PRACTICUM INSTRUCTIONS

ATOMIC PHYSICS

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PRACTICUM RULES

During student practicum activities:

1. Work quietly according to procedures and tool manuals.
2. Neat and polite clothing is required.
3. No T-shirts, tight-fitting clothing, sandals, or hats allowed.
4. No eating, drinking or smoking.
5. Students are required to be present on time according to the schedule. Students who are more than 15 minutes late are not allowed to participate in practicum activities.
6. The maximum number of inhalers allowed for students repeating the experiment due to illness is one (1) attempt.
7. Students who inhal more than one (1) experiment are declared to have failed the practicum.
8. Matters related to the implementation of practicum in the Laboratory are regulated separately in the practicum rules.

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TRIAL I

CATHODE RAY DEVIATION
BY THE ELECTROSTATIC FIELD

I. Introduction

The development of vacuum pumps and the availability of very high voltages in the mid-19th century has encouraged physicists to conduct research on the electrical conductivity of gases. In ordinary circumstances (gas pressure is equal to the pressure of the outside air), gas is a good insulator, because to conduct an electric current between two points in the air pressurized 1 atmosphere required voltage of about 30,000 volts / cm.

Research on the electrical conductivity of gas in gas discharge tubes showed that at low pressure (approximately 0.01 mmHg) the glass tube glowed greenish, especially in the area around the anode (the area opposite the cathode). Based on a series of studies conducted by physicists in 1870, it was concluded that greenish light is the result of radiation rays moving from the cathode to the anode, so these rays are called cathode rays. These cathode rays are then known as negatively charged particles1 which are now called electrons.

In 1897, J.J. Thomson (1856 - 1940) using a gas discharge tube successfully calculated the ratio between charge and mass (e/m) of electrons. In honor of his services, he was designated as the discoverer of the electron.

II. Destination

After doing this experiment, students are expected to have ability to:

1. Investigating the deflection of cathode rays by a magnetic field
2. Explain matters related to the deflection of the trajectory of cathode ray electrons by the field. magnet.
3. Determine the value of charge per unit mass (e/m) of electrons based on the trajectory of cathode ray electrons by the magnetic field in the cathode ray tube.

III. Basic Theory

The development of physical science, especially concerning atomic physi c s , experienced a very rapid development after J.J. Thomson (1856-1940) discovered elementary particles called electrons. The discovery of electrons was preceded by research on cathode rays by William Crookes (1892-1919) which obtained the conclusion that: (1) cathode rays propagate according to straight lines, (2) can reflect zinc sulfide and barium platinasianide, (3) consists of negatively charged particles, (4) can produce heat, (5) able to blacken the photo plate, (6) deflected by electric fields and magnetic fields in certain directions, (7) can produce X-rays.

Based on the properties of cathode rays above, J.J. Thomson proposed that cathode rays are a flow of electrons coming out of the cathode towards the anode at high speed. Furthermore, Thomson successfully designed and conducted experiments to determine the ratio between the charge per unit mass (e/m) of negatively charged particles contained in the cathode ray beam.

Electrons generated by the cathode due to the heating process using a heating filament (electron thermo process) are accelerated towards the anode by a potential difference between the anode and cathode of V. If the electron speed at the time of release from the cathode due to the heating process is ignored, then the electron velocity *v when* passing through the anode can be calculated based on the law of conservation of energy as follows:

$$\frac{1}{2} mv^2 = eV$$

or

$$v = \sqrt{\frac{2eV}{m}} \quad \text{...(1)}$$

with e = electron charge
m = electron mass

Electrons moving -with speed *v* perpendicular to the homogeneous magnetic field B, will perform circular motion with radius R due to the influence of the Lorentz force **F** = **ev** x **B** which functions as a centripetal force so that the equation applies:

$$evB = \frac{mv2}{R}$$

or

$$eB = \frac{m}{R} \quad \text{...(2)}$$

Based on equations (1) and (2), the ratio of charge to electron mass can be determined by the equation

$$\frac{e}{m} = \frac{2V}{r2B2} \quad \text{...(3)}$$

The magnetic field written in equation (3) is produced by a Helmholtz coil composed of two parallel coils and located in one axis (coaxial) with a radius of R. If the Helmholtz coil is electrified by an electric current I in the same direction, it will produce a homogeneous magnetic field that is parallel to the axis of the coil. According to the Biot-Savart law, the magnetic field strength between the two coils is :

$$B = \frac{8\,\mu 0 NI}{5\sqrt{5}\,R} \qquad \text{...}(4)$$

with μ_0 = permeability of vacuum

N = number of turns

By taking $\mu_0 = 4\pi\, x 10^{-7}$ H/m, and specifically for the tool used in this experiment has the number of turns N = 130 turns and R = 0.150 m, so that the magnitude of the magnetic field strength between the two coils is obtained.

$$B = 7.793\, x\ 10^{-4}\, I \quad (\text{Wb/m})^2 \text{...}(5)$$

Next, substitute equation (5) into equation (3) and obtain :

$$\frac{e}{m} = \frac{2V}{R^2 (7.793\, x\ 10\text{-}4 I)^2} \qquad \text{...}(6)$$

using equation (6) we will determine the price of the ratio of charge (e) to mass (m) of the electron.

