curve with the 'ordinate' or perpendicular axis

b = *slope of* a straight line curve

Determination of the value of coefficients *a* and *b* using the least squares method as follows:

$$a = \frac{\sum y \sum x^2 - \sum x \sum xy}{n \sum x^2 - \left(\sum x\right)^2} \tag{3}$$

$$b = \frac{n \sum xy - \sum x \sum y}{n \sum x^2 - \left(\sum x\right)^2} \tag{4}$$

where *n* represents the amount of data used.

The spread equation (*S*) expresses the degree of distribution error of the linear equation expressed as:

$$S_a = S_y = \sqrt{\frac{\sum x^2}{n \sum x^2 - \left(\sum x\right)^2}} \tag{5}$$

$$S_b = S_y = \sqrt{\frac{n}{n \sum x^2 - \left(\sum x\right)^2}} \tag{6}$$

$$S_y^2 = \left(\frac{1}{n-2}\right)\left[\sum y_i^2 - \frac{\sum x_i^2 \left(\sum y_i\right)^2 - 2 \sum x_i \sum x_i y_i \sum y_i + n\left(\sum x_i y_i\right)^2}{n \sum x^2 - \left(\sum x\right)^2}\right] \tag{7}$$

Correlation coefficient *r* states the strength of relationships between data y_i and x_i Stated:

$$r(x,y) = \frac{S_{xy}}{S_x S_y} = \frac{\sum((x_i - \bar{x})(y_i - \bar{y}))}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}} \quad (8)$$

$$r(x,y) = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{\left[n\sum x_i^2 - \left(\sum x_i\right)^2\right]\left[n\sum y_i^2 - \left(\sum y_i\right)^2\right]}} \quad (9)$$

2. Gaussian *Distribution* (Normal)

Gaussian distributions are used to process repetitive observational data.

The steps in this distribution are as follows:

1) Arrange data from smallest (e.g. A*) to largest data (e.g. Z*)
2) Specify the number of K classes. Choose odd numbers: 3, 5, 7, 9, ... For amounts of data greater than 40, when in doubt use the equation

   $$K = 3{,}3\log N + 1 \quad (10)$$

   where *N* = Amount of data
3) Calculate class interval with formula $\frac{Z - A}{K}$
4) Build a class interval table by specifying frequency *f* (the amount of data that meets the class). Use the first class number smaller than *A* and the number of the last class is greater than *Z*. Example *A* = 0.0803, *With* = 0.1278 dan *Towards* = 19 then the interval value $\frac{Z - A}{K} = 0{,}0025$

Class	f_i
0.0800 – 0.0825	....
0.0826 – 0.0850	....
...	
...	
...	
0.1256 - 0.1281	....

5) When the shape of the graph approaches symmetry, specify the middle data, for example 0.0800-0.0825 and express it as x_i
6) For the price x_i Big or very small, settlement can be made easier by drawing a

price x_i new integers from 0, 1, 2, 3, ... Dst.

7) Arrange the table as follows:

Table 1.Table for *Gaussian distribution*

No	x_i	f_i	x_i	$x_i - \bar{x}$	$f_i(x_i - \bar{x})$	$f_i(x_i - \bar{x})^2$
1 2 3 4	 x^*	 $f >$	0 1 $2 = \bar{x}$ 3			
		$\sum f_i$			$\sum f_i(x_i - \bar{x})$	$\sum f_i(x_i - \bar{x})^2$

Value x^* is the price x_i with the greatest frequency

8) Calculate the coefficient of friction and standard deviation

$$F = x* + \left[\frac{\sum i f_i (x_i - x)}{N} \frac{Z - A}{K}\right] \qquad (11)$$

$$S = \left[\frac{\Sigma i\, f_i(x_i - x)^2 - \left(\Sigma i\, f_i(x_i - x)\right)^2}{N(N-1)}\right]^{1/2} \frac{Z - A}{K} \qquad (12)$$

Final results $X = F \pm S$

Note

The price *of* $S > 0$ only when the distribution chart is normal or symmetrical. If it is not symmetrical, perform data selection, discard data that is expected to make large deviations. Then rearrange the new interval classes until they are symmetrical.

3. Important numbers (AP)

Important numbers are all numbers obtained from the measurement results. This figure consists of exact numbers and estimated numbers. Consider the results of measuring the thickness of the book as follows: $x_1 = (12.1 \pm 0.5)$ mm and $x_2 = (12.01 \pm 0.05)$ mm. The first means that the book thickness is in an interval of 11.6 mm - 12.6 mm, while the second means that the book thickness is in an interval of 11.96 - 12.06 mm.

The first thickness measurement is expressed in three important numbers, while the second measurement is expressed in four important numbers. *The more precise a magnitude is, the more numbers are included in its reporting*. This becomes even clearer by deepening the understanding of the accuracy of a measurement. Statement $x = x \pm \Delta x$, states the absolute accuracy of the measurement (KTP) of the magnitude *x* and describes the quality of the measuring instrument used. While $\frac{\Delta x}{x}$ stating a relative ID card that is associated with the accuracy of measurements and is usually in the form of percent. The smaller the relative ID card, the more precise the measurement.

From the example above, we get $\frac{\Delta x}{x} = \frac{5}{12} \times 100\% = 4{,}2\%$ for measurement firstand $\frac{\Delta x}{x} = \frac{0{,}05}{12} \times 100\% = 0{,}42\%$ for the second measurement. It is said that the second thickness measurement has an accuracy of about 10x that of the first measurement.

RULE OF THUMB

MEASUREMENT ACCURACY (RELATIVE KTP)	**NUMBER OF APS USED**
≅10%	2
≅1 %	3
≅ 0,1%	4

Example

x = 1202 ± 10% means (1202 ± 120.2).

With 2 AP measurement results are written x = (1.2± 0.1) x 103

x = 1202 ± 1% means (1202 ± 12.02).

With 3 AP the measurement result is written x = (1.20 ± 0.01)x 103.

x = 1202 ± 0.1% means (1202 ± 1.202).

With 4 AP measurement results are written x = (1.202 ± 0.001) x 103.

FINAL REPORT FORMAT

Report authoring

1. The report is written on A4 size HVS paper can go back and forth
2. Written using neat handwriting
3. Graphing the results of data processing is carried out on millimeter block paper with precise scale

Preliminary report format

1. Home page (using Major-specific colors)

Judul praktikum

Nama :
NIM :
Jurusan / Prodi :
Kelompok :
Nama Percobaan :
Tanggal Percobaan :
Tanggal Pengumpulan :
Nama Asisten :

LABORATORIUM FISIKA DASAR
FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM
UNIVERSITAS NEGERI JAKARTA
TAHUN

2. Next page :
   a. Purpose
   b. Tools and materials
   c. Basic Theory
   d. How it works

Final report format

The final report is prepared based on the preliminary report that has been made, as for the arrangement as follows:

1. Preliminary report that has been assessed by the assistant

2. Experiment data
3. Data processing
4. Analysis and discussion
5. Conclusions and advice
6. Bibliography

OPTICS(O)

O1: BIAS INDEX

A. PURPOSE

1. Determine the refractive indices of various solutions of various concentrations.
2. Determine the critical angle of the solution.

B. TOOLS AND MATERIALS

1. Refractive index measuring vessel,
2. Refractometer,
3. Various solutions of different concentrations.

C. BASIC THEORY

If a beam of light hits the boundary plane between two different mediums, then
The light beam will be reflected (reflection) and refracted (refraction). On reflection symptoms and the refraction applies Snellius's law:

a) If a beam of light comes in the boundary plane between two mediums with refractive indexes of n and n' respectively, the light will be reflected and refracted.
b) The reflected light beam is on the same plane as the incident light beam, and has a reflected angle equal to the incident angle or can be written (angle i) = (angle p), where (angle i) is the incident angle and (angle p) is the angle of reflection.
c) Meanwhile, if the light is refracted, it applies:

$$\frac{\sin i}{\sin r} = \frac{n'}{n} \qquad (1)$$

n'/n is called the relative refractive index of the second medium to the first medium

If the angle of refraction r = 90o, such that sin r = 1, then the angle of incidence i is called the critical angle (ic).
Thus, if all light beams are coming on the boundary plane between the mediums it will be reflected all/perfectly.

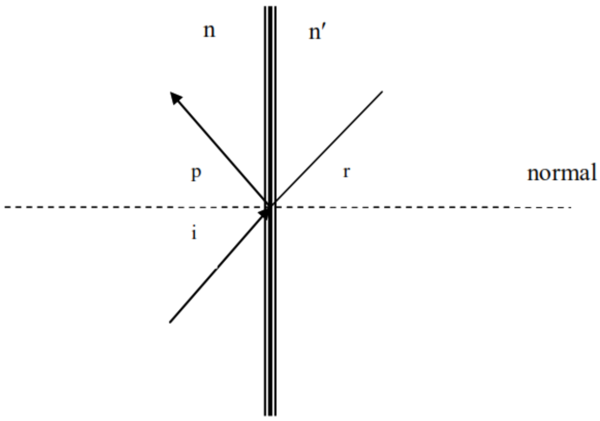


Figure 1. Refraction and reflection

In the event of reflection, the Law of Reflection applies:

a. Incident rays, reflected rays, and normal lines lie on one flat plane
b. The large angle comes *i* is equal to the large reflective angle *r*

As for the event of refraction applies **Snellius' Law** of refraction:

a. Incident rays, refractive rays, and normal lines lie on one flat plane
b. - If the beam comes from a tight medium to a less dense medium, it will be refracted away from the normal line
   - If the beam comes from a less dense medium to a denser medium, then the beam will be refracted close to the normal line
c. The ratio of the sine of the angle of incidence *i* to the sine of the refractive angle *r* is always constant, depending on the refractive index of the medium. Mathematically this sentence can be written:

$$\frac{\sin i}{\sin r} = \frac{n'}{n} \qquad (1)$$

If the magnitude of the angle of incidence *i* exceeds the critical angle, then all incoming light beams will be reflected, none of which are refracted, so this event is known as **Perfect Reflection**.

Calculating the relative refractive index coefficient

Based on equation 1) then it is obtained: n sin i = n' sin r. Continue to look at figure 1. Based on figure 1, then we will get the relationship n x / a = n ' x ' / a *so nx = n'x'* or n' / n = x / x' (n' / n *is called the relative refractive index)*

Refractometer

A refractometer is a device for measuring the concentration of dissolved materials. The working principle of this tool utilizes *light refraction*. If the light beam comes from a substance with a refractive index n *and hits the side of the prism (refractive index* n'*) with the angle of incidence* then: $i_1 = 90°$

1. At the moment when light enters the prism, based on equation (2) holds:

$$n = n' \sin r_1 \tag{2}$$

2. At the moment when light exits the prism, based on equation (2) holds:

$$n \sin r_2 = n' \sin i_2 \tag{3}$$

3. While

$$\beta = r_1 + i_2 \tag{4}$$

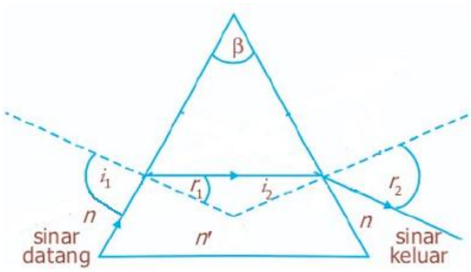


Figure 2. Refraction on prisms

The substitution equations (5), (6), and (7) are obtained:

$$\sin r_2 = \frac{n'}{n} \sin(\beta - r_1) \tag{5}$$

In a prism, quantities such as n□, □ and τηε χριτιχαλ ανγλε οφ τηε πρισμ (r1) are *quantities whose magnitude depends on the material and type of prism, and are* $n' \sin(\beta - r_1)$ a constant (let's call it k*) then* $\sin r_2 = \frac{k}{n}$. The refractive index value *n* can be calculated if r_2 known.

C. HOW IT WORK

Simple refractometer

1. Fill the vessel with a solution of a certain concentration.
2. Place the S standard on the wall of the back of the vessel.
3. Measure *A* and *X* as the angle of incidence.
4. Make *S*, *O* and *A visible if observed through solution (A will move to* A' if observed through solution).
5. Measure *x and* x' which indicate the position of points *A and A'*.

