Pre-Lab Report

Lab section:

Name & Surname:

Table #:

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You MUST justify your answers and show all steps. NO COPYCAT answers, or NO credits!

Please read the relevant presentation on PHYS LAB Website.

Q1. If you apply Kirchhoff's law to the circuit you will get the following relation:

$$L\frac{d^2q}{dt^2} + R\frac{dq}{dt} + \frac{q}{C} = V_{app}(t)$$

Convince yourself by inserting $q(t) = q_0 A\, e^{-Rt/2L}\sin(\omega_0 t + \delta)$ with $\omega_0 = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$ is a solution to this equation. **Show your calculations below explicitly or no credits!**

(2nd Question is on the next page!)

Q2. Show dimension analysis for Inductance L, Capacitance C and Resistance R clearly. **Show your calculations below <u>explicitly or no credits</u>!**

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Lab Report

Lab section:

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Table #:

***Complete this report YOURSELF except DATA taking parts! Use a pencil for plots only and a pen for the rest!* Show your work clearly, NO COPYCAT analysis allowed, or NO credits!**

OBJECTIVE : To study the oscillations of potential difference across a charged capacitor in series with a resistor and an inductor.

THEORY : In a series RLC circuit, the Kirchoff's loop rule results in the following:

$$L\frac{di}{dt} + Ri + \frac{q}{C} = V_{app}(t) \qquad \text{or} \qquad L\frac{d^2q}{dt^2} + R\frac{dq}{dt} + \frac{q}{C} = V_{app}(t)$$

since I = dq/dt. This is an equation for a damped oscillator driven by a time dependent voltage source or a signal generator. There are three different combinations of R, L, and C values where we can get specific solutions to this equation for a square wave signal as the applied voltage.

Underdamped:

If the values satisfy the following conditions, the circuit will be underdamped:

$$\frac{R^2C}{4L} < 1$$

Then the solution will be:

$$q(t) = q_o A e^{(-Rt/2L)} \sin(\omega_o t + \delta)$$

and the voltage across the capacitor will be:

$$V_C(t) = V_o B e^{(-Rt/2L)} \sin(\omega_o t + \delta),$$

where V_0 is the voltage when the square wave is at the maximum value and δ is the phase. ω_0 is given by:

$$\omega_o = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$

Oscillations decay exponentially with a time constant 2L/R. Signals reach their half values in:

$$t_{1/2} = \frac{2L}{R}\ln 2$$

which we can call half-life of the signals.

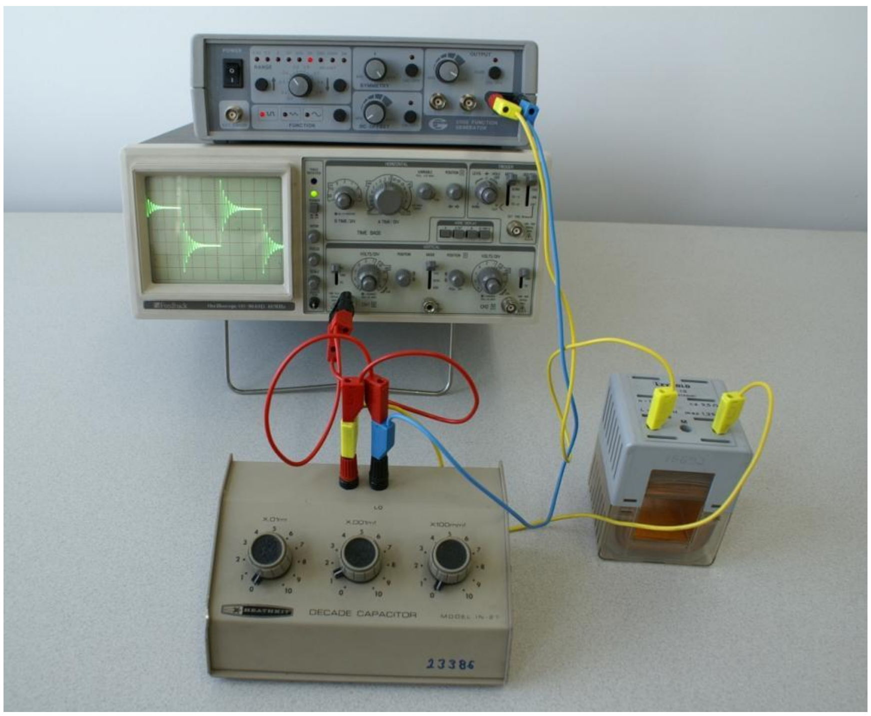
Critically Damped:

If $\frac{R^2C}{4L} = 1$, the circuit is critically damped. As you see from the equation for 0 above, the frequency of the oscillations is zero which means there is only an exponential decay.

Overdamped:

If, $\frac{R^2C}{4L} > 1$ the circuit is overdamped. The frequency of the oscillations, 0, is an imaginary number which means there is only an exponential decay similar to the Critically Damped Case.

APPARATUS : Capacitance and resistance boxes, inductor with an iron block, oscillator, oscilloscope.



PROCEDURE :

- Connect the circuit by using the A-E terminals of the 1000 turn coil for the inductor and 0.001µF capacitor, turn on the oscilloscope and make the initial adjustments. Internal resistance of the square wave generator and the coil resistance will be the total resistance in the circuit.
- Adjust the square wave frequency and the sweep frequency of the oscilloscope so that

one complete cycle of decaying oscillations cover the whole screen of the oscilloscope. Record the value of the sweep frequency in your report.