IV. Tools

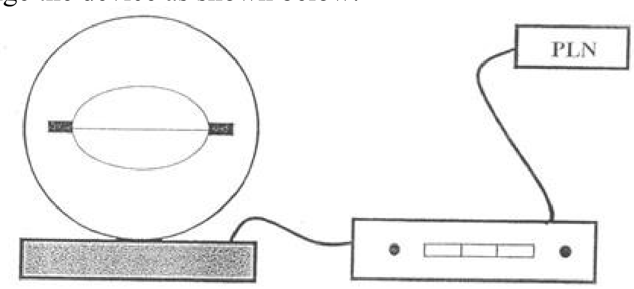
The tool used in this experiment is a set of equipment "e/m Apparatus EM-2N" which consists of:

1. A discharge tube containing Helium gas.
2. Power supply unit that provides heater voltage, accelerating voltage (V) at the anode and current (I) flowing in the Helmholtz coil.
3. Helmholtz coil with specifications N = 130 turns and R = 0.150 m

V. Work Steps

The steps of this experiment or experiment are as follows
The following:

1 . Arrange the device as shown below:



Gambar 1.1. Skema rangkaian peralatan percobaan e/m

2. Make sure the power supply unit switch is OFF and the anode voltage regulator switch V and the current I flowing in the Helmholtz coil are at a minimum.
3. Connect the power supply unit to the PLN voltage source. Turn on the power supply unit by pressing the power supply button in the ON position.
4. When the cathode turns red and hot, gradually increase the power supply voltage by turning the voltage regulator knob clockwise. At a voltage of about 90 V, the straight motion trajectory of the electrons will be observed in green.
5. Increase the current (I) flowing in the Helmholtz coil by turn the current control dial clockwise.
6. Observe the symptoms that occur in the electron release tube. It appears that the electron trajectory begins to bend and the trajectory is circular.
7. For a constant electron accelerating voltage (V), gradually increase the current (I) flowing in the Helmholtz coil and record the measurement of the radius I of the electron orbit center (R).
8. Record the observations in the following table: For a constant electron accelerating voltage (V).

V=......................Volts

No.	I (Ampere)	R (cm)

Tasks

1. Draw a graph of the relationship between the radius of the electron path (R) and the current (I) flowing in the Helmholtz coil.
2. Determine the value of (e/m) based on the two graphs.
3. Compare the (e/m) value obtained graphically with the (e/m) value obtained from the calculation.

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TRY II

HALL EFFECT

I. Introduction

A charged particle moving in a homogeneous magnetic field will experience a magnetic force, so that the motion of the charged particle is deflected. The magnitude of the magnetic force experienced by the particle is directly proportional to q (particle charge), v (particle velocity), B (magnetic field magnitude), and sin θ, where θ *is* the angle formed by the direction of velocity v and the direction of the magnetic field *h***.**

Electrons moving at speed *v perpendicular* to a homogeneous magnetic field B ($\theta = 90^\circ$) will perform circular motion with a radius of R and electrons moving at speed v not perpendicular to a homogeneous magnetic field B ($\theta < 90^\circ$) will perform motion with a helical trajectory due to the influence of the Lorentz force **F** = **ev** x **B** which functions as a centripetal force. Based on these symptoms, J.J. Thomson using a cathode ray tube succeeded in determining the value of the ratio between electric charge and electric charge mass (e/m).

The same symptom was also observed by Edwin H. Hall. He found the separation of electric charge in a semiconductor or conductor band due to the influence of a magnetic field. This magnetic field will cause a magnetic force on the charge carrier particles in the semiconductor tape or conductor beraru s, causing a potential difference across the semiconductor tape or conductor and commonly referred to as the *Hall potential.*

I. Destination

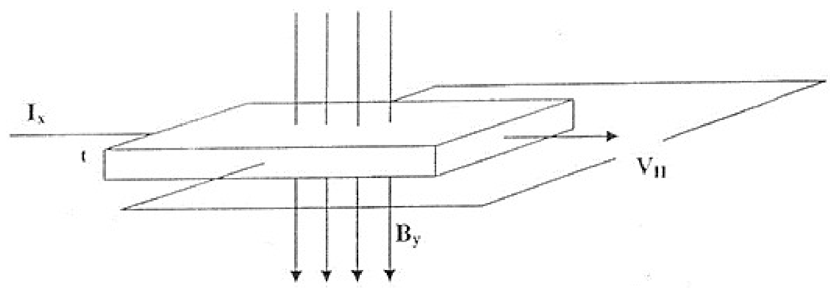
After conducting this experiment, students are expected to have the ability to

1. Studying the Hall effect or the onset of the Hall effect with the relevant quantities.
2. Measuring the magnitude of the Hall constant.
3. Calculate the density of charged particles in a material.
4. Calculating the type resistance of Hall elements.

II. Basic Theory

The Hall effect is the occurrence of a potential difference which is hereinafter referred to as the Hall electric potential difference between the surface (skin) of a material that is electrified and placed in a magnetic field. The process of Hall potential difference can be explained as follows:

Consider a thin material with thickness t, length p and width l see (Figure 2.1). When the material is placed in a magnetic field B_y and flowing electric current I_x, due to the influence of Lorent's force, then between the two sides in the *z-axis* direction arises a potential difference called the Hall potential difference (V_H).



Gambar 2.1. Gambar elemen Hall

The magnitude of the Hall voltage (V_H) that occurs between the two sides in the *z-axis* direction can be expressed as follows

$$V_H = \frac{R_H I_x B_y}{t} \quad \text{.....(1)}$$

with :

I_x : Electric Current
B_y : Electric Field
R_H : Hall Constant
t : Thickness of Plate

This effect shows balniva if electrons or positive holes as current-carrying particles in electrical conduction from one part to another will deflect due to the influence of a magnetic field. This deflection force is called the Lorentz force. The Hall constant RH in equation (1) can be expressed as:

$$R_H = \frac{V_H t}{I_x B_y} = \frac{I}{ne} \quad \text{.....(2)}$$

If the Hall element has a length *p* width *l* and thickness *t*, then the Hall element has a specific resistance ρ:

$$\rho = \frac{V_x p}{I_x t} \quad \text{.....(3)}$$

with V_x, being the voltage drop of the Hall element.