6. Measure the refractive angles as *A′* and *X′*.

7. Change the location of *S* and note the positions *of* A and A′ *as well as X and X*′ *as in steps 6 and 7*.

8. Do the above experiments for various concentrations, for example 50%, 40%, 30%, 20% and 10%.

Refractometer Abbe

1. Record the temperature in your workspace.
2. Adjust the lens of the refractometer so that the cross lines and scale are clearly visible.
3. Clean the prism with a soft, clean cloth.
4. Drop the liquid that will be measured for refractive index (a few drops) on the prism of the light, then close the prism of the light and gauge again.
5. Turn the player on the right so that the light dark border is right on the cross line. Read the scale!

D. CALCULATION

1. Count Index and corner kRitis each solution pexist experiment **Simple refractometer** !
2. Calculate the refractive index of each solution on the **Abbe Refractometer experiment**!
3. Based on the data from the experimental results that have been carried out, graph the relationship between the refractive index and the concentration of the solution and the relationship between the critical angle and the concentration of the solution!

E. QUESTION

1. Explain why when a beam of light reaches the boundary between two transparent mediums reflection and *refraction*!
2. If a beam of light comes from the vacuum of a substance, what happens? Explain based on equation (2)!
3. What do you think of the relationship between relative refractive index and absolute refractive index in this experiment?
4. What do you think about measuring refractive index with the Abbe Refractometer?

O2: C E R M I N

A. PURPOSE

1. Determines the distance of the fire point (focus) of concave and convex mirrors.
2. Determine the distance of objects and the distance of shadows on concave and convex mirrors.
3. Determines the properties of the image formed by concave and convex mirrors.

B. TOOLS AND MATERIALS

1. Optical bench system,
2. Candle as a light source
3. Nails or needles,
4. Arrow-shaped lattice as an object to be illuminated,
5. Concave mirror,
6. Convex mirror,
7. Flat mirror.

C. BASIC THEORY

Mirrors form shadows through the process of reflection. The shadow formed can be a real or virtual shadow. Virtual shadows can be seen directly by the eye, while real shadows need a screen to capture their shadows.

Concave mirrors are *convergent*, that is, they collect light. The beam of light coming to the surface of a concave mirror parallel to the main axis will be reflected and collected at a point called a focal point or fire point. The properties of the image formed have different properties and sizes depending on the position of the object with respect to the reflected plane of the mirror.

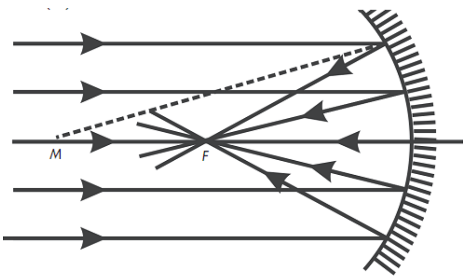


Figure 1. Concave mirror reflection

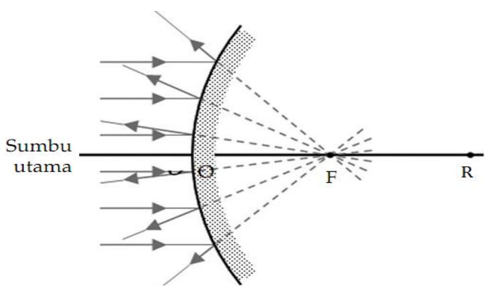


Figure 2. Convex mirror reflection

Convex mirrors are *divergent*, that is, scatter light. The incident light beam on the mirror surface parallel to the main axis will be reflected as if from the focal point. The nature of the image of this mirror is always virtual, upright, minimized. Virtual shadows cannot be captured on the screen, so in determining the fire point it is necessary to use the non-parallac method.

The basis for the application of the non-parallac method is carried out as follows:

Place a pencil about 30 cm in front of your eyes. Then hold another pencil and place it approximately 40 cm in front of the eye in line with the first pencil. Try moving your head slightly left and right. The pencil looks moving, doesn't it? If you place both pencils at the same point in front of your eyes, you can clearly see no movement from one pencil to the other, even though the head has been moved left and right. This principle will be used to determine the location of the convex mirror image. The image formed by a convex mirror will be aligned with another image, namely the image of a flat mirror. If there is no relative movement between the two shadows, it means that they are located in the same position. It is well known that the distance of a flat mirror image is always equal to the distance of the object. Thus the location of the convex mirror image can be known.

Mathematically, the distance of a mirror fire point is determined by the equation:

$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'} \qquad (1)$$

Information:

F : Mirror Fire Point Distance (cm)

S : the distance of the object to the mirror (cm)

s' : distance of shadow to mirror (cm)

D. HOW IT WORK

Observation of the image properties of concave mirrors and convex mirrors

1. Place a concave mirror as close to the eye as possible.
2. Move the mirror away from the eyes to arm's length from the face.
3. Investigate changes in eye image during mirror movement, note your observations!
4. Repeat step 3 by using a convex mirror.
5. Place the object (grid illuminated by the light source) at a certain distance in front of the concave mirror. Using the screen, get a clear shadow of the object.
6. Note the distance of the object, the distance of the shadow and the nature of the shadow.
7. Perform step 5 for several measurements and record the results.

Determine the distance of a concave mirror fire spot

1. Design the equipment as shown in figure 3.
2. Place the object on one end of the optical bench
3. Place a concave mirror about 0.5 m away from the object.
4. Place the screen between the object and the concave mirror. Position the screen so that it does not block light from going to the mirror.
5. Slide the screen until you see a sharp shadow
6. Record the distance of the object and the distance of the shadow.
7. Repeat the experiment several times by varying the distance of objects and shadows.
8. Then calculate the distance of the mirror fire spot.

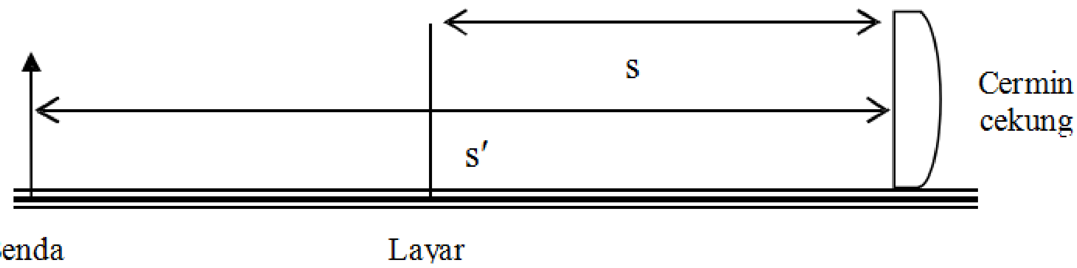


Figure 3. Experimental scheme of image formation on a concave mirror

<u>Determining the distance of the convex mirror fire point</u>

1. Set tools as shown in figure 4.
2. A nail or needle erected in a place acts as an object. Investigate where the image formed by the convex mirror is. The trick is to use the non-parallac method, which utilizes another image from a flat mirror, then you will see the image of a nail or needle on both mirrors.

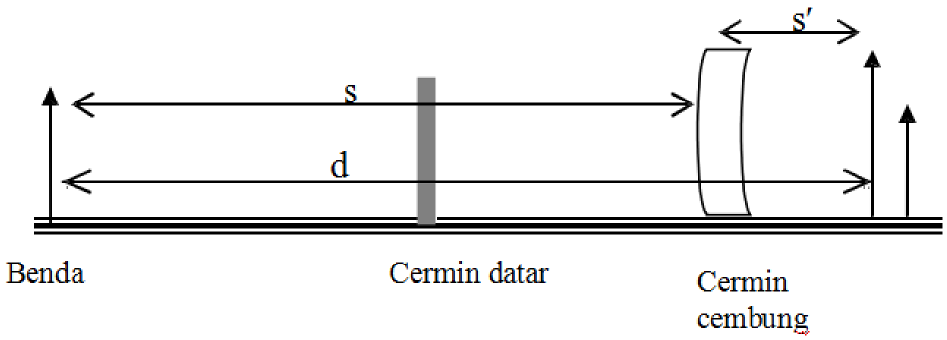


Figure 4. Experimental scheme of image formation on convex mirrors

3. By moving the eye from one side to the other, as described in the non-parallac method, it will be known whether the flat mirror image lies in the same position as the convex mirror image. If the positions are not the same, shift the mirror flat so that the two images agree (*coincide*).
4. Now it can be known the location of the convex mirror image, which is as large as d cm behind the flat mirror. By measuring *d* and *s will be able* to obtain s *from a*

convex mirror.

5. Record the data obtained.
6. Repeat the experiment several times by changing the position of the nail or needle against the convex mirror.

E. CALCULATION

1. Calculate the distance of the concave mirror fire spot!
2. Calculate the distance of the convex mirror fire spot!

F. QUESTION

1. What is the non-parallac method?
2. Show it with a drawing of the shadow formation diagram formed by each mirror!
3. Using an image, explain the formation of shadows produced by concave mirrors and convex mirrors at the time of the distance of objects:
   a. shorter than the distance of the point of fire.
   b. same as the point of fire.
   c. greater than the distance of the fire spot.
4. Based on your answer to question 3, give a conclusion about how the nature of the image formed by concave mirrors and convex mirrors!
5. If you put a concave mirror in front of your face. Explain how your eyes image when the mirror is moved. How will your eyes image if a convex mirror is used?
6. Explain the general conclusions with respect to the shadows formed by each mirror!
7. Give examples of the use of concave mirrors and convex mirrors with regard to their properties!
8. Plot the relationship between the distance of the object and the distance of the image on a concave mirror and a convex mirror. (The distance of the shadow on the Y-axis and the distance of the object on the X-axis).
9. The relationship 1/f = 1/s + 1/s□ is a form of the equation x + y = constant. Prove that the relationship diagram between 1/s and 1/s□ is a straight line!

O3: LENS PROPERTIES AND SHADOW DEFECTS

A. PURPOSE

1. Understand the refractive properties of light in lenses.
2. Determine the focal distance of the lens.
3. Observe shadow defects (*aberrations*) and find out their causes.
4. Reduce the occurrence of shadow defects.

B. ALAT AND MATERIALS

1. Strong positive lens (++),
2. Weak positive lens (+),
3. Negative lens (-),
4. Objects in the form of
5. Diaphragm and diffuse
6. Incandescent lamp,
7. Shadow capture screen,
8. Optical bench,
9. Connecting cables and power supply sources.

C. BASIC THEORY

<u>Determining the focal distance of a positive (convergent) lens</u>

A positive lens is a convex lens that is converging, that is, it collects light at the focal point. The nature of the image formed from this lens depends on the position of the object from the lens. For example, an object O is placed to the left of the positive *lens at a distance of s from the lens so as to produce an image of O' to the right of the lens at a distance of* s' that can be observed on a screen. The magnification of the shadow M is the ratio *of* s' to s. The focal distance of an f *lens* can be determined by the equation:

$$f = \frac{s'}{1+M} \tag{1}$$

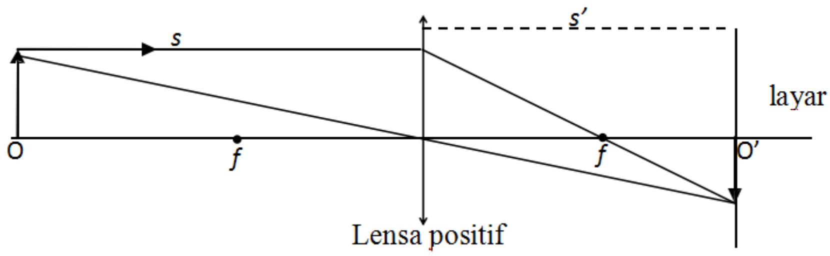


Figure 1. Positive lens image formation

Another way of determining the focal distance of a positive lens is the *Bessel way*. This method starts by placing an O object at a distance of L from the screen. Then the lens is shifted between object O and the screen, so that two positions (e.g. positions 1 and 2) are obtained that produce a clear image on the screen. The shadow of one is magnified and the other is scaled down. If r is the distance between the two positions, the focal distance of the lens can be determined by:

$$f = \frac{L^2 - r^2}{4L} \tag{2}$$

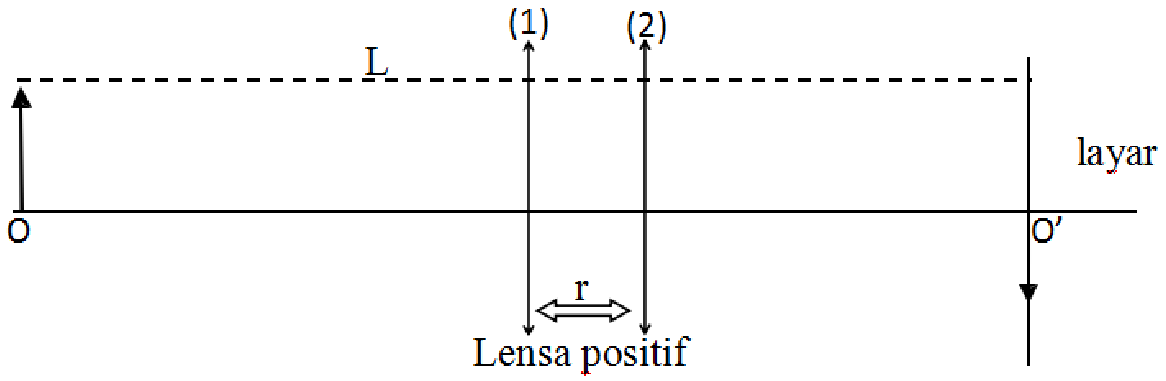


Figure 2. Bessel's way positive lens focus point determination

Determining the focal distance of a negative (divergent) lens

Negative lenses or concave lenses are divergent, scattering light. Each beam of light that comes parallel to the main axis is refracted spreading out as if from a focal point. The nature of the image formed from this lens is always virtual, upright, minimized. The focal distance of a negative lens can be determined with the help of a positive lens. Positive lenses were first used to form real images on the screen. Then between the positive lens and the screen is installed negative lens.