- Choose two peaks at least 5-6 cm far from each other and count the number of the complete cycles in this chosen range l. Determine the length of one complete cycle, period, and the frequency of the decaying oscillations.
- Measure the half-life of the decaying oscillations.
- Using the half-life equation, calculate the inductance L of the coil in millihenries and calculate the frequency of oscillations by using this value.

$$t_{1/2} = \frac{2L}{R} \ln 2$$

$$f_o = \frac{1}{2\pi} \left[\frac{1}{LC} - \frac{R^2}{4L^2} \right]^{1/2}$$

- When a piece of iron is inserted into a coil, a large change occurs in the inductance of the coil. With the iron fully inserted, determine the new value of the inductance.

CIRCUIT DIAGRAM

Draw the circuit diagram

DATA & CALCULATIONS

Description / Notation			Value & Unit	# of Significant Figures
Capacitance	C	=	....	....
Resistance	R	=	....	....
Frequency of the Square Wave Generator	f_{SWG}	=	....	....

Description / Notation			Value & Unit	# of Significant Figures
[TIME / DIV] Dial of the Oscilloscope <u>without</u> Iron Block		=	....	....
[TIME / DIV] Dial of the Oscilloscope <u>with</u> Iron Block		=	....	....
Length between the chosen peaks	ℓ	=	....	....
Number of complete Cycles in ℓ	n	=	....	....

5

DATA & CALCULATIONS

WITHOUT IRON BLOCK INSIDE THE INDUCTOR

Description / Symbol		Value / Calculations (show each step)	Result
Half-Life	$t_{1/2}$ (cm) =	....	....
Half-Life	$t_{1/2}$(sec) =	....	....
Inductance of the coil	L_1 =	....	....
Wavelength	λ =	....	....
Period of the Oscillations	T =	....	....
Frequency of the Oscillations	f_{measured} =	....	....
Frequency of the Oscillations	$f_{\text{calculated}}$ =	....	....

% Error for f:

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WITH IRON BLOCK INSIDE THE INDUCTOR

Description / Symbol		Value / Calculations (show each step)	Result
Half-Life	$t_{1/2}$ (cm) =	....	....
Half-Life	$t_{1/2}$(sec) =	....	....
Inductance of the coil	L_2 =	....	....

QUESTION

What is the reason for the difference you observe when you insert the iron block inside the inductor?

Consult to the resources for this experiment from PHYS LAB Website:

PHYL202 Intro

Presentation #1

PHYL202 Lab Book

Pre-Lab Report

Lab section:

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Table #:

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In this experiment various series circuits are going to be connected; RC, RL, RLC. Phasor diagrams are going to be drawn for each case.

Q1. Give the definition of the following concepts. You may give examples, show plots etc.

a) Resistance:

b) Reactance:

(Cont'd on the next page!)

c) Phasor diagram:

d) What is the unit of reactance?

1

Lab Report

Lab section:

Name & Surname:

Table #:

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OBJECTIVE : To study the alternating current circuits.

THEORY : To study the alternating current circuits.

$$V(t) = V_p \sin(2\pi ft) \tag{1}$$

where Vp is the peak voltage and f is the frequency of the power supply. When we connect various circuit elements to an alternating current source, we can determine the current through the circuit by Ohm's Law. The current through a resistor, a capacitor, and an inductor will be given by:

$$I_R = \frac{V_p}{R}\sin(2\pi ft) \tag{2a}$$

$$I_C = C\frac{d\left(V_p \sin(2\pi ft)\right)}{dt} = V_p 2\pi fC \sin(2\pi ft + 90^o) \tag{2b}$$

$$I_L = \frac{1}{L}\int V_p \sin(2\pi ft)dt = \frac{V_p}{2\pi fL}\sin(2\pi ft - 90^o) \tag{2c}$$

Hence the current through a resistor is in phase with the voltage across it; the current through a capacitor leads the voltage by 90°; and the current through an inductor lags the voltage by 90°.

Because of these differences in the phases, analyzing alternating current circuits involving different types of circuit elements is somewhat tricky and not as simple as the DC circuits. We can solve this problem by using either complex algebra or the phasor method which are similar to each other.

In the complex algebra method we define reactances for each element:

$$X_R = R \qquad X_C = \frac{1}{i2\pi fC} \qquad X_L = i2\pi fL \tag{3}$$

and treat the voltage and the current as real numbers. Then the circuit analysis for the alternating currents turns into a form similar to the DC circuits. Of course, the reactances contain all the information relevant to the alternating current circuit, that is, the frequency and the phases in the form of the imaginary numbers. Solutions will include both real and imaginary parts. As you know, we can also represent the complex numbers as pairs of numbers on a Cartesian coordinate system where the horizontal axis corresponds to the real and the vertical axis corresponds to the imaginary part. Phasor method simply uses the graphical representation of the complex numbers. In this experiment we will be using the phasor method.