Based on equation (2), the equation for the number of charge carrier particles n delivered can be obtained, namely

$$n = \frac{I}{R_H e} \quad \text{.....(4)}$$

with $e = 1,602 \times 10^{-19}$ C is an electric charge that is delivered. While the mobility (degree of flow motion) of Hall is expressed by the equation:

$$\mu = R_H \sigma = \frac{R_H}{\rho} \quad \text{...(5)}$$

where σ is the electrical conductivity ($\sigma = \frac{1}{\rho}$).

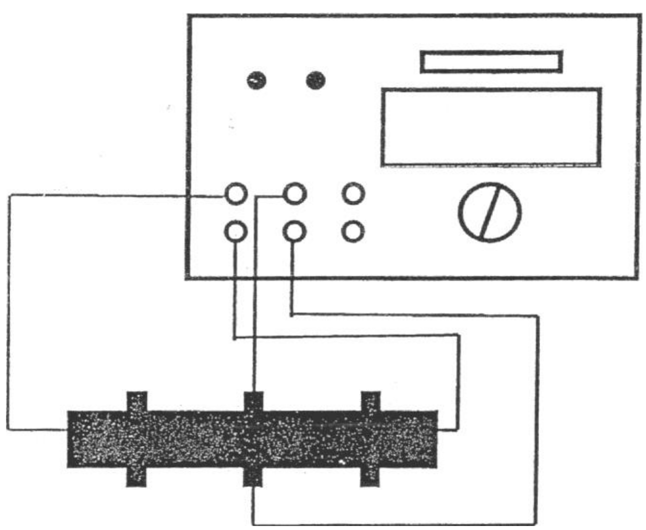
III. Equipment

The equipment used in this experiment is a set of "Hall Effect Experiment" equipment consisting of:

1. Measuring Tools
2. Hall element type P
3. Hall element type N
   Silicon Semiconductor Hall Element with length: 20.0 mm, width: 4.0 mm and thickness: 0.5 mm
4. Iron magnet with stand
5. Gauss meter
6. Connecting Cable

IV. Work Steps

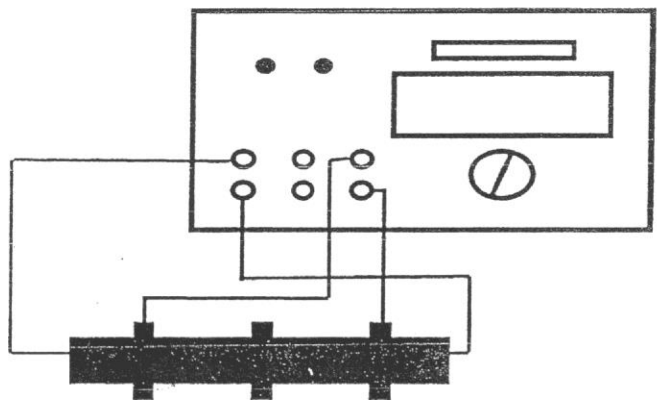
1. Determining the magnitude of the Hall potential difference (V_H)
   a. Assemble the measuring device with the Hall element as shown below:



   b. Increase the value of electric current I_X gradually from 0.5 mA to 1.5 mA. Make sure that when $I_x = 0$ the Hall potential difference (V_H) = 0 by sliding the zero adjustment button.
   c. Record the Hall potential difference (V_H) that occurs for each value of amperage I_X.

d. Repeat steps a to c for the other leg of the Hall element.
e. Repeat steps a s. d d for different magnetic field strengths.
f. Repeat steps a to e for the other Hall elements.

2. Determining the magnitude of the Hall element type resistance *(ρ)*
   a. Assemble the measuring relay with the Hall element as shown below:



b. Increase the value of the electric current I_X gradually from 0.5 mA to 1.5 mA. Make sure that when $I_X = 0$ the potential difference (V_x) = 0 by sliding the zero adjustment button.
c. Record the potential difference (V,) that occurs for each value of electric current.
d. Repeat steps a to c for the other leg of the Hall element.
e. Repeat steps a to d for different magnetic field strengths.
f. Repeat steps a s.d e for other Hall elements

V. Tasks

1. Prove equations (1) and (2)
2. Establish the relationship between V_H and I_x for each Hall element.
3. Calculate the Hall constant (R_H) for each Hall element.
4. How much charge is delivered for each Hall element.
5. Establish the relationship between V_x and I_x for each Hall element.
6. Calculate the specific resistance ρ for each Hall element.

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TRY III

FRANK HERTZ EXPERIMENT

I. Destination

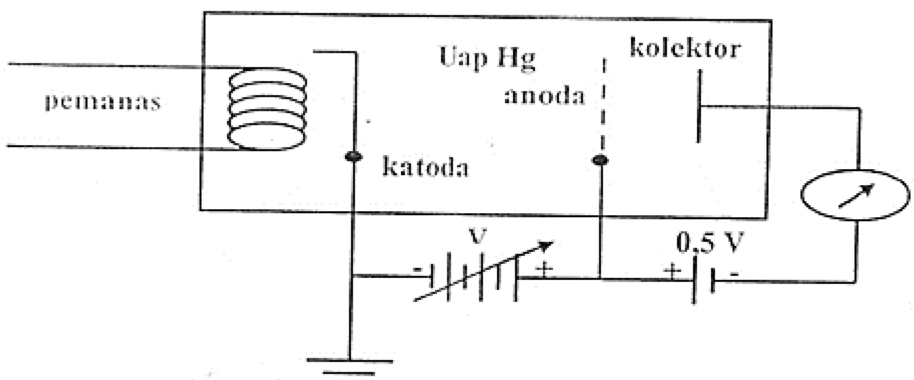
After conducting this experiment, students are expected to have the ability to:

a. Describe the technique used by Frank-Hertz to investigate collisions between atoms in a gas, and state the existence of energy levels in atoms.
b. Calculate the magnitude of excitation energy levels in neon gas atoms.
c. Have the skills to use measuring instruments, data processing to draw a conclusion.