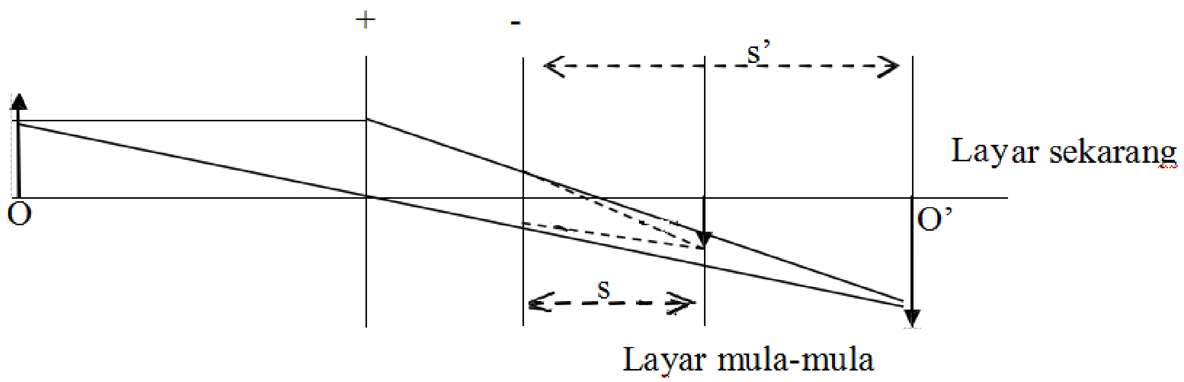


Figure 3. Determination of the focal point of the negative lens

The image on the screen is a virtual image of the negative lens. Therefore, in this state, the distance from the screen to the negative lens is called the object distance s. Now, the screen is shifted back away from the lens to acquire new shadows. In this state the distance from The screen until the negative lens is called the shadow distance s'. The focal distance of a negative lens can be

Determined by the equation:

$$f = \frac{s \times s'}{s + s'} \qquad (3)$$

When two lenses with focal distances of *f1* and *f2* respectively are combined (closed), a combined lens is obtained whose focus is *fgab* whose magnitude can be determined from the equation:

$$\frac{1}{f_{gab}} = \frac{1}{f_1} + \frac{1}{f_2} \qquad (4)$$

Shadow Defects

The lens equation given above can be derived conditionally that it applies only to "paralacsial" rays. If these conditions are not met, there will be shadow defects (*aberrations*).

D. HOW IT WORK

Determining the focal distance of the positive lens

1. Measure the height of the arrow used as an object.
2. Arrange the optical system in a row as follows:
    a. objects with lights behind them,
    b. weak positive lens (+), strong positive lens (++), and
    c. sail.
3. Keep the distance of the object to the screen (L) greater than 1 meter. Measure and record the distance of objects.
4. Mount a weak positive lens (+) between the object and the screen. Slide the lens until you get a clear and upright shadow on the screen; Note the position of the lens and measure the height of the shadow on the screen.
5. Shift the position of the lens back until you get another clear image (the distance of the object to the screen should not be changed).
6. Repeat the steps with a different L.
7. Repeat experiment step 4 for strong positive lenses (++).

Determining the focal distance of a negative lens

1. Create a clear image of the O object on the screen with the help of a positive lens.
2. Place the negative lens between the positive lens and the screen, measuring the distance of the negative lens to the screen.
3. Slide the screen so that a new, clear shadow is formed on the screen. Measure the distance

of the negative lens to the screen again.

4. Repeat these steps several times.

Determining the focal distance of a compound lens

1. Close the strong positive (++) lens with the weak positive lens (+) as tightly as possible. Use the *Bessel method* to determine the combined focus distance.
2. Repeat several times with the capricious L.

Observing shadow defects (*aberrations*)

1. Use a strong positive lens (++) with an incandescent lamp as an object. Slide the screen, observe and note the shadow state from each lens position.
2. Install the diaphragm in front of the incandescent lamp. Repeat step (1) and note the state of the light shadow.
3. Repeat step (2) with different diaphragms.
4. To observe astigmatism, place the lens tilted towards the axis of the system of objects and the screen. Place the diffuse glass (object) in front of the lamp.
5. Place the diaphragm in front of the object (diffuse glass), and slide the screen again. Note the changes that occur in the shadow.

E. CALCULATION

1. Calculate the focal distance of a weak positive lens (+) and a strong positive lens (++) using equation (2)!
2. Also calculate using equation (1)!
3. Explain which way is more thorough!
4. Calculate the focal distance of a negative lens using equation (2)!
5. Calculate the focal distance of the combined lens using equations (2) and (4). Compare the two results and explain!

F. QUESTION

1. What are parallaxial rays?
2. Prove formulas (1) to (4)!
3. From *Bessel's* formula, how can L be selected so that 2 shadows are enlarged and reduced on the screen?
4. Why to determine the focal distance of a negative lens should use the help of a positive lens?

5. What does *chromatic* aberration mean?
6. What is astigmatism called?
7. Explain the occurrence of shadow defects that occurred in the experiment above!
8. Shadow defects can be reduced by using a small diaphragm. Why? Are there other ways to reduce shadow defects? Explain!

O4:
MICROSCOPE

A. PURPOSE

1. Get to know microscopes from a practical perspective.
2. Understand the working principle of the microscope.
3. Skillfully use a microscope.

B. TOOLS AND MATERIALS

1. Microscope	3. Ruler,
2. Micrometer	4. Hair or other small objects.

C. BASIC THEORY

A microscope is a tool to see tiny objects at close range. This tool is composed of two positive lenses, namely objective and ocular lenses. The objective lens is near the object, while the ocular lens is near the observer's eye. The observed object is placed between the focal point and twice the focus of the objective lens. The resulting magnification varies and has a certain range. Maximum magnification occurs when the observer's eye accommodates maximum, i.e. the final image of the microscope is exactly at the point near the observer. While the minimum magnification is obtained when the eye is not accommodated, that is, the final image formed from the microscope is right at the far point of the observer. If the observer has a normal eye, then the image formed by the objective lens is exactly at the focal point of the ocular lens so that the final image result from the microscope is at the far point of the normal person, which is infinite.

Determining the magnification of the microscope

The total magnification of the microscope is the comparison of the angle of view when looking at objects using a microscope to the point of view when looking at objects without using a microscope. For example, an object as high as h is right at the point near or the *punctum proximum* (PP), the observer produces a α angle of view when not using a microscope. Assume the observer is someone with normal eyes so has $PP = 25$ cm. When using a microscope with the eye unaccommodated, the image from the objective lens h' is exactly at the focal point of the ocular lens f_{ok}, resulting in an angle of view of α' as shown in Figure 1.

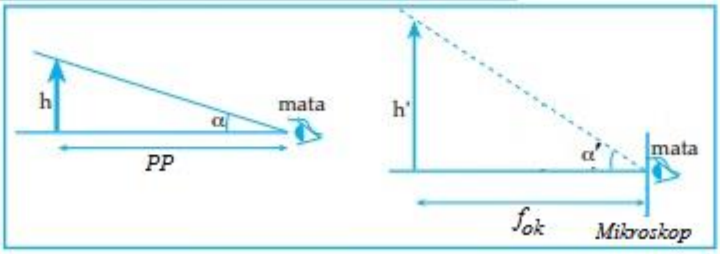


Figure 1. Point of view comparison scheme

Based on the analysis of Figure 1 obtained the equation:

$$\tan\alpha = \frac{h}{PP} = \frac{h}{25}$$
$$\tan\alpha' = \frac{h'}{f_{ok}} \qquad (1)$$

Mathematically, the total magnification of the microscope can be formulated as follows:

$$M = \frac{\tan\alpha'}{\tan\alpha} = \frac{h'}{h} \times \frac{PP}{f_{ok}} \qquad (2)$$

The ratio *of* h' to h *is the magnification* of the objective lens while it is the magnification of $\frac{PP}{f_{ok}}$ the ocular lens when the eye is not accommodated.

Determining Total Magnification Directly

The total magnification is calculated according to the equation:

$$M = \frac{\tan\alpha'}{\tan\alpha} = \tan\alpha' \times \frac{25}{h} \qquad (3)$$

where h is the size of the object. If the object is hair, then h can be obtained by measuring the diameter of the hair using a micrometer. Meanwhile h' can be measured using two eyes. One eye sees the hair with a microscope while the other eye sees the scale line of the bar outside the microscope. Thus the diameter of the hair measured with a microscope can be measured with a bar. If a is the distance of hair to eye, then it can $\tan\alpha' = \frac{h'}{a}$ be known. This method may not be done when the microscope used is sophisticated because the glass has been equipped with scales. But this manual method still needs to be done to emphasize to all of us the importance of a measurement process.

Splitability and Numerical Aperture

The image of a point object on a lens is not a dot, but a circle surrounded by a light dark ring called a diffraction pattern. This is due to diffraction by the aperture. This diffraction pattern is practically considered a roundabout because 85% of light collects on this roundabout. Two very close points of light, the shadow is in the form of two intersecting roundabouts.

These two roundabouts are considered separate if their minimum distance is equal to their radius. This is fulfilled if the distance between two objects (points of light) is:

$$R = \frac{0{,}61\lambda_0}{n \sin \beta} \tag{4}$$

R = the distance between two starting objects can be separated by a lens (= minimum distance),

λo = wavelength of light used for vacuum, n = refractive index of the medium of the environment around the object,

β = 1/2 peak angle of the incoming light cone of the objective lens.

$n \sin \beta$ is called numerical aperture (AN). See the following image:

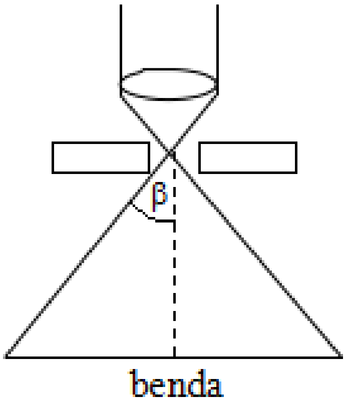


Figure 2. Separation power determination scheme

An optical device is said to have a large separation power if the distance between two objects that begin to be separated by the device is very short or the separation power is greater if R is smaller.

D. HOW IT WORK

1. Prepare a set of microscopes and small objects to be observed
2. Place the microscope near the light source and adjust the direction of the mirror under the microscope so that the microscope gets enough light.
3. Place a strand of hair or other small object on the table of the object, overlapping it with glass so that its position does not change. Turn the objective lens controller until the lens position almost offends the object table. Be careful not to pound the glass.
4. With your eyes looking at the object in the microscope, turn the objective lens rotation slowly to gain focus until the hair image is clear and sharp.
5. Place the bar on the table next to the myoscope.

E. CALCULATION

Calculate the total magnification of the microscope!