RC Circuit:

When you connect a capacitor and a resistor in series to an alternating voltage source, the phase of the current through the capacitor will be 90° ahead of the voltage. If we were to take the current as our reference for the phase, then the voltage across the capacitor will be 90° behind the current hence the voltage across the resistor. The total voltage across the RC series combination will be equal to the applied voltage:

$$V_{app} = \sqrt{\left(V_R^2 + V_C^2\right)} \tag{4}$$

RL Circuit:

When you connect an inductor and a resistor in series to an alternating voltage source, the current through the inductor will be 90° behind the voltage. If we were to take the current as our reference for the phase, then the voltage across the inductor will be 90° ahead of the current hence the voltage across the resistor. The total voltage across the RL series combination will be equal to the applied voltage:

$$V_{app} = \sqrt{V_R^2 + V_L^2} \tag{5}$$

However, the inductor also has some internal resistance, RL. Because of its internal resistance, the voltage across the inductor will not be exactly 90° ahead but at an angle calculated from:

$$\tan\theta = \frac{2\pi fL}{R_L} \tag{6}$$

We should also modify Equation (5) accordingly:

$$V_{app} = I\sqrt{\left(R + R_L\right)^2 + X_L^2} \tag{7}$$

RLC Circuit:

When you connect an inductor, a capacitor, and a resistor in series to an alternating voltage source, the current through the inductor and the capacitor will be 90° behind and ahead of the voltage, respectively. If we were to take the current as our reference for the phase, then the voltage across the inductor and the capacitor will be 90° ahead of and behind the current (hence the voltage across the resistor), respectively. The total voltage across the RLC series combination will be equal to the applied voltage:

$$V_{app} = \sqrt{(V_L - V_C)^2 + V_R^2} \tag{8}$$

Because of its internal resistance, RL, the voltage across the inductor will not be exactly 90° ahead but at an angle calculated from:

$$\tan\theta = \frac{2\pi fL}{R_L} \tag{9}$$

We should also modify Equation (8) accordingly:

$$V_{app} = I\sqrt{(R+R_L)^2 + (X_L - X_C)^2} = IZ \tag{10}$$

where the total impedance of the RLC circuit is given by

$$Z = \sqrt{(R+R_L)^2 + (X_L - X_C)^2} \tag{11}$$

Now the phase difference between the current and the voltage is more complex and given by:

$$\tan\Phi = \frac{(X_L - X_C)}{R_{total}} \tag{12}$$

This Φ angle is the angle between the applied voltage and the resulting current phasors. It determines the total average power used in an RLC circuit:

$$\overline{P} = V_{rms} I_{rms} \cos\Phi \tag{13}$$

We should remind that the values measured by instruments like voltmeters, ammeters, etc. are root-mean-squared values and not the peak values. You can determine the peak values using an oscilloscope.

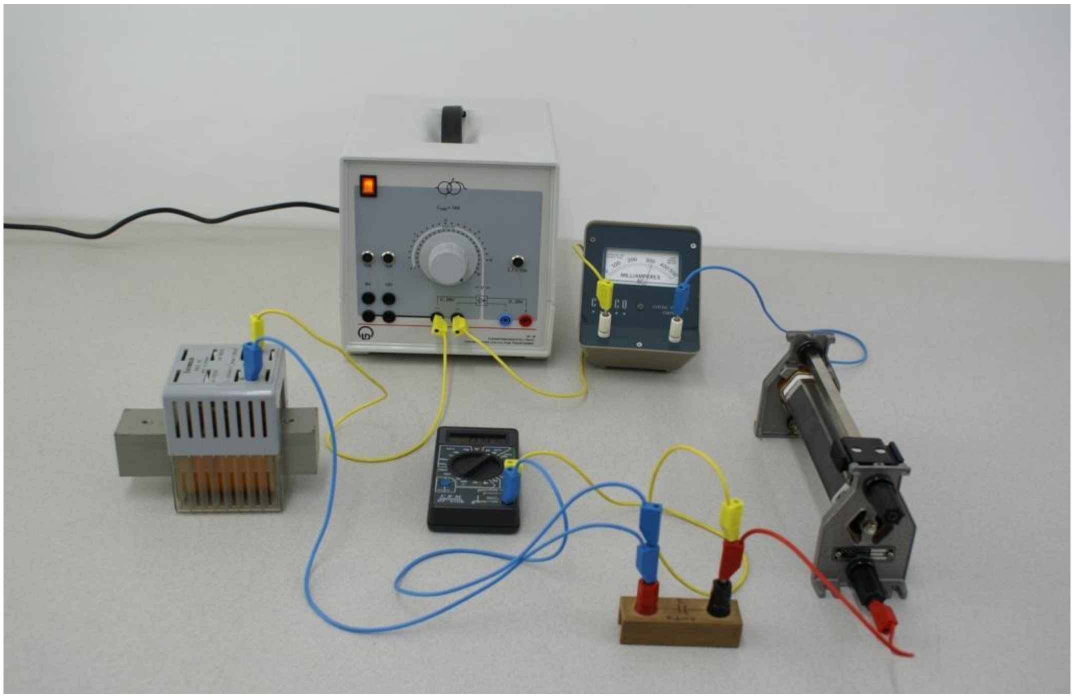
APPARATUS : Inductor with an iron block inside, resistance box, capacitor, AC voltmeter and ammeter, 24-V AC power supply.

PROCEDURE :

1. Use the two fixed ends of the rheostat as a resistor. Use 24 V, 50 Hz output of the power supply as your AC source.
2. Construct an RC circuit and measure the voltage across each element. Then draw the phasor diagram by taking the current (i.e. the voltage across the resistor) as the reference.
3. Then draw two circles with radii equal to VC and Vapp from each end of the phasor corresponding to the voltage across the resistor. Phasors for VC and Vapp will meet each other at the point where the circles intersect. Determine the angle between

VC and VR.

4. Repeat the previous step by constructing an RL circuit this time. Determine the internal resistance of the inductor by measuring the current through the circuit and the horizontal component of VL from your phasor diagram.



5. Repeat the previous step by constructing an RLC circuit this time. Again measure the current value through the circuit. You should draw the phasor diagram in this case by assuming that VC is 90° behind VR (or perpendicular in the negative direction).