II. Theoretical basis

Frank and Hertz's experiment (1914) in addition to proving that the energy state of atoms is discrete, also shows the absence of changes in atomic energy levels if the atom gets another energy contribution (coming from outside) which is smaller than the difference in energy levels between one energy level to the next energy level.

Frank and Hertz used a tube filled with mercury vapor *(Hg) in* which there is an anode, cathode and collector electrode, as shown in Figure 3.1. as follows

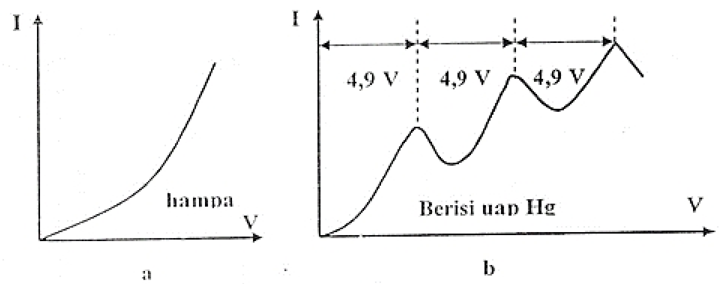


Gambar 3.1. Tabung Frank-Hertz

When the cathode is heated, electrons are released from its surface. These electrons are attracted by the anode which has a positive potential to the cathode. Electrons that penetrate the anode with small energy will be rejected by the collector so as not to cause current I on the microamperemeter. If the energy of the electrons penetrating the anode is greater than 0.5 *eV, the* electrons have enough energy to resist the electric field of the collector and cause the flow of current I on the microamperemeter. Frank-Hertz's train of thought is as follows: electrons coming out of the cathode are accelerated by the electric field between the anode and cathode. The energy that electrons have when they are at potential V is $U = eV$. If an electron with this energy hits an atom in *Hg* vapor and the *Hg* atom can only take a certain amount of energy, for example *Uo,* then the electron that has hit the *Hg* atom will have a residual energy of *U-Uo.* This residual energy is carried over as the kinetic energy of the electron. If the remaining energy is less than 0.5 *eV, the* electrons will be rejected by the collector so that there is no flow of electric current I in the microamperemeter. When the electron energy *U is* less than the price of *Uo, the* atom does not increase the current flow.

energy in and collisions between electrons and atoms are elastic. When this happens, the electrons will easily reach the collector resulting in the flow of electric current *I* in the microamperemeter. Frank-Hertz expected that if the anode potential was changed, the current would initially increase. At certain anode potential prices, namely when the kinetic energy of electrons is equal to *U*, the current will decrease, because the energy is absorbed by atoms so that the remaining electron energy is not enough to overcome the collector potential. As a result at this price the current *I* will drop, and the symptoms expected by Frank-Hertz really occur.

The Frank-Hertz experiment is run as follows: when the tube is made vacuum, and when the anode potential is increased, the current *I* will change as shown in Figure 3.2a. Meanwhile, if the tube contains *Hg* vapor*, the current* I will be obtained as shown in Figure 3.2b.



Gambar 3.2. a. Perubahan arus *I* terhadap *V*, bila tabung Frank-Hertz dibuat hampa udara.
b. Perubahan arus *I* terhadap *V*, bila tabung berisi uap *Hg*.

The second minimum in current *I* when the anode potential *V* is changed is because the **electrons** hit the *Hg* atoms twice. When this happens the electrons will lose energy of 2 x 4.9 eV = 9.8 *eV.* In further experiments with *Hg* vapor, it was also found that energy transfer resonance occurs at energies of 6.7 *eV* and 10.4 *eV.*

The conclusion that can be drawn from this experiment is that the energy in an *Hg* atom can only change in a discrete way, so it cannot be continuous. The multiple internal energy prices that an atom can have are called *energy levels. The* ground level expresses the energy of the atom before it takes on energy. The few energy levels above it express the *state of excitation.* If an atom is hit by an electron with enough energy, it will move into an excited state. If the energy given to the atom is more than 10.4 *eV,* the *Hg* atom will be excited to the ionization state, meaning the electrons bounce out of the atom.

Like the experiments conducted by Frank-Hertz, in this experiment electrons are accelerated between a filament and the grid of a tube containing neon gas *(Ne)* with a variable potential V. A low return potential VR is placed between the grid and the collector plate. A low return potential *VR is* placed between the grid and the collector plate. In order to reach the collector, the electrons must have kinetic energy greater than the reverse potential energy *VR* between the grid and the collector. As the accelerating potential is increased, electrons with greater and greater kinetic energy reach the collector, resulting in an increase in current. At some point, the electrons acquire kinetic energy equal to the energy of the excitation state.

first *Ne* atom. At this time, electrons can excite the *Ne atoms* to this state, so they lose kinetic energy. Thus fewer electrons will have enough energy to overcome the V_R back potential, resulting in a decrease in the collector anus.

A further increase in V I causes the current to rise again as the electrons gain additional kinetic energy after exciting a *Ne* atom. At higher accelerating potentials, the electrons will have enough energy to excite two *Ne* atoms resulting in a second drop for current I, and so on. The voltage difference between the various current peaks appears to correspond to the energy required to excite a *Ne atom to* its first excitation state. This price is obtained from the difference between the two V valleys multiplied by the electron charge, so :