F. QUESTION

1. Image of shadow formation on a microscope!
2. Explain the steps to get the total magnification of the microscope in equation (2) by analyzing the shadow formation diagram!
3. Why is there no lateral magnification for the ocular lens when the eye sees without accommodating?
4. Which is more advantageous, looking with a microscope without accommodating or accommodating as hard as possible? Why!

O5: SPECTROMETER

A. PURPOSE

1. Determine the peak angle of the prism.
2. Determine the refractive index of a prism by the minimum deviation method.
3. Understand the working principle of spectrometers and skillfully use them.

B. TOOLS AND MATERIALS

1. Prism spectrometer.
2. Monochromatic light sources, such as sodium lamps.

C. BASIC THEORY

A spectrometer is a device used to measure the angle of deviation (deviation) of a light beam due to reflection, refraction, interference, diffraction and scattering. Broadly speaking, this tool has 4 main components, namely:

Collimator

A collimator is a tube equipped with an achromatic lens at one end facing the prism and a wide adjustable gap. The gap is used to obtain parallel light beams that have the same deviation angle for each ray. The position of the gap can be adjusted with the button on the collimator. This collimator is placed on a static pole to the base of the spectrometer.

Telescope

Telescopes are composed of objective and ocular lenses. The objective lens faces the spectrometer table while the position of the ocular lens against the objective lens can be adjusted. The ocular itself consists of two lenses (eyepiece and field lens) whose positions can be adjusted to each other. Precise positioning of slit shadows can be determined using cross threads mounted in a plane perpendicular to the light source between the eyepiece and the field lens in the ocular. The telescope is placed on a stalk that can be rotated against the axis of the spectrometer. If the base of the spectrometer is horizontal, then the axis of the vertical spectrometer and the telescope rotate in a horizontal plane with its axis continuing towards the center of rotation located on the axis line. While the position of the telescope with respect to collimator or other reference positions can be read on the two nonius opposite positions and rotate with the telescope.

<u>Prism</u>

The prism is the most important part of the spectrometer, placed on the spectrometer table.

Spectrometer table

The spectrometer table has a rotation axis close to the telescope's rotation axis. This table can be positioned by raising or lowering or can be rotated by loosening the screws and then strengthening them. This setting can also be used to adjust the straightness of the reflecting plane. By measuring the minimum deviation that occurs for a given monochromatic light used, the refractive index of a prism can be determined according to the following formula:

$$n = \frac{\sin \frac{1}{2}\left(D_m + \beta\right)}{\sin \frac{1}{2}\beta} \qquad (1)$$

where n *is the* refractive index of the prism, Dm is the minimum deviation and β is the peak angle of the prism.

D. HOW IT WORKS

Preparation

1. Point the telescope to see distant objects so that they are clearly visible. Please note that the beam entering the telescope is aligned.
2. Place the telescope and collimator in a straight line and arrange them so that they are perpendicular to the light source.
3. Fill the gap with the light source and set the width, so that the image of the gap is clearly visible on the telescope.
4. Set the height of the prism table so that measurements can be made easily.

Measurement of the peak angle of the prism

1. Place the prism on the spectrometer table so that the angle to be measured faces the direction of the light source.
2. Bring the collimator gap close to the light source.
3. Adjust the position of the prism so that the reflection of light from the collimator can be seen by the telescope ocular in two places, namely at position I and position II.
4. Handicapped angle of position shift θ. Prove that the magnitude of the apex angle of the prism is equal to θ.
5. Repeat steps 1–4 several times to get the average price from the peak angle of the

prism.

Minimum deviation angle measurement

1. Align the telescope ocular with the collimator slit until the light is clearly visible, and record its position. This is called position I.
2. Place the prism on the spectrometer table, so that the rays from the gap will fall on one side of the prism (note figure 3).
3. Turn the telescope ocular until arbitrary refractive rays are obtained.
4. While observing the refractive beam through the ocular, rotate the prism slowly by rotating the spectrometer table so that it appears that the refractive beam is shifting.
5. Watch the movement of the refractive beam through the ocular until at some point the beam reverses direction even though the prism is rotated in one direction. By shifting the spectrometer table back and forth in that area, find the position where the beam reversed direction. That position is called position II.
6. The angle formed by the final position with respect to the initial ocular position (straight with the gap) is the minimum deviation angle, *Dm*.
7. Repeat steps 1 through 6 several times to get the average value of the minimum deviation.

E. CALCULATION

1. Determine the peak angle of the prism!
2. Determine the refractive index of a prism by the minimum deviation method!

F. QUESTIONS

1. Based on relevant references, mention other ways of determining prime refractive index. Briefly explain!
2. Derive the formula: $Dm = (n-1)\beta$ that we used in this experiment!
3. Explain what the usage differences between the following two formulas are:
   - First formula $Dm = (n-1)\beta$
   - Second formula   n sin1/2□ = sin1/2(Dm + β)
4. In each experiment, the results obtained are not always the same as numerical calculations, meaning that there are always errors or errors. Explain what caused it to happen!

O6: POLARIMETER

A. TUJUAN

1. Understand the working principle of polarimeters.
2. Determine the sugar content of a solution.

B. TOOLS AND MATERIALS

1. Polarimeter,
2. Monochromatic light source,
3. Gula,
4. Gelas ukur,
5. Aquadest,
6. Mistar,
7. Thermometer.

C. BASIC THEORY

If a beam of light is linearly polarized through a sugar solution, or another solution that has optically active properties, then the polarization plane of the beam will be rotated by a certain angle, mass α. The magnitude α depends on 4 factors namely: the length of the solution through which the beam passes, the degree of solution, the wavelength of the ray and temperature.

Angle measurement α using Laurent's polarimeter or 1/2 shadow polarimeter. In this tool there are 5 important components, namely: polarizer, ½ λ plate from Laurent, solution holder tube, rotatable analyzer, and binoculars. Schematically positioned
Each of these components can be seen in the following figure.

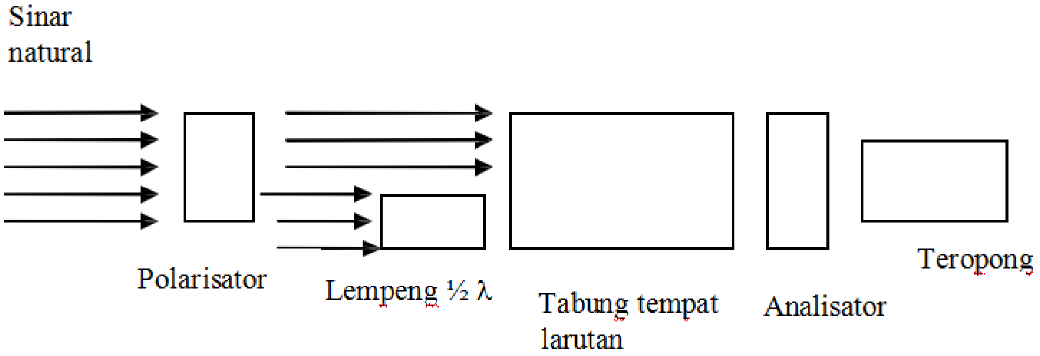


Figure 1. Scheme of arrangement of components on the polarimeter

The polarizer and plate ½ λ are installed in such a way that the main plane of the polarizer forms a small angle with respect to the optical axis of the plate. This angle is called the shadow angle. About half of the beam passing through the polarizer will enter the ½ λ plate and the rest will move outside the plate. The polarization plane of the rays passing through the plate is rotated. If initially the polarization plane is located to the left of the optical axis with an angle α, then after leaving the plate ½ λ, this polarization plane is located to the right of the optical axis with an angle α too. The plane of polarization of light outside the plate does not rotate. Now there is a beam of light with two polarizations, each to the left and right of the optical axis of the plate, and each forming an angle α.

If the analyzer is rotated with binoculars, then the field of vision will change. Generally, half of the part looks darker than the other half. In one situation, the two parts look the same. In the state of the tube containing aquadest, the equally dark state means that the plane of polarization of the analyzer is perpendicular to the optical axis of the plate. This state is used as the zero of the polarimeter. If aquadest is replaced with a sugar solution, then at this position the viewing area is equally dark again. This is because the polarization field has rotated. To change the situation to the same darkness again, the analyzer must be rotated so that the main plane is perpendicular to the line that bisects the same angle between the planes of polarization of the beam. The magnitude of this rotating angle is equal to the magnitude of the rotation angle of the polarization plane of the ray.

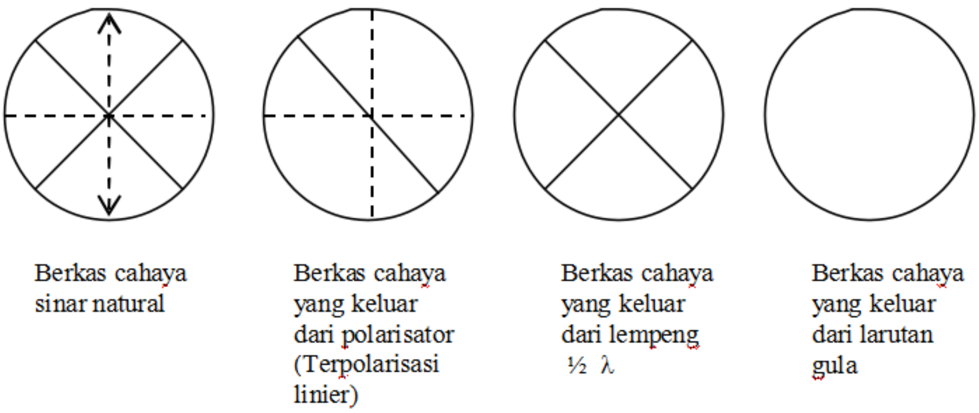


Figure 2. Patterns of polarization fields

Information:

KL : The polarization plane of the rays coming out of the polarizer.

MN : the plane of polarization of the rays coming out of the ½ λ plate.

AB : optical axis ½ λ.

PQ : The position of the optical axis of the analyzer gives the same dark conditions to the aquadest.

PQ' : the position of the optical axis of the analyzer that gives There is equally dark for sugar solution.

The size of the rotating angle can be written as follows:

$$a = \alpha \frac{Lm}{100} \qquad (1)$$

where α ισ τηε rotating power type, that is, the rotational angle of the polarization plane of the rays passing through the solution (1 gram of optically active material in 1 cc of solution). The number of grams of optically active material in 100 cc of solution *is expressed in m*, and the length of the tube in dm is expressed in *L*. For cane sugar (α_{20}) = 66.54^o for yellow light and temperature 20^{o}C. The observed sugar solution content can also be calculated using equation (1).

D. HOW IT WORKS

Determining the zero point

1. Carefully clean the glass of the tube cover.
2. Carefully clean the tube and then shake it with aquadest.
3. Fill the tube with aquadest to the brim. To prevent air bubbles from entering the tube, slide the cover glass from the edge and then lock the glass with a coupler (the center of the glass should not be touched by hands).
4. Insert the tube in the polarimeter.
5. Regulate the course of the beam by aligning the polarimeter with respect to the optical axis so that the rays enter through the binoculars. Focus the binoculars so that the gap appears light dark.
6. Turn the analyzer (with its handle on the nonius scale) left and right until an equally dark state is obtained, then read the main scale and the nonius scale. This legible number represents the zero point of the polarimeter.
7. Repeat step (6) repeatedly and note the zero point of the polarimeter (repeat 8 times).

Determining the turning angle of the sugar solution

1. Clean the tube carefully.
2. Shake the jar several times with the sugar solution to be used (a sea of sugar of a certain concentration).
3. Fill the tube with the sugar solution to half and then insert the thermometer into the tube and wait a few moments. Record the temperature.
4. Fill the tube with sugar solution and close it carefully until there are no air bubbles in it.

5. Put the tube in place and then read the nonius after the analyzer is rotated so that both sides of the light field look equally dark. The readings were carried out 8 times as in the previous work.
6. Measure the temperature of the solution again as in step 3. Record the average temperature of the solution.
7. The size of the rotation angle is the difference from the attitude of the analyzer between before and after there is an optically active solution.
8. Repeat this experiment with various concentrations of solution, at least 3 different concentrations.

E. CALCULATION

1. Calculate the type of rotational power of each solution!
2. Graph the relationship between solution concentration and type rotation based on your experimental data! What conclusions can you draw from that chart?

F. QUESTION

1. What if the tube is filled with aquadest? Will the polarization field also rotate? Why is that, explain your answer!
2. Why is sodium lamp light commonly used in this experiment?