6. Then draw two circles centered at the beginning of the phasor for VR and the tip of the phasor for VC with radii equal to Vapp and VL, respectively. Draw Vapp and VL phasors from the centers of the circles to the intersection point.

7. Using the current value and the internal resistance of the inductor determined in the previous step, determine the capacitive and inductive reactances first and then calculate the value of the capacitor and the inductor.

8. Finally determine the phase angle and the average power dissipated in the RLC circuit.

5

PART – 1: RC CIRCUIT

Draw the RC circuit diagram

Description / Notation		Value & Unit	# of Significant Figures
Potential difference across the resistance V_R	=	....	....
Potential difference across the capacitor V_C	=	....	....
Applied potential V_{app}	=	....	....

6

Draw Phasor Diagram of the RC Circuit:

Angle between V_C and V_R = ...

PART – 2: RL CIRCUIT

Draw the RL circuit diagram:

Description / Notation		Value & Unit	# of Significant Figures
Current in the circuit I	=	. . . .	. . . .
Potential difference across the resistance V_R	=	. . . .	. . . .
Potential difference across the inductor V_L	=	. . . .	. . . .
Applied potential V_{app}	=	. . . .	. . . .

Draw Phasor Diagram of the RL Circuit on the next page and show the results below:

Description / Symbol		Value / Calculation	Result
Potential difference due to the internal resistance of the inductor Vr_L	=	. . . .	. . . .
Internal resistance of the inductor r_L	=	. . . .	. . . .

8 **Draw Phasor Diagram of the RL Circuit:**

9

PART – 3: RLC CIRCUIT

Draw the RLC circuit diagram:

Description / Notation		Value & Unit	# of Significant Figures
Current in the circuit I	=	. . . .	. . . .
Potential difference across the resistance V_R	=	. . . .	. . . .
Potential difference across the inductor V_L	=	. . . .	. . . .
Potential difference across the capacitor V_C	=	. . . .	. . . .
Applied potential V_{app}	=	. . . .	. . . .

10

Draw Phasor Diagram of the RLC Circuit:

11

Description / Symbol	Value / Calculation (show step by step)	Result
Capacitive reactance X_C =	. . . .	. . . .
Value of the capacitor C =	. . . .	. . . .
Inductive reactance X_L =	. . . .	. . . .
Value of the inductor L =	. . . .	. . . .
Internal resistance of the inductor r_L =	. . . .	. . . .
Total resistance R_{tot} =	. . . .	. . . .

12

Description / Symbol	Value / Calculation (show step by step)	Result
Impedance Z =	....	....
Phase angle φ =	....	....
Average dissipated power P =	....	....

QUESTION

If the angle between VC and VR is different from 90°, what could the reason be?

Consult to the resources for this experiment from PHYS LAB Website:

PHYL202 Intro

Presentation #2

PHYL202 Lab Book

Pre-Lab Report

Lab section:

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Please read the relevant presentation on PHYS LAB Website.

Q1. Write down the relation between focal length and radius of curvature for a mirror.

Q2. Write down the relation between focal length and radius of curvature for a lens.

(3rd Question is on the next page!)

Q3. Write down the index of refraction formula for a prism.

Q4. What is the definition of index of refraction and what is the unit of it?

1

Lab Report

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OBJECTIVE : To study the law of reflection, principles of mirrors, lenses, and prism by ray tracing.

THEORY : In this experiment you will be tracing the light rays reflected or refracted from various optical elements and determine some relevant quantities of these elements. Here are some crucial points you may need.

- In a plane mirror the incident and reflected angles with respect to the normal are equal

- Focal lengths of concave and convex mirrors are simply half the radius of curvature for the respective surface.

$$f = \frac{R}{2}$$

- Focal length and the radius of curvature of a lens is related through the following expression:

$$\frac{1}{f} = (n-1)\frac{2}{R}$$

where n is the index of refraction.

- We can calculate the index of refraction of the transparent material a prism made of as following:

$$n = \frac{\sin\left(\frac{D_{min} + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

where A is the prism angle at the corner that the light rays are refracted and D_{min} is the minimum angle of deviation between the incident and the refracted rays.

Spring 2024

APPARATUS : Ray box, lens, mirror and prism set, ruler, protractor.

PROCEDURE :

1. For each of the following experiments, place the optical element and light source on a different sheet of paper. Draw the outline of the optical element, paths of incident, reflected, and refracted rays as needed.
2. You will determine the radii of curvatures using the Chord Method. First draw at least two chords on the curved (circular) outline of the elements. Then draw perpendicular bisectors to each of the chords. The center of the circle is where the bisectors intersect. You can determine the radius by measuring the perpendicular distance between the intersection point and any point on the curved outline.
3. Show your Chord Method Analysis on the back of each corresponding sheet.
4. In case of the prism, determine the minimum angle of deviation D_{min} and then the index of refraction for the material of the prism.

PART – 1: REFLECTION

A) Plane Mirror :

Incident ray angle θ_i = ...

Reflected ray angle θ_r = ...

B) Concave – Converging Mirror:

Focal Length of the mirror f_{EV} = ...

Radius of the mirror
(From Chord Method) R = ...

Focal length of the mirror
(From Chord Method) f_{CV} = ...

% difference in focal lengths = ...

C) Convex – Diverging Mirror:

Focal Length of the mirror f_{EV} = ...

Radius of the mirror
(From Chord Method) R = ...

Focal length of the mirror
(From Chord Method) f_{CV} = ...

Thickness of the mirror x = ...

% difference in focal lengths = ...

PART – 2: REFRACTION

D) Convex – Converging Lens :

Refraction Index n = ...

Focal Length of the lens f_{EV} = ...