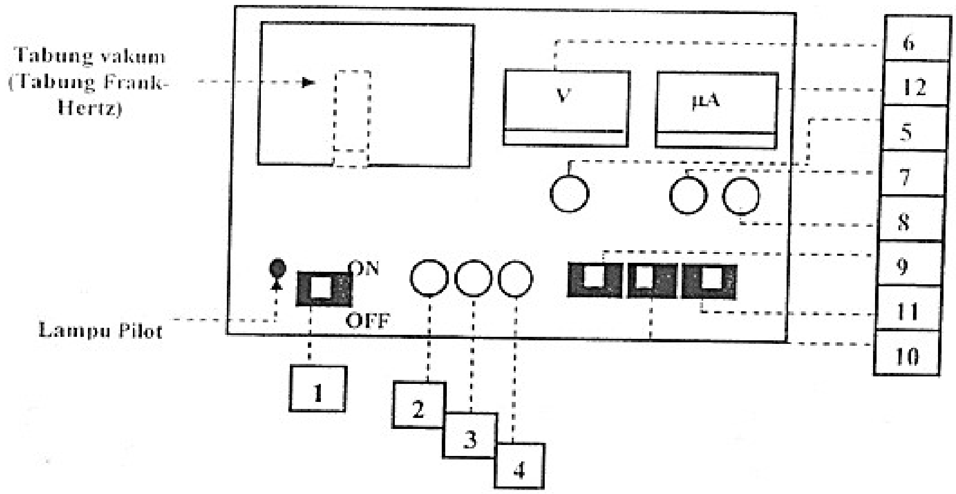
$$\Delta E = e\Delta V \qquad (1)$$

Furthermore, this experiment will observe the excitation energy level of *Ne* gas atoms generated by the relationship between current *I* and anode potential *V*.

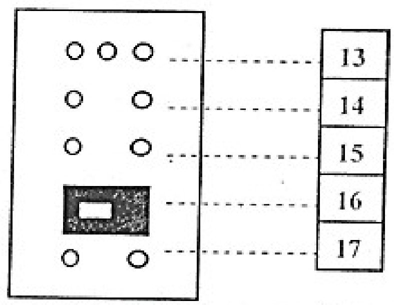
III. Tools and Materials

The equipment used in this experiment is the "Frank-Hertz Experiment" apparatus with the following construction:

(i). Surface Panels:



(ii). Sisi Kanan



Gambar 3.4. i. Sisi depan peralatan percobaan Frank-Hertz
ii. Sisi kanan peralatan percobaan Frank-Hertz

Description:

1. POWER switch
2. HEATER VOLT ADJUSTMENT button
3. GI-K VOLT ADJUSTMENT button
4. $_{G2}$ button -P VOLT ADJUSMENT
5. $_{G2}$ button -K VOLT ADJUSMENT
6. VOLTMETER
7. ZERO ADJUSMENT button
8. GAIN knob
9. AUTO MANU switch
10. EXTERNAL- INTERNAL switch
11. METER-OSCILLOSCOP switch
12. AMMETER

13. OSCILLOSCOP
14. Terminal P- G2(1)
15. G2-K(K) Terminal
16. HEATER SWITCH, TERMINAL, SHORT SWITCH
17. HEATER Terminal (I)

IV. Work Steps

The work steps to be carried out to measure the variables required in this experiment are as follows:

1. Unscrew the "acryl" cap and install the Frank-Hertz tube into the socket.
2. Turn all knobs counterclockwise as far as possible and turn the switch (9), (10) and (11) positions down, and the switch (16) position to SHORT. -(If changing the switch (16) to the OPEN position, connect the AC ammeter to terminal (15)).
3. Connect the 220 V AC power cord, then turn the POWER switch (1) to the "I" position.
4. Set the ammeter needle (12) to the zero position by turning the ZERO ADJUSTMENT knob (7). Next, turn the GAIN knob (8) so that the mark on the knob slightly exceeds the center position. (Since it takes 2-3 minutes for the ammeter pointer to stabilize at the zero position, then perform "zero adjustment" again).

Description:
The heating current, voltage $_{G1}$ to K, voltage $_{G2}$ to P and current $_{G2}$ to P are "4 points in the adjustment". The voltage $_{G1}$ to K is determined by the Frank-Hertz tube. Furthermore, the current $_{G2\ to}$ P can be magnified by the amplifier. The Gain button (8) is for adjusting the amplifier.

5. Turn the $_{G2\text{--}K}$ VOLT ADJUSMENT dial (5) clockwise to adjust the voltage so that the indicator needle on the volmeter (6) is about 30 V.
6. Turn the HEATER VOLT ADJUSMENT dial (2) clockwise so that the mark on the dial slightly exceeds that in the center position. Waiting for a moment, then setting the $_{G1\text{-}K}$ VOLT ADJUSMENT dial (3) at a certain position by slowly turning the dial such that the ammeter needle (12) deviates as far as possible. (Set the ammeter needle pointer at the center of the scale. If you turn the dial (3) further, the ammeter needle drops)

Description:

- If the ammeter needle (12) deviates irregularly despite turning the G1-K VOLT ADJUSMENT dial (3) counterclockwise as far as possible, then turn the HEATER VOLT ADJUSMENT dial (2) clockwise just slightly and adjust the current by slowly turning the dial.
  (3) so that the ammeter needle deviates properly.
- Furthermore, if the ammeter needle (12) deviates too much to the right after the above steps, attempt to lower the current by slowly turning the dial (2) counterclockwise. (Repeat the above steps several times if necessary). This means that you have set the HEATER VOLT ADJUSMENT knob (2) and the $_{G1\text{-}K}$ VOLT ADJUSMENT knob (3) such that the ammeter needle (12) is deviated by the $_{G2\text{-}P}$ current until the ammeter needle is in the center position.

Therefore, it is desired that the heating current is as small as possible and the ammeter needle drops (G_{2-P} current drops) from the rightmost position if turning the G_{1-K} VOLT ADJUSMENT knob (3) counterclockwise or clockwise.