ELECTRICITY (L)

L1: OSILOSCOPE

A. PURPOSE

1. Know the function of the oscilloscope.
2. Understand the principle of action of oscilloscopes.
3. Design and explain the occurrence of the Lissayous pattern.
4. Calculates the frequency of a voltage source using the Lissayous pattern.

B. TOOLS AND MATERIALS

1. oscilloscope,
2. Two generators,
3. AC voltage source (Transformer),
4. DC voltage source (Batrei or DC power supply)
5. Multimeter
6. A set of connecting cables,
7. Millimeter Paper.

C. BASIC THEORY

An oscilloscope (*cathode ray osciloscope,* abbreviated as CRO) is a tool to visually see the dynamics of electrical quantities as a function of time. The magnitude of the signal from a source can be determined by measuring the shift of bright spots generated by the electron beam hitting the screen from its normal position. This bright spot is just like the pointing needle on a voltmeter. The deviation/shift of bright spots is made in a vertical direction, while the horizontal shift is proportional to the rate of increase in time.

Vertical deviation _is specified in units of volts/scale or volts/cm. _While the horizontal direction deviation _is determined in units of seconds / scale or seconds / cm. In addition to showing the description of the signal as a function of time, the oscilloscope can also act as a measuring instrument for parameters on the signal, including: time duration, maximum swing period, amplitude, phase, and frequency.

By removing lejang tension (*sweep voltage*) that is, the voltage that protrudes or extends the bright spot into a straight line, then the deviation can be given from the outside or as a second input. In this case there are two signals that are perpendicular to each other in the same time so that the relationship between the two signals can be shown directly as a function of time. If both signals are the input and output of a system, then the image appears on the

The screen shows the characteristics of the system/work unit. Note that the projection of a bright spot into a straight line is basically the rapid and continuous movement of the electron beam to the right.

Oscilloscopes have 5 main components, namely:

1. Cathode ray tube (*Chatode Ray Tube* = CRT)
2. Y deviation amplifier (Y amplifier)
3. X deviation amplifier (X amplifier)
4. Time based generator
5. Beam control

Cathode ray tube (*Chatode Ray Tube* = CRT)

The CRT is shaped like a *funnel* with a flat right end and appears as a screen as shown in Figure 1. The inner side of the screen is coated with *fluoresence* that emits light when exposed to electrons. On the neck of the tube there are a number of electrodes that can affect the motion of electrons before they reach the screen.

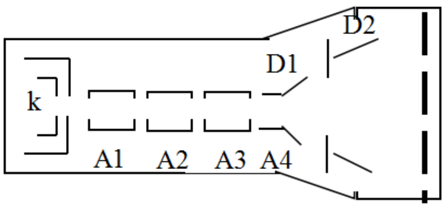


Figure 1. Schematic of CRT

The leftmost electrode is called an electron gun that can catapult electrons to the right in a narrow beam. The electron gun consists of a K cathode as an electron source cylinder, and a cylindrical Wehnelt W lattice for regulating the intensity of electron current. The electrons are accelerated and directed by a number of anodes, A1 to A4, which provide an electric field to allow the electrons to cross the space between the flat deviation plates, D1 and D2. While the main anode A5 which is given a high voltage (thousands of volts) is used so that electrons have a high enough motion energy, so that when it hits the fluorescent screen, it will produce bright spots with high intensity.

Y deviation amplifier (Y amplifier)

This amplifier is useful for enlarging the input signal so as to enhance the sensitivity of the CRO expressed in mV/scale. CRO with a sensitivity of 20 mV/scale with a distance between the scale lines = 6 mm means that the highest input sensitivity, which is 20 mV, results in a deviation on the screen as far as 6 mm. The measurement area can be expanded by several hundred vollts as needed by varying the input sensitivity.

X deviation amplifier (X amplifier)

This amplifier functions as a horizontal deviation reinforcement when the oscilloscope is positioned to receive signals from outside. The X deviation amplifier has a smaller gain compared to the Y deviation amplifier so that it has a lower sensitivity. In addition to changing the price of the horizontal scale at a position connected to the time base, this deviation amplifier can adjust the speed of the time base or as a speed adjuster. In other words, the timescale can be changed as needed. In practice, this is useful for making input images in the form of period signals more stable and as a synchronizer regulator. Similar to the Y deviation amplifier, the X deviation amplifier has a left-right positioner. The function of these regulators (horizontal or vertical position) will be clearly visible if the inputs are zero or no signal at all, these adjusters will move bright spots up or down or also left and right.

Time based generator

In the time base voltage plant there are several settings related to the parameter signal generated, namely the saw voltage parameters as shown in figure 2. It is called saw tension because the signal looks like a sawtooth. The settings that can be changed in this plant are:

a. Stratified frequency setting, f = 1/T. b.

Slow rate setting dvs/dt = vs/Ts.

c. Setting horizontal (malar) position means changing Vdc.

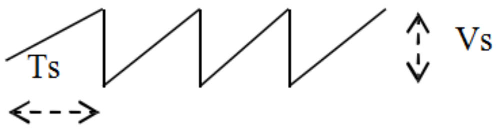


Figure 2. Saw tension

File manager (*Beam control*)

The result of this setting is a change in bright spots on the screen. These changes are:

1. Intensity, that is, the change in the number of electrons.
2. Focus, that is, the change in the magnitude of the bright spot.

In addition to these settings, there is an automatic intensity setting called intensity modulation. The intensity decreases as the electron beam is pulled to the left of its maximum deviation. The modulating voltage is called the extinguishing voltage (*blanking voltage*). This modulation can also be performed by an outside signal through the rear input base, which is the Z input. For comparison, on television sets the Z input *is* in the form of a video signal (image), while in the X and Y directions it is a flash signal, so that the entire surface of the screen is explored by electrons. At the Z input, the light spots are modulated by the video signal, resulting in light and dark forming the image.

Lissayous pattern

Lissayous pattern is an appearance on the oscilloscope screen that images the difference or comparison of the Phase Difference, Frequency & Amplitude of 2 input waves on the oscilloscope probe. If 2 oscillations with the same or different frequencies are perpendicular to each other, they are combined together to form a curve called a lissayous pattern as shown in Figure 3. The name is used to honor Jules Antonie Lissayous who demonstrated these curves for the first time in 1857.

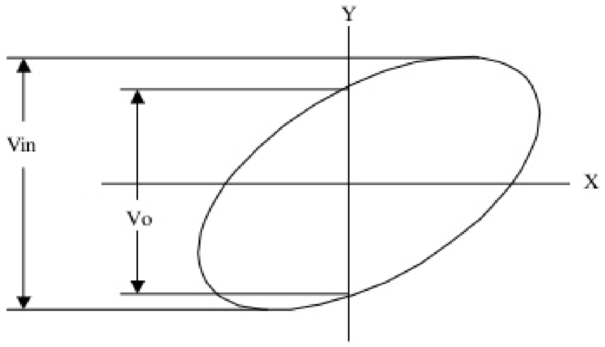


Figure 3. Lissayous pattern

D. HOW IT WORKS

General instructions for oscilloscope operation

1. CRO should only be turned on at the time it will be used. Turn off CRO for delayed usage. Rest for more than 5 minutes.
2. Before turning on the oscilloscope, check the AC voltage source used. Adjust to the voltage required to turn on the CRO.
3. Use The intensity is lower than the maximum limit. If not required, set the AC-DC switch to the AC condition.
4. Lower the blah bale to keep the luminescent screen from being easily damaged as electrons are constantly falling at the same point with high intensity.
5. Set the button in the center position to get bright spots or electron trails (if they are not visible on the screen).

Oscilloscope calibration instructions

1. Turn on the oscilloscope by turning the power button in the ON direction.
2. Set the intensity until you get a bright line or point on the screen, don't use too much intensity, set the position of the line in the center by rotating the position dial (up-down) and position

button (right-left).

3. Make sure the CAL VOLTAGE (in voltage/div in red) and CAL SWEEP TIME (in Sweep Time/div in red) buttons are at maximum.
4. Set the magnification on the probe, at position 10□.
5. Make sure the input position is for Ch1(Y) or Ch2(X). If Ch1(Y) is to be used, set the position of the mode button at Ch1(Y) and the source button at the Ch1(Y) position and vice versa if Ch2(X) is used, set the position of the mode button and source button at the Ch2(X) position.
6. For example, just select Ch2(X) to be calibrated first, set it like step (5).
7. Set the AC-DC position to the AC condition.
8. Clamp the probe tip to the CAL point on the oscilloscope.
9. Clamp the probe in the ground position.
10. Position the image on the screen by rotating the position button (up-down) and position button (right-left) on the channel you're using.
11. If the image appears moving, position the "level" button in the middle position.
12. Calculate the display voltage and frequency with the following formula:
    - Vp-p voltage calculation

      $$V_{p-p} = \text{jumlah kotak posisi vertikal} \times \text{variabel } {}^{\text{volt}}\!/_{\text{div}} \times \text{probe}$$

    - Frequency calculation

      $f = \dfrac{1}{T}$ where T = number of squares of one wave × Sweep time/div variable.

    Calculate the voltage size Vp-p and calibration frequency. If the results match those listed on the CAL point, then the oscilloscope is ready for use. If not appropriate, set the CAL button (red) on the volt/div variable to adjust the voltage and the CAL button (red) on the sweep time/div variable to adjust the period or frequency. Re-calibrate on Ch1(Y).

Note:

a. Variable voltage/div button to set the number of displays vertically b. Sweep time/div button to set the number of views horizontally
c. The measured voltage on the oscilloscope is the maximum voltage

Measuring the voltage and frequency of a source

1. Prepare the oscilloscope, the buttons are prepared so that in a state of no load, on the screen appears a point that shows the intensity and focus is sufficient and is in the

middle of the screen. Reduce the intensity below the maximum and don't turn on the point on the screen for too long.

2. Provide a signal generator with the output of each providing a sinusoidal voltage.
3. In the "*off*" state, connect the output of the signal generator with an oscilloscope. The position of the probe tip is connected with the positive pole of the signal output. The clamp on the probe is placed on the generator signal ground. Turn on the generator signal.
4. Set the *sweep time*/div and volt/div buttons on the oscilloscope like a calibration step to get a good single sinusoidal image.
5. The image on millimeter paper results are visible on the oscilloscope screen. Note:
   a. position of oscillator control buttons and signal generator.
   b. Determine the source voltage and source frequency.
6. Measure the voltage using a multimeter for 5 repetitions. Compare the results with measurements through an oscilloscope. Comment!
7. Repeat steps (3) through (6) with varying source voltage and frequency.

Determining the Lissayous pattern

1. Install signal generator I at horizontal input Ch2 (X) and generator II at vertical input Ch1 (Y) on oscilloscope.
2. The ratio used is 1:2; 1:3; 1:4; Dst. or 2:1; 3:1; 4:1 ff.
3. Set the frequency of signal generator I as f1 *on channel X (Mode at position X) to 100 Hz, change the mode at position Y, set the frequency of signal generator II as* f2 *until 200 Hz is obtained, so that the ratio of f1 : f* 2 is 1:2.
4. Turn the time/div dial in the X-Y position, and set the mode to the dual position.
5. Set volts/div to get a square image.
6. Display image at multiple positions.
7. Do it for comparison.
8. Compare your data with existing references.

E. CALCULATION

1. Calculate the measured voltage and frequency with an oscilloscope and the measured voltage with a voltmeter. Compare!
2. Comment on the Lissayous patterns you obtained based on other references.

F. QUESTIONS

1. Write down the general shape of the wave function and explain the meaning of each symbol!

2. Explain the meaning of the following magnitudes:
    a. wave amplitude.
    b. wave period.
3. Draw a sinusoidal electric wave with an amplitude of 2cm and a period of 0.02 seconds on millimeter paper!
4. Name three fields of science other than physics that use oscilloscopes!
5. What quantities of electricity can be measured with an oscilloscope directly and what quantities can be measured indirectly?
6. What is the name of the long tube that is in the oscilloscope and name the important components that are in it?
7. What does electron gun mean? Briefly explain!
8. What does Lissayous pattern mean?
9. Why is there a difference in the measurement results between the oscilloscope and the voltmeter?

L2: ALTERNATING CURRENT

A. PURPOSE

1. Measures the physical magnitude of alternating current.
2. Measures the impedance of alternating current.
3. Finds the resonant state of an alternating current circuit.
4. Understand the characteristics of alternating current.