Radius of the convex lens
(From Chord Method) R = ...

Focal length of the convex lens
(From Chord Method) f_{CV} = ...

% difference in focal lengths = ...

E) Concave – Diverging Lens:

Refraction Index n = ...

Focal Length of the lens f_{EV} = ...

Radius of the concave lens
(From Chord Method) R = ...

Focal length of the concave lens
(From Chord Method) f_{CV} = ...

% difference in focal lengths = ...

5

F) Prism:

Minimum deviation between incident and refracted rays	D_{min}	=	. . . .
Prism angle	A	=	. . . .
Index of Refraction	n_{EV}	=	. . . .
True Value for the Index of Refraction	n_{TV}	=	. . . .
% difference for *n*		=	. . . .

Consult to the resources for this experiment from PHYS LAB Website:

PHYL202 Intro

Presentation #3

PHYL202 Lab Book

Pre-Lab Report

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Q1. Write down the lens equation. Give the definitions of elements in the equation.

(2nd Question is on the next page!)

Q2. Use Euclid geometry to derive the relation $R = \frac{D}{2} + \frac{A^2}{6D}$ for spherometer. **Show your calculations below <u>explicitly or no credits</u>!**

1

Lab Report

Lab section:

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Table #:

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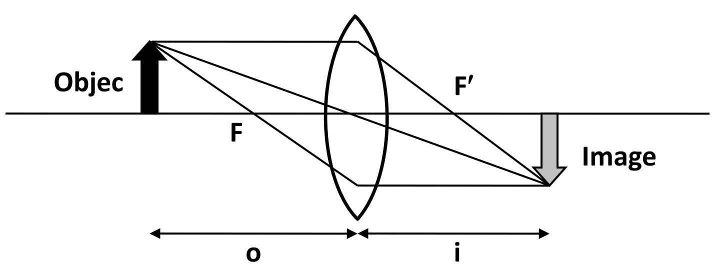
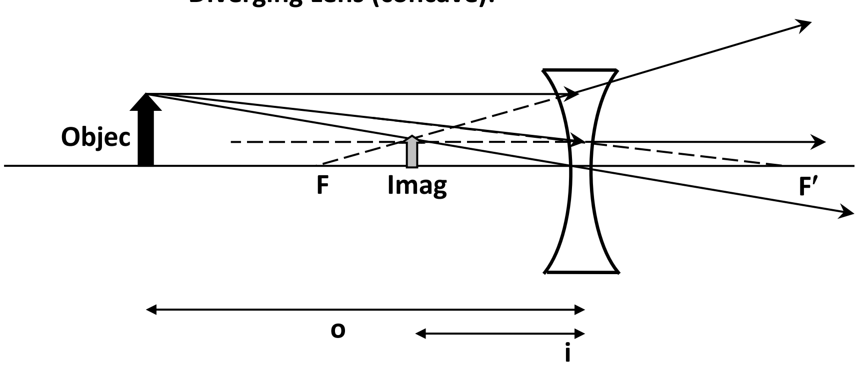
OBJECTIVE : To determine the focal lengths, radii of curvature and index of refraction of various lenses, and to investigate image formation by lens combinations.

THEORY : A thin lens is defined as a lens whose thickness is much smaller than its focal length. Thin lenses that are thin at the edge and thick at the center bend the light rays toward the optical axis (converging lenses) and those that are thick at the edge and thin at the center bend the light rays away from the optical axis (diverging lenses).

Converging Lens (convex):



Diverging Lens (concave):



Thin lenses have two basic equations, the lens equation,

$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i}$$

and the lens maker's equation:

$$\frac{1}{f} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

where r1 and r2 are the radii of curvatures of each surface. If both surfaces have the same curvature, the lens maker's equation becomes

$$\frac{1}{f} = \pm(n-1)\frac{2}{R}$$

where plus and minus signs are for converging and diverging lenses, respectively.

The sign conventions for the quantities used in the equations above are as following:

1. The image distance is positive if the image is formed on the right side of the lens and negative if it forms on the left side. We assume that the light source is on the left.
2. Similarly, the object distance is positive if the object is on the left side of the lens and negative if it is on the right side. (If the object is actually an image from another lens, it may be on the right side.)
3. The radii of curvatures are positive if the corresponding center for a surface is on the right side. This is the reason for positive and negative focal lengths for converging and diverging lenses.
4. The magnification m, which is the ratio of the image size to the object size, is m= -i/o. To denote the inverted images a minus sign is added.

Spherometer:

Spherometer is an instrument to determine very small thicknesses and the radius of curvature of a surface. First you should place the spherometer on a level surface to get a calibration reading (CR). You turn the knob at the top until all four legs touch the surface. When the middle leg also touches the surface, the knob will first seem to be free and then tight. The reading at this position will be the calibration reading (CR). Then you should place the spherometer on the curved surface and turn the knob until all four legs again touch the surface. The reading at this position will be the measurement reading (MR). You will read the value from the vertical scale first and then the value on the dial will give you the fraction of a millimeter. Then you can calculate the radius of curvature of the surface as:

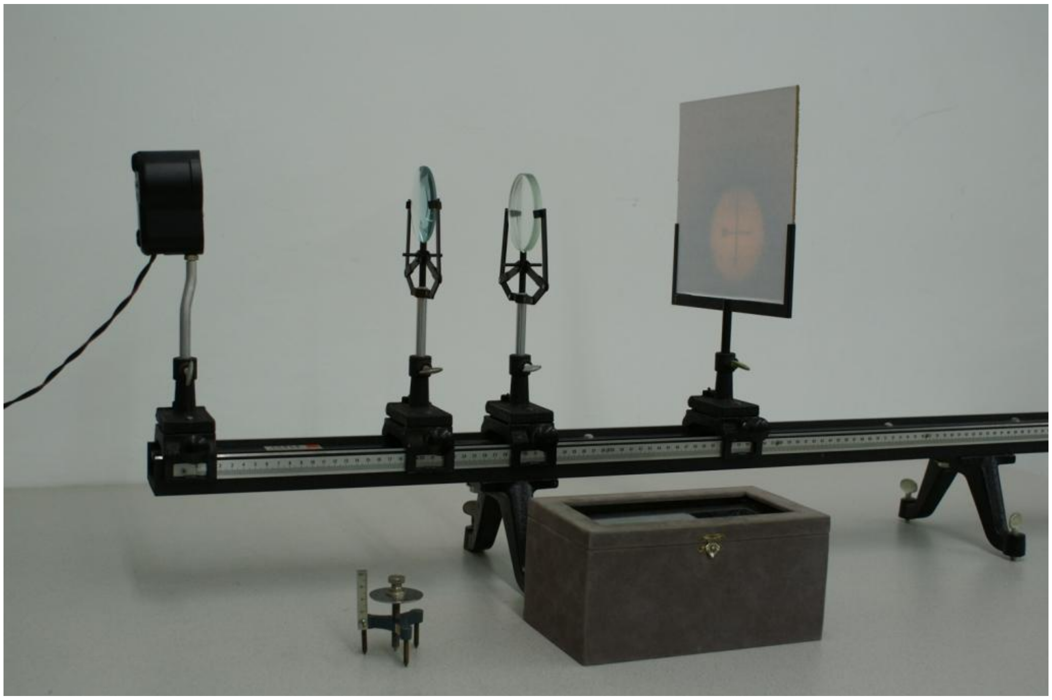
$$R = \frac{D}{2} + \frac{A^2}{6D}$$

where D = |CR-MR| and A is the distance between the outside legs.

APPARATUS : Various thin lenses, light source and cross object, ruler, screen, spherometer.

PROCEDURE :

1. Mount large and small converging lenses one by one. Adjust the position of lenses and the screen to obtain a very sharp and clear image of the illuminated cross. By measuring object and image distances for two different positions of lenses, calculate focal length and magnifications of lenses separately.



2. Use the two converging lenses to form an image of the object. Measure the image distance from the nearest lens and calculate this distance from the lens equation applied to each lens. Repeat this using converging lens of known focal length and a diverging lens. Calculate the focal length of the diverging lens.
3. Measure the radius of curvature of any large lens by a spherometer. (R1=R2=R). Determine the refractive index of the lens.

4

PART – 1: CONVERGING LENSES

A) Small Converging Lens:

Object distance o_1 = ... Object distance o_2 = ...

Image distance i_1 = ... Image distance i_2 = ...

Focal length f_1 = ... Focal length f_2 = ...

Magnification m = ... Magnification m = ...

Average focal length $f_{average}$ = ...

B) Large Converging Lens:

Object distance o_1 = ... Object distance o_2 = ...

Image distance i_1 = ... Image distance i_2 = ...

Focal length f_1 = ... Focal length f_2 = ...

Magnification m = ... Magnification m = ...

Average focal length $f_{average}$ = ...

5

PART – 2: LENS COMBINATION

C) Two Converging Lenses:

Draw the diagram of the system:

<u>Measure</u>:

Object distance

for the first lens o_1 = ...

Image distance

for the second lens i_2 = ...

Distance between the lenses d = ...

<u>Calculate</u>:

Image distance

for the first lens i_1 = ...

. . . .

Image distance

for the second lens i_2 = ...

. . . .

% Error for i_2 = ...

6

D) **Large Converging & Large Diverging Lenses:**

Draw the diagram of the system:

Measure:

Object distance

for the first lens o_1 = ...

Image distance

for the second lens i_2 = ...

Distance between the lenses d = ...

Calculate:

Image distance

for the first lens i_1 = ...

....

Focal length

of the diverging lens $f_{\text{diverging}}$ = ...

....

7

PART – 3: SPHEROMETER

True Value of the

Index of Refraction n_{TV} = ...

Distance between the legs A = ...

Calibration reading CR = ...

Measurement reading MR = ...

Difference in readings $D = |CR - MR| =$ . . . .

. . . .

Radius of curvature

of the lens surface $R = \frac{D}{2} + \frac{A^2}{6D} =$ . . . .

. . . .

Index of Refraction n_{cal} = ...

. . . .

% Error for Index of Refraction, n = ...

Consult to the resources for this experiment from PHYS LAB Website:

PHYL202 Intro

Presentation #4

PHYL202 Lab Book

Pre-Lab Report

Lab section:

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Table #:

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You MUST justify your answers and show all steps. NO COPYCAT answers, or NO credits!

Please read the relevant presentation on PHYS LAB Website.

In this experiment spectrum of the mercury gas is going to be studied by using a spectrometer and a prism. It is really amazing.

Q1. Write down the functional dependence of the index of refraction to the wavelength and comment on it. What does this dependence tell you about refraction of light? Give an example.

(2nd Question is on the next page!)

Q2. What is the dimension for A and B in this expression? **Show your calculations below <u>explicitly or no credits</u>!**

1

Lab Report

Lab section:

Name & Surname:

Table #:

***Complete this report YOURSELF except DATA taking parts! Use a pencil for plots only and a pen for the rest!* Show your work clearly, NO COPYCAT analysis allowed, or NO credits!**

OBJECTIVE : To study the refraction of light by a glass prism, and to construct the dispersion curve for the prism.