7. If the settings as written in point (6) have been completed, then adjust the G_{2-K} VOLT ADJUSMENT knob (5) counterclockwise so that the G_{2-K} voltage is zero, and then set the ammeter needle (12) in the zero position. After "zero adjustment", by turning the knob (5), return the G2-K knob to about 30 V. (Keeping the ammeter needle back in the center position).
8. Slowly turn the G_{2-P} VOLT ADJUSTMENT dial (4) so that the ammeter needle drops to the center 2/3 position. Then turn the dial (5) counterclockwise as far as possible.
9. After the above operation, while slowly turning the G2-K VOLT ADJUSMENT knob (5), draw a graph of the voltage indicated by the voltmeter (V) and the current indicated by the ammeter (1). If changing the switch
   (9) to the "AUTO" position, then turn the G 2-K VOLT ADJUSTMENT knob.
   (5) clockwise as far as possible. (The voltage of G_{2-K} automatically changes continuously)

   If you now adjust the G_{2-P} voltage with button (4), the bottom of the graph becomes deep or shallow depending on the setting made. In addition, the depth or shallowness of the graph is also determined by the setting of the heating current.
10. Enter the measurement results in the following table

No	V (Volt)	I (mA)

V. Task-tngas

1. Draw a graph between accelerating voltage (V) and anode current (I)
2. Based on the results obtained, calculate the amount of energy required to excite the Neon atom to the first level?
3. Why is there more than one maximum in the graph above?
4. From the result of no.1, calculate the wavelength of light emitted by the Ne atom as a result of the excitation of electrons from the first to the ground level?
5. Give an interpretation of the graph you obtained from this experiment.

TRY IV
ATOMIC SPECTROSCOPY

I. Experiment Objective:

After conducting this experiment, students are expected to have the ability for :

1. Explaining the structure of atoms based on their atomic structure.

II. Basic Theo ri

Light emitted by a gas with a high temperature or stimulated by a potential difference depends on the type of gas used. The study of light emitted by a solid or gas generally includes its wavelength and intensity.

Observations show that high-temperature gas emits a spectrum characterized by a series of spectral lines that have high regularity. The existence of a spectrum of lines in the light emitted by high-temperature gas shows that the energy of electrons in atoms can only have certain prices, or exist at certain energy levels. If the electron energy changes to a lower level, it will emit a photon with a quantum as large as the energy change. This process of light emission was first thought of by Niels Bohr in 1913.

The energy of the electrons in the atom is regularly discrete. The energy that can be possessed by electrons in the atom will form an array of energy levels called the energy state.

A sketch of the arrangement of the tools used to observe the spectrum emitted by an atom is as follows:

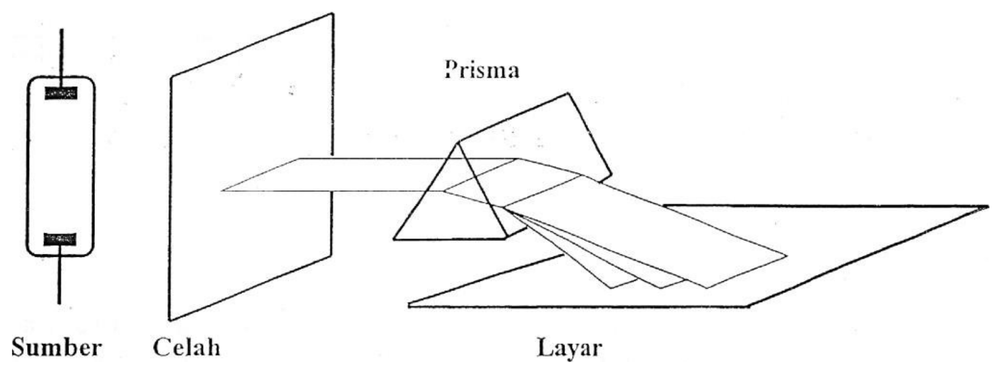


Figure 4.1. Sketch of the spectrometer setup

While the results of observations of spectra emitted by Hydrogen, Helium and Mercury gases are described as follows:

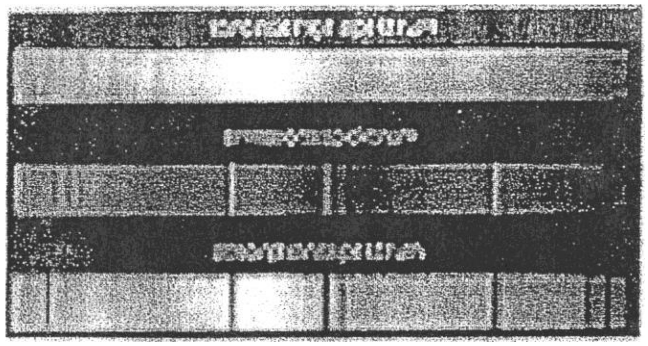


Figure 4.1. Spectra emitted by Hydrogen, Helium and Mercury gases

In 1855 J.J. Balmer managed to find an empirical formulation with a fairly thorough accuracy in determining the wavelength of the Hydrogen spectrum line located in the visible light region. The wavelengths and frequencies of the hydrogen atom spectrum in the visible light region are presented in Table 4.1 as follows:

Table 4.1. Wavelengths and frequencies of the spectrum of the hydrogen atom in the visible light region

Garis	Panj. Glb (nm)	Frekuensi (x 10^{4} Hz)
H_{α}	656,28	4,569
H_{β}	486,13	6,168
H_{γ}	434,05	6,908
H_{δ}	410,17	7,310
H_{∞}	364,56	8,224

Mathematically, the empirical formula obtained by Balmer for the spectrum of the Hydrogen atom is expressed as

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$$

withn = 3, 4, 5, ...
λ = wavelength of spectrum line R = Rydberg constant
= 1.097×10^{7} m^{-1}

The line H_{α} , corresponds to n = 3, the line H_{β} corresponds to n = 4, and so on. The sequence limit corresponds to n = ∞, so the wavelength is equal to 4/R. Furthermore, it is known that the spectrum of the hydrogen atom has many series, each of which is in a different region of electromagnetic radiation. In the ultra violet region there is the Lyman series, and in the infrared region there are Paschen, Brackett, Pfund series.