B. TOOLS AND MATERIALS

1. Source DC dan AC ”var. Extra low voltage transformers”,
2. Adio generator,
3. DC milliampermeter,
4. AC milliampermeter,
5. Resistor 3900 ohm,
6. Induktor (kumparan),
7. capacitor 1 μΦ,
8. multimeter.

C. BASIC THEORY

Arus Bolak-Balik / *Alternating Current* (AC)

Alternating current is a large electric current and its direction changes periodically. The simplest form of alternating current mathematically resembles a sinusoidal graph as figure 1.

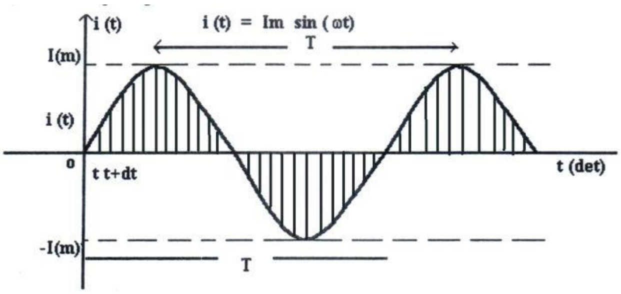


Figure 1. Alternating current forms

From the picture, it can be seen that the amount of electric charge passing in the interval between t to *t* + *dt* is:

$$dq = idt \tag{1}$$

The magnitude of the maximum *current Im* and the period *T* of the alternating current can be measured using an oscilloscope. While measuring the current using an ammeter on alternating current will show the amount of effective current *(ief)*. Effective current is AC current which each period produces heat equal to the heat produced by direct current / *Dirrect Current* (DC). The relationship *of Ief* to *Im* is given by the equation:

$$I_{ef} = \frac{I_m}{\sqrt{2}} \quad (2)$$

Inductive Reactance and Impedance

An inductor *coil L* contains resistance in (resistance) *r*. The schematic of an inductor with inner resistance looks like Figure 2. If point AB is supplied with direct current of constant magnitude, then the pure conductor *L* does not react to current. So what inhibits the current is only *r*. AB is connected by alternating current, both *L* and *r* react to current.

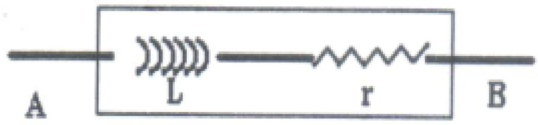


Figure 2. Inductor schemes with inner barriers

Mathematically, the function of AC current with respect to time is formulated where $i(t) = I_m \sin(\omega t)$ ω is the angular frequency. In AC current, the inductor *L* will produce Electromotive Force (GGL) of $E = -L\frac{di}{dt}$ so that the end of AB in Figure 2 has a potential difference:

$$\begin{aligned} V &= ri - E \\ V &= rI_m \sin(\omega t) + L\frac{di}{dt} \\ V &= rI_m \sin(\omega t) + \omega L I_m \cos(\omega t) \\ V &= V_m \sin(\omega t) + V_{Lm} \sin\left(\omega t + \frac{\pi}{2}\right) \end{aligned} \quad (3)$$

From equation (3), it can be seen that AC current will experience a phase shift of $\frac{\pi}{2}$ radians when passing through the inductor. This equation can be proved using a phasor diagram such as Figure 3.

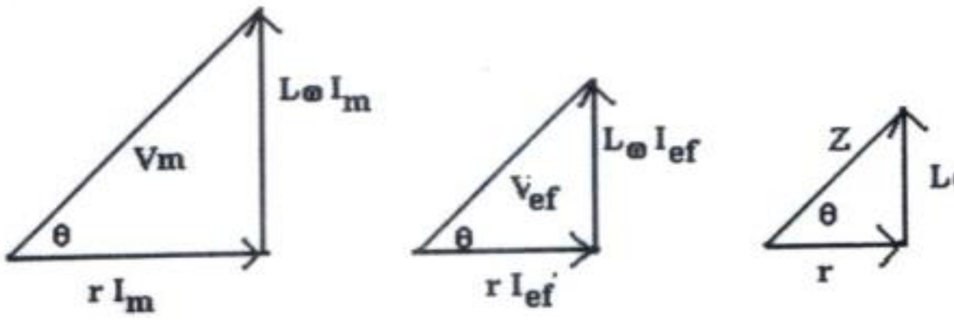


Figure 3. Phacor diagram

Based on the phasor diagram, the total resistance value (impedance) of the series is:

$$Z = \sqrt{r^2 + X_L{}^2} \quad (4)$$

with inductive reactance $X_L = \omega L$ and $\tan\theta = \frac{X_L}{r}$.

Capacitive Reactance and Impedance

Capacitors are electronic components that can store electric charge in a temporary time with the unit of capacitance is Farad. A capacitor with capacitance *C* can only conduct electric current when installed in an AC circuit. Whereas when installed in a DC circuit, the capacitor cannot be passed by electric current. The circuit of a capacitor coupled with an AC voltage source is shown as Figure 4.

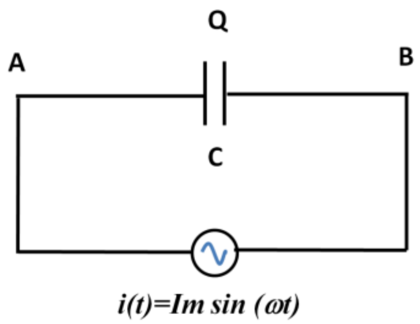


Figure 4. Alternating current capacitor circuit

The amount of electric charge stored in the capacitor in the circuit of Figure 4 is:

$$dQ = C.dV \quad (5)$$

The potential difference (voltage) between point A and point B in Figure 4 has the equation:

$$V = V_{Cm}\sin(\omega t - \frac{\pi}{2}) \quad (6)$$

with the maximum voltage of the capacitor $V_{Cm} = I_m X_C$ and capacitive reactance. $X_C = \frac{1}{\omega C}$

From equation (6), it can be seen that the AC current through capacitor C has a phase delay of $\frac{\pi}{2}$ radians.

D. HOW IT WORK

Measuring the Physical Magnitude of Alternating Current

1. Turn on "*Var.extra low voltage transformers*" by connecting it with the PLN current source. Turn on the osciloskop in the same way. (Ask the assistant if you get into trouble).
2. Measure the output voltage that reads 12 V AC from the "transformers" using an oscilloscope.

Make a note of the Vpp and its frequency. (V_{pp}: peak to peak voltage = 2 Vm)

3. Now measure the output voltage of the "transformer" using an AC multimeter, using a measuring limit greater than 12 V. Repeat by flipping the "probe" of the AC multimeter, (the probes are connecting rods).

Measuring the Impedance of an Alternating Current Circuit

A. **R-L circuit**

1. Use an Inductor L and a resistance R = 3900 Ω.
2. Arrange the circuit as follows

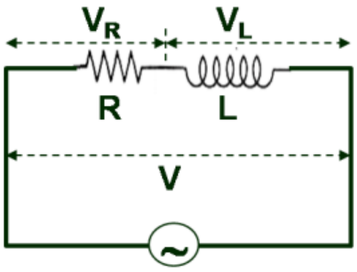


Figure 5. R-L series range

3. Measure VL, VR, and source V voltages using a multimeter. Also measure the current through milliamperrneter. Calculate the value of XL and impedance Z.

B. **R-C circuit**

1. Arrange the circuit as shown in Figure 6 with C = 1 μΦ and R = 3900 Ω.
2. Measure the capacitor voltage Vc, VR, and the voltage that the source V uses using a multimeter. Calculate the Z impedance of the R-C circuit.

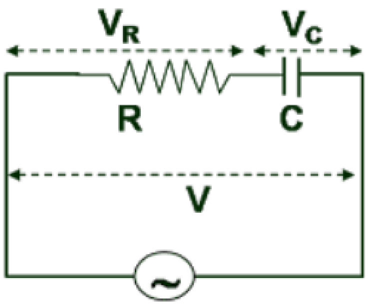


Figure 6. R-L series range

C. **R-C circuit**

1. Arrange the circuit as Figure 7 using the previous resistance, inductor, and capacitor.
2. Measure VR, VL, and VC voltages and source voltage V using a multimeter. Calculate the Z impedance of the R-L-C circuit.

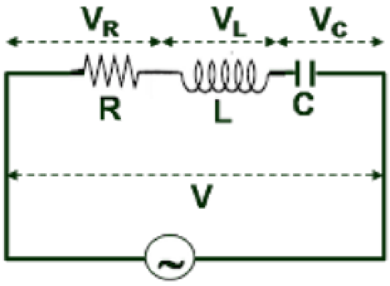


Figure 7. R-L-C series series

E. QUESTION

1. GAmber the phasor diagram of the R-L series of the experimental results and explain the meaning of Physics!
2. GAmber the phasor diagram of the R-C series of the experimental results and explain the meaning of Physics!
3. GAmber the phasor diagram of the R-L-C series of the experimental results and explain the meaning of Physics!

L3: INCANDESCENT LAMP DISPOSITION

A. PURPOSE

1. Understand Ohm's Law.
2. Demonstrate the measurement of current and voltage of an incandescent lamp.
3. Make an interpretation of electrical charts.
4. Make a graphical interpretation of the relationship between;
   a. The voltage attached with the current flowing. b. The
   voltage attached with its resistance.
   c. Voltage attached with absorbed power.
5. Determine the resistance of the lamp.
6. Understand the Character Characteristics of incandescent lamps.

B. TOOLS AND MATERIALS

1. Voltrneter AC
2. Ampermeter AC
3. Incandescent
4. Voltage source (variac)

C. BASIC THEORY

Ohm's Law is a basic law that states the relationship between Electric Current *I*, Voltage *V*, and Resistance *R*. According to George Simon Ohm, the current flowing in a conductor is proportional to the voltage *V* between the conducting ends. The ratio between *V* to *I* in an electrical circuit is always a constant value called resistance R. Mathematically, the comparison is expressed by the equation:

$$I = \frac{V}{R} \tag{1}$$

Conductors who follow Ohrn's Law are called linear conductors. In general, prisoners change with changes in temperature. For metal conductors, the amount of resistance increases as the temperature gets higher.

Dissipation Power in Conductors

Electric power *P* is the amount of electrical energy per unit time. If energy is expressed in joules and units of time in seconds, then the unit of electrical power is "watts" or joules per second. Power in alternating current is a function of time, so the mention of power in alternating current is the average power over a period T.

Mathematically the average power can be expressed as $P = \frac{1}{T}\int_0^T VIdt$

When an electric current flows in a conductor, there will be electrical energy lost and turned into thermal energy. The electrical energy lost per second is known as the dissipation power P and has units of Watts. Mathematically, the amount of dissipation power is formulated by the equation:

$$P = V.I \tag{2}$$

Incandescent Lamp Disposition

Because there is power dissipated into heat, the resistance of an incandescent lamp will change with changes in voltage. In the Incandescent Lamp Disposition experiment, the relationship between I and V, R with V, and P with V will be examined.

1. The voltage attached with the electric current flowing.
2. The voltage attached to its resistance.
3. The voltage attached with the power taken.

Chart Selection in Measurements V and I

To obtain the character of an incandescent lamp, it is necessary to measure V and I simultaneously by installing a Voltmeter and Ampermeter as Figure 1 and Figure 2.

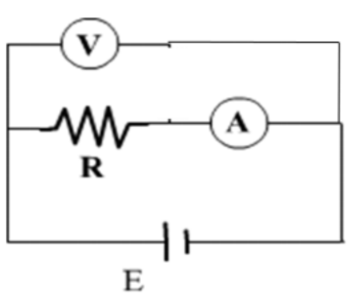


Figure 1. Chart schema 1

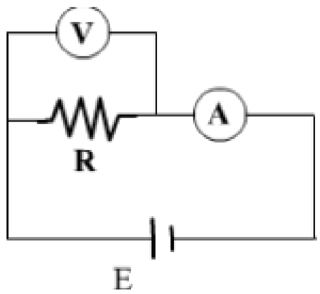


Figure 2. Chart schema 2

Chart 1

In Figure 1 can be analyzed the error of the amperemeter reading because the measured value is the sum of the current through the lamp and voltmeter. The overread current equal to $\frac{r}{R}\times 100\%$ r is the resistance of the lamp and R is the resistance of the voltmeter. If the desired error is a maximum of a%, then $\frac{r}{R}\times 100\% < a\%$

Chart 2

In Figure 2 can be analyzed the error reading of the Voltmeter, because what is measured is the sum of the voltages in the lamp and ammeter. The voltage that is read as excessive as

$\frac{\rho}{r}\times 100\%$ ρ is the resistance of the ammeter. If the desired error is a maximum of a%, then

$\frac{\rho}{r}\times 100\% < a\%$

Chart Selection

If $\frac{r}{R} < \frac{\rho}{r}$ then chart 1 is selected , but if then chart $\frac{r}{R} > \frac{\rho}{r}$ 2 is selected.