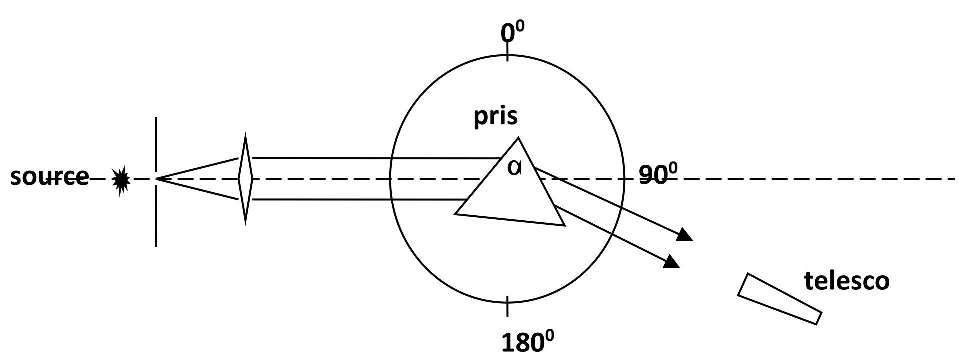
THEORY : Snell's law states that light at a specific wavelength refracts at an angle determined by

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

However, index of refraction varies as a function of wavelength. This is called dispersion and when you plot the index of refraction as a function of wavelength, the curve you obtain is called the dispersion curve for that material. The functional dependence of the index of refraction to the wavelength is given by the empirical relationship:

$$n = A + \frac{B}{\lambda^2}.$$

We can study the dispersion curve using a prism, since the light shining on a prism will separate into individual lines because of the dispersion phenomenon. If we use a spectral lamp, then the individual lines will belong to the spectrum of the element that the spectral lamp is made of. Orienting the prism until you get the minimum deviation angle between the incident and the refracted light rays for each spectral line will give you the data necessary to plot the dispersion curve for the material of the prism. Then you can calculate the index of refraction for each wavelength using the following expression:



$$n = \frac{\sin\left(\frac{D_{\min} + \alpha}{2}\right)}{\sin\left(\frac{\alpha}{2}\right)}$$

where α is the corner angle of the prism where the light is refracted.

APPARATUS : Spectrometer, mercury lamp and its power supply, prism.

PROCEDURE :

1. Adjust the zero position of the spectrometer so that it is equal to the absolute zero. Align the collimator and the telescope such that you can see the slit clearly and sharply through the telescope. Next, adjust the cross-hair so that it is on the slit. Then, fix the telescope and rotate the body until the zero positions of the body and the telescope are aligned. Finally, fix the body and release the telescope to move freely.
2. Set the prism in the center of the prism table.
3. Using the white light source, place the prism in such a way that the light falls on both faces of the prism. Then measure the reflected ray from both side and calculate the angle A.
4. Using the mercury lamp as the light source, determine the angle of minimum deviation for all the lines in the mercury spectrum. Then calculate the refractive index of the prism corresponding to different wavelengths (colors).
5. On an ordinary graph paper, plot n versus $1/\lambda^2$ to obtain the dispersion curve.

DATA:

White light reflection:

Angle (left) θ_{left} = ...

Angle (right) θ_{right} = ...

Prism Angle α = ...

Measurements for the Mercury spectrum:

COLOR	λ (A°)	θ	D_{min} (*show your calculations*)
Yellow-1	5790		
Yellow-2	5769		
Green	5460		
Blue (weak)	4916		
Blue	4358		
Violet-1	4077		
Violet-2	4046		

4

CALCULATIONS:

COLOR	$1/\lambda^2$ ( )	$n = \frac{Sin[(\alpha + D_{min})/2]}{Sin(\alpha/2)}$	*n* *(result)*
Yellow-1			
Yellow-2			
Green			
Blue (weak)			
Blue			
Violet-1			
Violet-2			

5

PLOT: n versus $1/\lambda^2$

6

From the graph, choose two SLOPE POINTS other than data points,

SP_1 : (;)

SP_2 : (;)

RESULTS:

Notation	Calculations (show each step)	Result
A =	....	....
	....	
B =	....	....
	....	

Consult to the resources for this experiment from PHYS LAB Website:

PHYL202 Intro

Presentation #5

PHYL202 Lab Book

Pre-Lab Report

Lab section:

Name & Surname:

Table #:

***Before the Lab* complete this page YOURSELF! Hand it in *in the first 5 min*. of the session PERSONALLY!**

You MUST justify your answers and show all steps. NO COPYCAT answers, or NO credits!

Please read the relevant presentation on PHYS LAB Website.

In this experiment spectrum of an unknown gas is going to be studied by using a spectrometer and a diffraction grating.

Q1. What is diffraction grating?

Q2. What is the maximum number of orders that can be observed with the grating used in the experiment? **Justify your answer, show calculations if needed or no credits!**

Q3. Why is it preferable to use a grating with a small d for accurate spectral analysis? **Justify your answer or no credits!**

(3rd and 4th Questions are on the next page!)