The electron energy difference is expressed by a set of quantum numbers n, l, m_l and m_s in this case:

- n : principal quantum number
- l : orbital quantum number
- m_l : orbital magnetic quantum number
- m_s : spin magnetic quantum number

Electrons that occupy a certain energy state have constant energy. These electrons are called in a stationary state. Electrons in atoms have a tendency to fill lower energy states by releasing their excess energy in the form of electromagnetic radiation. Electrons in atoms can receive energy from outside to occupy higher energy states and vacate stationary energy states. The movement of electrons from one energy state to another must fulfill the conditions:

$$\Delta l = \pm l$$

$$\Delta m_l = 0, \pm 1$$

which is known as the selection rule. While electromagnetic radiation that emitted satisfies the Bohr-Enstein frequency condition:

$$f = \frac{E1\text{-}E2}{h} \text{ or } \lambda = \frac{hc}{E1 - E2}$$

with :

- f : frequency of electromagnetic radiation
- λ: wavelength of electromagnetic radiation
- h : Planck's constant
- c : speed of light propagation in air
- $E1$: initial energy state
- $E2$: final energy state

If radiation can be measured, then we can calculate the price of $E1 - E2$. If the difference between the two energy states is obtained, a picture of the energy states of the electrons in the atom is obtained. Most atomic emissions are located in the light region (visible light) so optical wavelength measurements can be done easily. But for measuring instruments with poor separation power can not distinguish two adjacent wavelengths.

III. Equipment used

1. Optical spectrometer.
2. Flashlight.
3. Hydrogen, argon, neon lamp tubes

IV. Experiment Work Steps

1. Install the desired light tube and turn on the light!
2. Observe the spectrum using a spectrometer!
3. With the help of a flashlight, read the wavelength scale for each spectrum!
4. Calculate the prices $E1 - E2$ for each source and compare them with theoretical calculations. Also determine the Rydberg constant (R) from the experiment!

TRIAL V

PHOTOELECTRIC EFFECT

I. Introduction

The photoelectric effect is a symptom of the release of electrons from the surface of an object (generally metal) because the object or metal is illuminated by light (photons). Electron energy is highly dependent on the amount of photon energy absorbed. While the number of electrons released depends on the value of the light intensity received. Hertz, in his experiments found that (*light*) flashes of light in the transmitter gap occur if ultra-violet light is directed at one of his metal balls. Other physicists continued the experiment, and they found that the cause of *light* is the emission of electrons at a high enough frequency. The phenomenon is known as the photoelectric effect.

II. Destination

After conducting this experiment, students are expected to have the ability to:

1. Investigate the symptoms of the photoelectric effect
2. Explain the effect of light frequency and light intensity on the electrons emitted in the photoelectric effect.
3. Understand and explain the characteristics of the *phototube* used.

III. Basic Theory

The photoelectric effect was discovered in the l9th century, and has been studied systematically and in detail by Lenard, with the following results:

1. If light of a certain frequency can eject electrons from a metal surface, the resulting current is directly proportional to the light intensity.
2. The maximum wavelength that can produce photo electrons is different for each metal surface and photo electrons cannot be produced at all wavelengths regardless of intensity.
3. Light whose wavelength is shorter than the limit price (limit) can produce electrons photo time from the point of light touching the metal surface from the start of the flow of photo electricity, very short.
4. The kinetic energy of the electrons produced is proportional to the frequency of the light that produced the electrons and has nothing to do with the intensity of the light.
5. The phenomenon at the time was very difficult to explain using the wave theory of light.

The symptoms of the photoelectric effect can be explained as follows: Light waves carry energy, and some of the energy absorbed by metals can be concentrated in certain electrons and appear as quintessential energy. One property that has raised questions for observers is the distribution of the emitted electrons (photoelectrons), which is dependent on the intensity of the light. A strong beam of light produces more photoelectrons than a weak beam for the same frequency, but the average electron energy is the same. Within the limits of experimental accuracy, there is no time delay between the arrival of light at the metal surface and the emission of electrons.

The quantum energy of light in the photoelectric effect is used as energy to free electrons from the metal surface and the rest is used as electron kinetic energy, which is formulated mathematically:

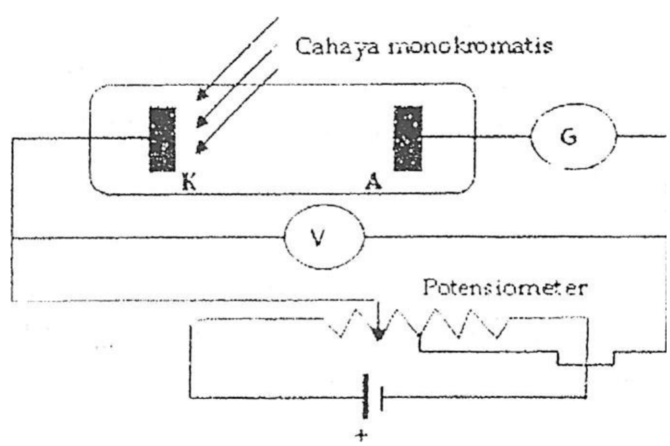
$$hv = \mathrm{Kmax} + hvo$$

with : hv = quantum energy of light

$Kmax$ = maximum kinetic energy of electrons

hvo = work function, the minimum energy required to release an irradiated electron.

A schematic of the photoelectric effect can be seen in Figure 5 below:



Schematic of the photoelectric effect

IV. Alat

The tool used in this experiment is a set of *photoelectric effect experiment device PC-BNB,* which consists of a transmitter, *phototube,* and receiver. (Instruction manual for the use of the tool is attached).

V. L a n g k a h K e r j a n d s

The steps of this experiment are as follows:

1. Putting the *phototube* in front of the transmitter (on the light source part) at a certain distance (fixed light intensity)
2. Connecting the phototube with the receiver
3. Turn on the transmitter and receiver
4. Set the voltage (at the receiver) to a certain value (starting from 0 Volts), then measure the current with an ammeter (output at the receiver).
5. Varying the voltage from 0 volts to 80 volts, measuring the current at each voltage.
6. Repeating steps 1-5 for different phototube-transmitter distances (different intensities).