To find out the magnitude of r/R and ρ/r, measurements can be made as in the experimental procedure. By assuming that the internal resistance of the source is negligible, it can be proven that:

$$\frac{r}{R} = \frac{V}{V^I} = \frac{I^I - I}{I} = \frac{V}{V^I}\left(\frac{I^I}{I} - 1\right) \quad (2)$$

and

$$\frac{\rho}{r} = \frac{\frac{V^{II}}{I^I}}{\frac{V}{I} - \frac{\left(V - V^I\right)}{I^I}} - 1 \quad (3)$$

The value of r/R against ρ/r is compared. Then a better chart is selected for the three voltage examples above.

Electrical power

Electric power is electric power per unit time. If power is expressed in joules and the unit of time is in seconds, then the unit of electrical power is "watts," or joules per second. Power in alternating current is a function of time; therefore, what is often called power in alternating current is essentially the average power over one period.

Mathematically, the average power can be expressed $P = \frac{1}{T}\int_0^T V.i\,dt$

with T = Period, V = instantaneous voltage value, and i = instantaneous current value

if $V = V_{max}\sin\omega t$ and $I = I_{max}\sin\omega t$, so $P = V.I\cos(\theta)$ **(prove it!)**

with V and I the effective values of voltage and current, while θ is the phase difference between V and I. In this experiment, it is assumed that there is no phase difference (θ = 0). So: P=V.I

Thus, we can make the relationship P = f(V) based on the observations above.

D. HOW IT WORK

Chart Selection

To find out the magnitude $\frac{r}{R}$ and $\frac{\rho}{r}$ which is used for chart selection, take the following measurements:

1. The source voltage (variac) is measured when the lamp and ammeter are not attached (the voltmeter is installed directly at the output end of the variation). For example, 25 volts. The reading of this voltmeter = V.
2. Ampermeters are installed in series with lamps and connected with variate ends.
3. The current passing through the lamp is measured without measuring the voltage (the voltmeter is not attached). Suppose the reading of the ammeter = I.
4. Once the measurements V and I are obtained, create a series like chart 1. Mass l voltmeter readings (ends of ammeters with sources) = VI and ammeter readings = I'.
5. Then create a series like chart 2. Suppose the voltmeter readings (the ends of the source) = V" and the ammeter readings = I''.
6. Record the measurement results V, I, V', I', V'', I'' to get the value, (formula in theory). Specify the chart to be used in the experiment of other characteristics of incandescent puu.

Characteristics of Incandescent Lamps

With the chart selected, perform the following steps:

1. Set the voltage source so that the voltage indicated by the voltmeter is 10 Volts. Read the ammeter. Record the current (I) for 5 repetitions.
2. Repeat step 1 for voltages: 20, 30, 40, 50, 60, 70, 80, 90, and 100 volts.

E. CALCULATION

1. Calculate the trial data to find out which chart to choose!
2. Determine the amount of Resistance (R) and Power (P) in the experiment you are doing!
3. Graph the relationship between I = f(V), R = f(V), and P = f(V)!

F. QUESTION

1. What is the difference between measurement functions in chart I and chart II?
2. What is a linear conductor?
3. From Ohm's Law, draw a graph of the relationship V-I, V-R, V-P ?
4. Describe all the formulas you use!

5. From the experimental results, I = f (V) turned out not to be smooth, why? Explain!
6. Name the conditions that must be met for Ohm's Law to apply!

L4: RESISTORS

A. PURPOSE

1. Able to recognize the shape and type of resistor.
2. Able to calculate the resistance value of a resistor through the sequence of its color rings.
3. Able to assemble resistors in series or parallel.
4. Understand the use of Ohm's law in resistor circuits.

B. ALAT AND MATERIALS

1. Power Supply
2. Multitester (2 pieces)
3. Resistor
4. Connecting cable
5. Circuit board

C. BASIC THEORY

Resistors are electrical components that function to limit the amount of current flow in a circuit. Resistors are resistive and are generally made of carbon. The unit of resistance of a resistor is Ohm and is denoted by the symbol Ω (omega). The shape of the resistor is generally like a tube with two legs on the left and right. On the body there is a circle forming a color-coded ring to determine the amount of resistance without measuring the magnitude with an Ohmmeter. The illustration is as in Figure.

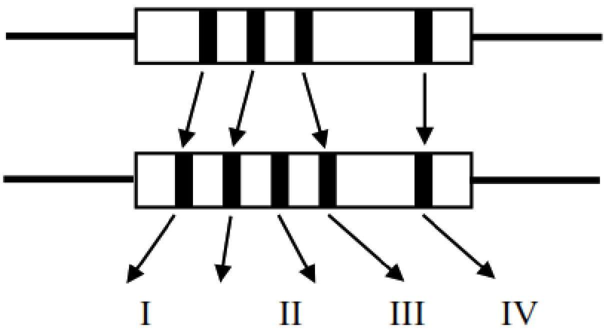


Figure 1. Sequence of color rings on a resistor

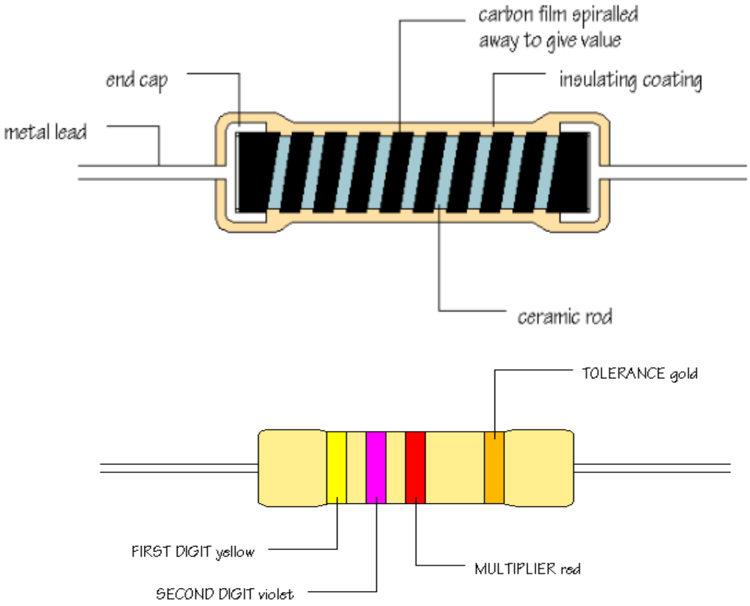


Figure 2. Sequence of color rings on resistors (continued)

The shape of resistors varies according to the needs in the circuit. This is related to the power capable of acting on the resistor. Resistors that work at low power, ranging from (0.25 - 1) Watts, generally have a small shape. While resistors for large enough power, ranging from (2 - 25) Watts, generally have a larger shape as shown in Figure 2.

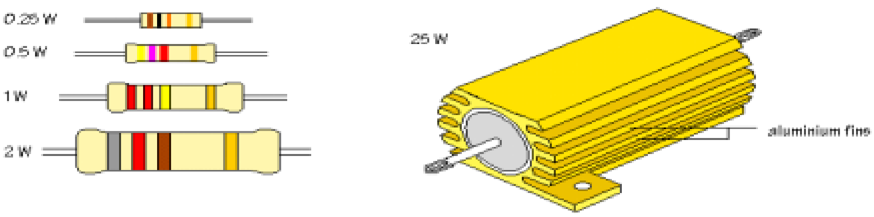
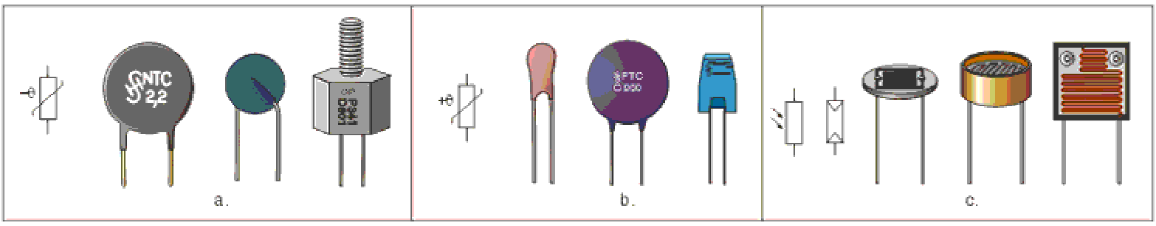


Figure 3. Various sizes of resistors

Figure 4. Several forms of variable resistors: a, b: trimpot, c: multiturn, d: potentiometer

Non linear resistors

This is a resistor whose resistance value is not linear, meaning that the resistance is influenced by other factors, for example for ***LDR (Light Dependent Resistor),*** will be affected by changes in the intensity of light hitting the LDR surface.



Gambar 3. Nonlinear resistor a. NTC, b. PTC, c.

LDR

Code wArna resistors are ejected by **EIA** (*Electronic Industries Association*) as shown in Table 1.

Table 1. Color values on resistor rings

Color Ring	Ring I 1st number	Ring II 2nd number	Ring III 3rd number	IV Ring Multipli	Ring V Tolerance
black	0	0	0	x100	
coklat	1	1	1	x101	± 1 %
red	2	2	2	x102	± 2 %
orange	3	3	3	x103	
kuning	4	4	4	x104	
green	5	5	5	x105	
biru	6	6	6	x106	
purple	7	7	7	x107	
gray	8	8	8	x106	
white	9	9	9	x109	
gold				$x10^{-1}$	± 5 %
perak				$x10^{-2}$	± 10 %
colorless					± 20 %

The size of the resistor depends on the maximum power that the resistor is able to withstand. The following is an example calculation:

Color ring sequence (resistor 4 color rings): **red-yellow-blue gold**

Red	Purple	Biru	Gold	Result
2	7	106 X	± 5 %	27M Ω ± 5 %

Color ring sequence (resistor 5 color rings): **brown red-black orange brown**

coklat	Red	Black	Orange	Coklat	Result
1	2	0	X 103	± 1 %	120K Ω± 1%

Resistor Circuit

Resistor circuits in series will result in a greater total resistance value. Below is an example of resistors assembled in series.

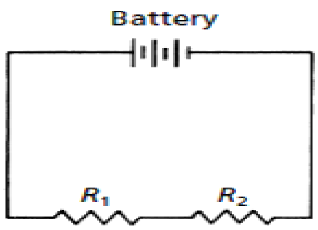


Figure 4. Resistor circuit in series

In the series resistor circuit applies the formula

$$R_{TOTAL} = R_1 + R_2 \quad (1)$$

While that pexist series Resistor that Compiled Directly pArale will result in a smaller replacement resistance value. Below is an example of resistors assembled in parallel.

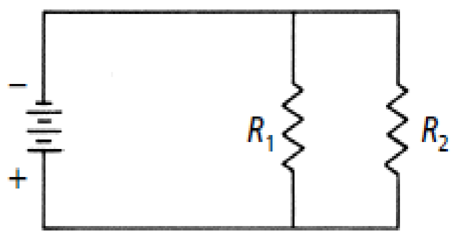


Figure 5. Resistor circuits in parallel

In parallel resistor circuits two resistors apply the equation:

$$R_{PENGGANTI} = \frac{R_1 R_2}{R_1 + R_2} \quad (2)$$

Hukum Ohm

Around 1825, George Simon Ohm from Germany, conducted a series of experiments that showed that there is no perfect conductor of electricity, meaning that every type of substance has the property of inhibiting electric current. Ohm showed that for the same material, long wire has greater resistance than short wire. In addition, in a circuit, the greater the resistance, the greater the potential needed to conduct electricity.