Tasks

1. Draw a graph between voltage and current for each distance (intensity)!
2. Explain what can be inferred from the graph!
3. Describe the characteristics of the phototube you used in the experiment.

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Instruction Manual of Photoelectric Effect Experiment Device PC-BN

EXPERIMENT VI X-
RAY DIFFRACTION

A. Destination

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

1. Determining the X-ray spectrum
2. Determining the distance between Bragg planes (d)

B. Basic Theory

X-ray diffraction (XRD) spectroscopy is one of the oldest and most frequently used material characterization methods to date. This technique is used to identify the crystalline phase in materials by determining the p a r t u r e of the crystalline material. X-ray diffraction occurs in the elastic scattering of X-ray photons by atoms in a periodic lattice. The monochromatic scattering of X-rays in the phase gives constructive interference. The basis for using X-ray diffraction to study crystal lattices is based on the Bragg equation:

$$n \lambda = 2 \, d \sin \theta \; ; \; n = 1,2,...$$

where λ is the wavelength of the X-ray used, *d is* the distance between the two planes of the grating, θ is the angle between the incident ray and the normal plane, and *n* is an integer referred to as the order of refraction.

Based on the Bragg equation, if a beam of X-rays is dropped on a crystal sample, the crystal plane will refract X-rays that have a wavelength equal to the distance between the lattices in the crystal. The refracted rays will be captured by the detector and then translated as a diffraction peak. The more crystal planes there are in the sample, the stronger the refraction intensity it produces. Each peak that appears in the XRD pattern represents one crystal plane that has a certain orientation in the three-dimensional axis. The peaks obtained from this measurement data are then matched with X-ray diffraction standards for almost all types of materials. This standard is called JCPDS.

The main advantage of using X-rays in material characterization is their penetration ability, as X-rays have very high energy due to their short wavelength. X-rays are electromagnetic waves with a wavelength of 0.5-2.0 microns. They result from shooting metals with high-energy electrons. The electron slows down as it enters the metal and causes electrons in the metal's atomic shell to bounce off to form a void. Electrons with higher energy enter the void by emitting their excess energy as X-ray photons. The X-ray diffraction method is used to determine the structure of the thin layer formed. The sample is placed in the sample holder of the X-ray diffractometer. The X-ray diffraction process begins by turning on the diffractometer so that the diffraction results are obtained in the form of a diffractogram which states the relationship between the diffraction angle and the intensity of the reflected X-rays. For an X-ray diffractometer, X-rays are emitted from an X-ray tube. X-rays are diffracted from a converging sample that is received by a slit in a symmetrical position with a response to the X-ray focus. These X-rays are captured by a scintillator detector and converted into an electrical signal. The signal, after eliminating the noise component, is calculated as a high-pulse analyzer. X-ray diffraction techniques are also used to determine crystal size, lattice strain, chemical composition and other states of the same order.

C. Tools and Materials.

1. X-ray tube with target (anode) Cu
2. G- M detector
3. Counter
4. Crystal reflectors and crystal tweezers

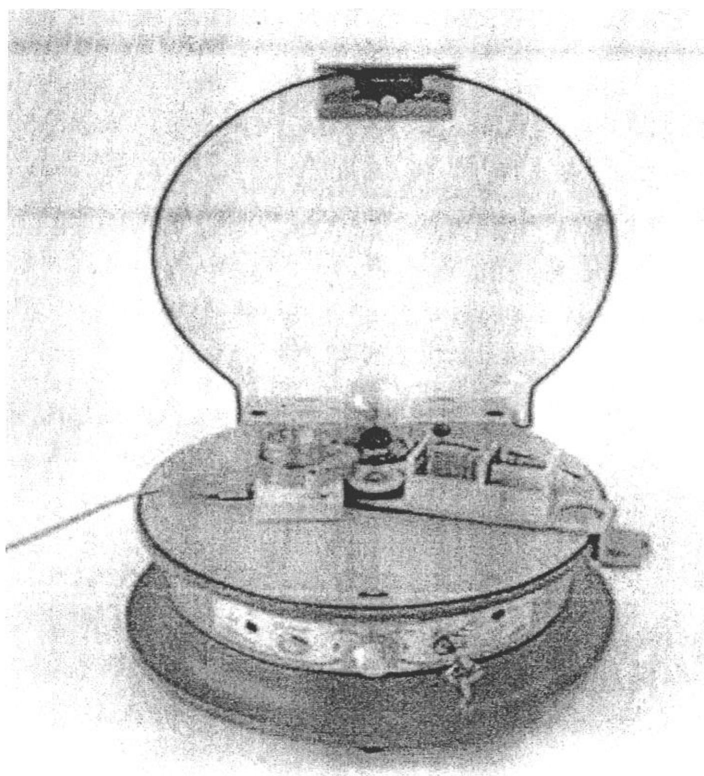

Figure 6: X-ray Diffraction Apparatus

D. Work Steps

1. Set the time switch according to the time required.
2. Set the count control at N/10 s
3. Once everything is ready, start the experiment from angle $2\theta = 13^\circ$ (for example), calculate the number of counts!
4. Take count measurements for every 1° increment until the angle $2\theta = 100^0$, or until the amount of data deemed sufficient to describe the X-ray spectrum.
5. Record the observation data in the table

below: Experiment Data Table

No.	2θ angle	N/10 s
1	13^o	
2	14^o	
...	...	
...	100^o	

6. Draw a graph of the relationship between 2θ and N/10s
7. Calculate the distance between Bragg planes.

Note: wavelengths K_a and 0.154×10^{-9} m and 0.138×10^{-9} m, respectively