Ohm's law which states "the amount of electric current flowing through a conductor is always directly proportional to the potential difference applied to it". A conducting body is said to obey Ohm's law if its resistance value does not depend on the magnitude and polarity of the potential difference imposed on it. Mathematically Ohm's law is expressed by equations

$$V = I \times R \quad (3)$$

The description of the equation is:

V = Potential difference (voltage) of both conducting ends (Volt) R = Resistance or resistance (Ohm)

I = Strong current flowing in the conveyor (Ampere)

However, it should be emphasized that the relationship "V = IR" is not a statement of Ohm's law. A conductor obeys this law only if the potential difference and current strength are comparable. Ohm's law is a specific property of certain materials and is not a general law of electromagnetism.

D. HOW IT WORKS

Fixed current strength

1. Install the electrical circuit as Figures 4 and 5 and report to the Assistant for inspection before the circuit is connected to a voltage source.
2. After checking, set the switch in the connected position (ON)
3. Set the potential difference in the power supply so that the ammeter shows a certain number (I1). Record the data shown Ammeter, Voltmeter, and the amount of resistor value used.
4. Repeat steps 2-3 by replacing the resistor.
5. By changing the current value, perform steps 2-4 until you get 7 current variations.

Fixed barriers

6. Install the electrical circuit as Figures 4 and 5 and report to the Assistant for inspection before the circuit is connected to a voltage source.
7. After checking, set the switch in the connected position (ON)
8. Set the end of the voltmeter at a resistance with a certain value (R1) and record the amount of current and voltage
9. On the same resistor, perform 7 variations of voltage values and note the amount of voltage and current obtained.
10. Repeat steps 2-4 by replacing the resistor (R2) with up to 3 resistance variations.

E. QUESTION

1. Draw a graph of current to voltage (I vs V)!

L5: KIRCHOFF'S LAW

A. PURPOSE

1. Studying Kirchhoff
2. Calculates the equivalent resistance of a mixed relationship resistor circuit
3. Make an analysis of resistor electrical circuits with Kirchhoff's Law.

B. TOOLS AND MATERIALS

1. Power Supply Module
2. R circuit module
3. Multimeter
4. Jumper

C. BASIC THEORY

Kirchhoff's law is one of the laws of the electrical field that plays a very important role in analyzing current and voltage in circuits. The law first introduced by Gustav Robert Kirchhoff consists of two parts, namely Kirchhoff's Law 1 and Kirchhoft's Law 2.

Kirchhoff's Law I read, "The amount of strong electric current that enters a point is equal to the amount of strong electric current that comes out of that point". Kirchhoff's Law I is mathematically written as follows:

$$\sum I_{In} = \sum I_{Out} \qquad (1)$$

Kirchhoff's Second Law is used on closed circuits since there are circuits that cannot be simplified with series and parallel circuits. Kirchhoff's Second Law reads "In a closed circuit, the algebraic sum of electromotive forces (ε) with voltage drop (IR) equals zero". Kirchhoff's Second Law can be mathematically written as follows:

$$\sum \varepsilon + \sum IR = 0 \qquad (2)$$

D. HOW IT WORKS

1. Determine the R equivalent and calculate the values for I1, I2, V1 and V2 first then make a circuit like Figure 1 and take measurements using a multimeter. Compare the results of measurements and calculations made!
2. Calculate R equivalent and first calculate the values for It, I1, I2, V1 and V2 then make a circuit like Figure 2 and take measurements using a multimeter. Compare the results of measurements and calculations made!

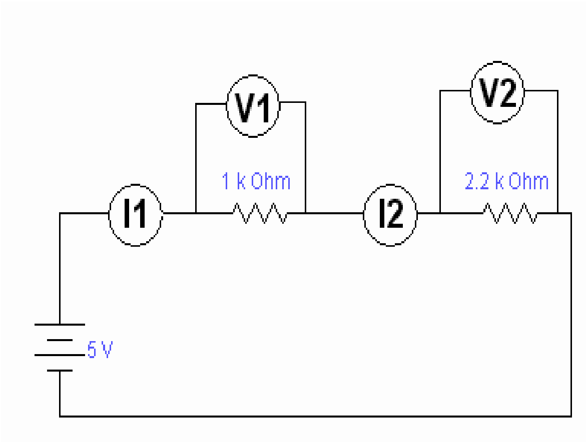


Figure 1

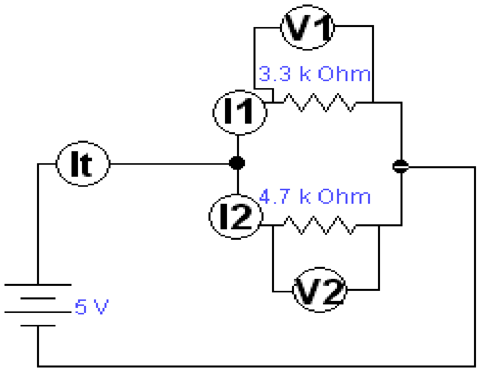


Figure 2

3. Calculate the current strength I and potential difference V2. Make a circuit like figure 3 and take measurements. Compare the calculation results with the measurements taken!

4. Calculate the current strength at I1, I2, I3 and the potential difference at points A and B (V_{AB}). Make a series like figure 4 and take measurements. Compare the calculation results with the measurements taken!

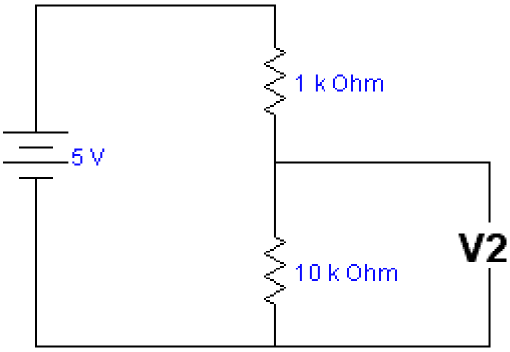


Figure 3

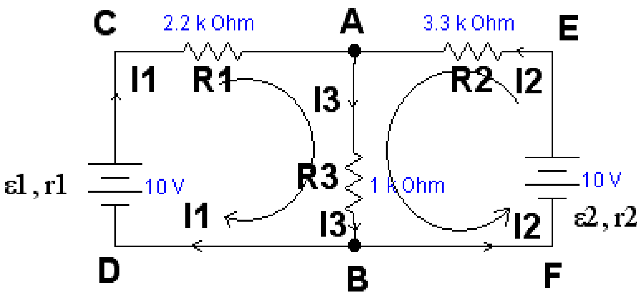


Figure 4

L6: TRANSFORMER

A. PURPOSE

1. Understand the working principle of the transformer.
2. Determine the value of deep heat loss, winding, voltage fold factor and regulation factor.

B. TOOLS AND MATERIALS

1. Power transformer
2. Voltage meter
3. Flow meter
4. Regulator slides,
5. Incandescent lamp as a load,
6. Multimeter

C. BASIC THEORY

Transformer or transformer is an electrical device to lower or increase the voltage. A transformer that functions to increase voltage is called a step up transformer *while a voltage lowering transformer is called* a step down transformer. The transformer consists of 2 types of coils, namely primary and secondary coils wrapped around an arrangement of soft iron plates called transformer cores. The transformer display is more or less like Figure 1.

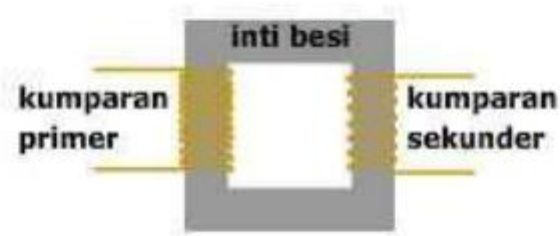


Figure 1. Scheme of the transformer

The primary coil with the number of windings Np is the place of input of electrical power, while the secondary coils of the number N_s are where electrical power is taken from the transformer by the load. If the primary coil is connected to an AC power source, then on the terrace a magnetic flux is generated. Since the secondary coil also has the same core, the secondary coil also winds the core magnetic flux generated by the primary coil. The flux in the terrace always changes according to the primary current so that the secondary coil will be raised induction emf (according to Faraday's law).

The magnitude of the voltage is proportional to the many windings, so if the magnitude of the primary coil voltage Vp and the voltage of the secondary coil Vs, then ideally the equation applies:

$$\frac{N_p}{N_s} = \frac{V_p}{V_s} \quad (1)$$

By and large, the secondary coil of the transformer is not only one, but consists of several coils. However, the voltage of each coil is always proportional to the number of windings of each coil.

An ideal transformer is one that has almost no power loss so that the power exerted on the primary coil is equal to the power exerted on the secondary coil, or mathematically stated:

$$V_p I_p = V_s I_s \quad (2)$$

The equation is usually expressed in the form of:

$$V_p I_p \cos\varphi_p = V_s I_s \cos\varphi_s \quad (3)$$

with $\cos\varphi_p$ is the primary power factor and as the $\cos\varphi_s$ secondary power factor.

The output power of a transformer is usually smaller than the input power because during the induction process, electrical energy in the primary part is changed to heat so that the energy in the secondary part becomes smaller. This power loss can be in the form of heat arising in the primary and secondary windings, which is I2R (copper loss), heating in the core due to hysteresis and eddy current (core loss). Theoretically copper losses can be written down:

$$K_r = I_p{}^2 R_p + I_s{}^2 R_s \quad (4)$$

Refers to equation (1), so that equation (4) can be written

$$K_t = I_p^2 \left[r_p + \left(\frac{N_p}{N_s} \right)^2 r_s \right] = I_s^2 R_{tp} \quad (5)$$

$$K_t = I_s^2 \left[r_s + \left(\frac{N_s}{N_p} \right)^2 r_p \right] = I_p^2 R_{ts} \quad (6)$$

with Rtp, *and* Rts is a primary tara and a secondary tara.

$$R_{tp} = r_p + \left(\frac{N_p}{N_s} \right)^2 r_s \quad (7)$$

$$R_{ts} = r_s + \left(\frac{N_s}{N_p} \right)^2 r_p \quad (8)$$

The magnitude of Rtp can be calculated by making the secondary coil connected short and the inlet power (Rp) and current (Ip) are observed so that the equation is obtained

$$R_{tp} = \frac{R_p}{I_p^2} \tag{9}$$

The primary tare lempedance is $Z_p = \frac{V}{I_p}$ so that the reactance can be calculated by:

$$X_p = \sqrt{Z_p^{\ 2} - R_{tp}^{\ 2}} \tag{10}$$

In general, the value of Vs depends on the load. If Vso = secondary voltage without load, while V_{Sb} = secondary voltage with full load, hence defined factor regulation (R) as:

$$R = \frac{V_{so} - V_{sb}}{V_{sb}} \tag{11}$$

Theoretically the regulation factor *r can be calculated by measuring the* primary and secondary voltages at the time of the secondary coil without load, r can be calculated by the formula:

$$r = \frac{\frac{N_s}{N_p} V_p - V_s}{V_s} = \frac{V_s - V_p}{V_p} \tag{12}$$

D. HOW IT WORK

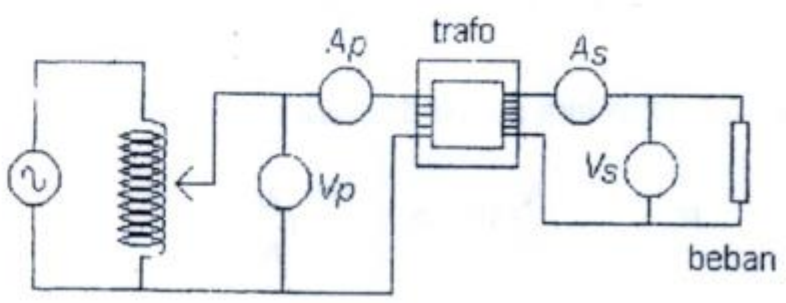


Figure 2. Transformer trial circuit scheme

Before determining the value of heat loss in the winding, voltage folding factor, and regulatory factor:

1. Make a sequence like figure 2.
2. Measure large *Vp, Vs,* and Ip in a no-load state.
3. Measure the magnitude of *Vp, Vs,* and Ip in a state where there is a load (the load is given by the assistant). Measure the secondary current and voltage.
4. Determine the value of heat loss in the winding, voltage fold factor and regulation factor

E. CALCULATION

Calculate the crease factor, loss, regulation factor with load and no load of the transformer!

F. QUESTION

1. The derivative of the formula for finding the voltage ratio on the transformer!
2. Explain how the transformer works!
3. Explain with Faraday's law the existence of a relationship between the existence of primary voltage and the appearance of secondary voltage!

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