Q4. Should the angular separation between two lines be the same for each order? Why? **Justify your answer or no credits!**

Q5. Prove that the angular dispersion of a grating can be written as: D = tan θ/λ. Hint: Use the grating equation. **Show your calculations below explicitly or no credits!**

#6 Diffraction Grating

1

Lab Report

Lab section:

Name & Surname:

Table #:

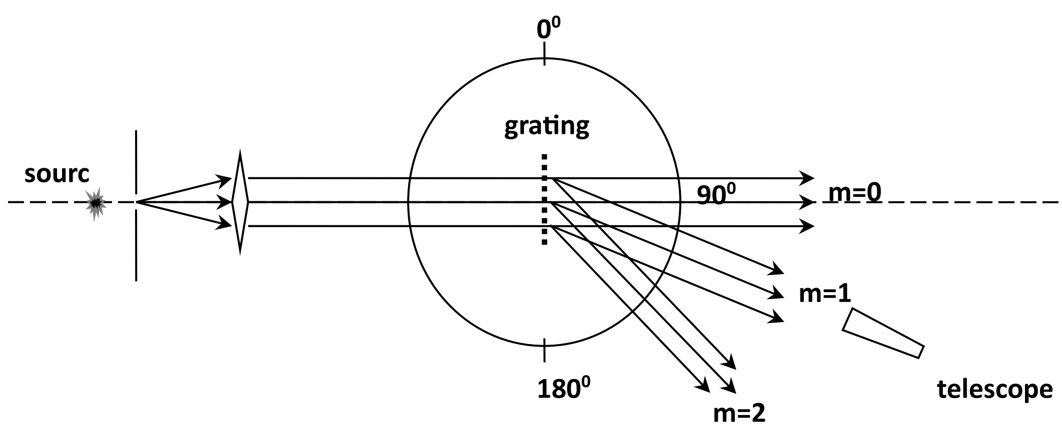
***Complete this report YOURSELF except DATA taking parts! Use a pencil for plots only and a pen for the rest!* Show your work clearly, NO COPYCAT analysis allowed, or NO credits!**

OBJECTIVE : To use a diffraction grating to determine the wavelengths corresponding to various spectral lines.

THEORY : Light shining perpendicularly on a diffraction grating produces an interference pattern on a screen or on your retina if you are viewing from behind the grating. Positions of the maxima in the resulting interference pattern are given by the grating equation:

$$m\lambda = d \sin \theta$$

where *m* is the order of the spectrum, λ is the wavelength of the incident light, *d* is the distance between the lines on the grating, and θ is the angle at which the maximum intensity occurs. Angles are measured with respect to the incident light direction.



If the incident light has components with many wavelengths then you will see these different wavelengths separated from each other. The resolving power of a grating is given in terms of its ability to separate two wavelengths which differ by $\Delta\lambda$:

$$R = \frac{\lambda}{\Delta\lambda}$$

where λ is the average of these two wavelength values. Resolving power is also related to the number of lines (*N*) on the grating through

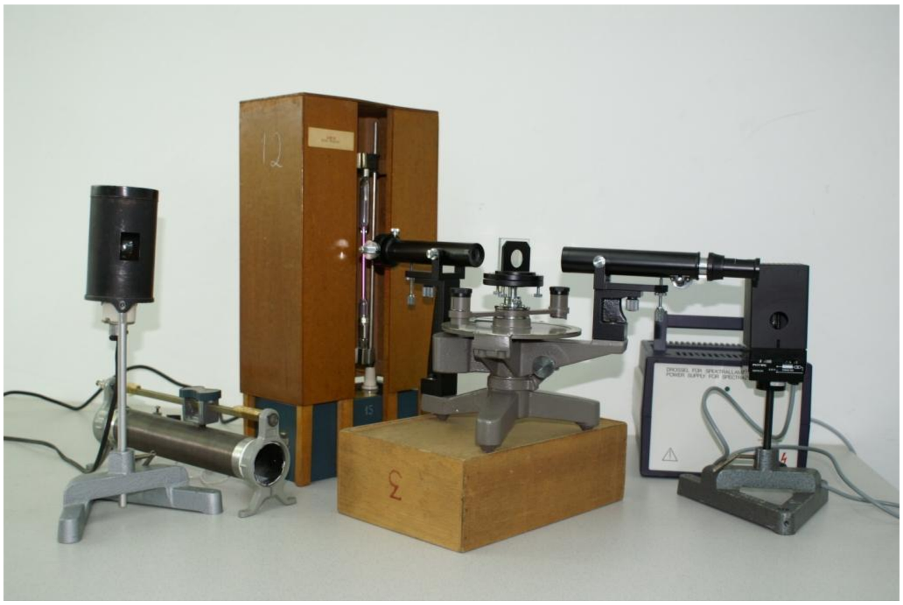
$$R = Nm$$

The angular dispersion *D* of a grating is defined as a measure of the angular separation produced between two monochromatic light waves whose wavelengths are close to each other.

$$D = d\Theta / d\lambda = \tan\Theta / \lambda$$

where Θ is the average of the angles corresponding to the two lines that are close to each other in wavelength and λ is the average of these wavelength.

APPARATUS : Spectrometer, sodium lamp with its power supply, discharge tube with its power supply



PROCEDURE :

1. Adjust the collimator for parallel light, focus the objective on a distant object, and adjust the cross-hair so that it is visible on the image of the distant object and fix the telescope so that the zero position of the body becomes the zero position of the telescope.
2. Release the telescope to move freely. Then mount the diffraction grating carefully on the spectrometer.
3. Using the sodium lamp as the light source, determine the angular position of the first order maximum for the yellow line on either side of the center. C
4. Calculate the diffraction separation d.
5. Using the discharge tube containing unknown gas as the light source, determine the angles for all visible lines.
6. Calculate the wavelengths of those spectrum lines. Identify the gas in the discharge tube by making use of the table in Appendix A.
7. Selecting two barely separated lines in your discharge tube spectrum, determine the angular dispersion of your grating.
8. Use the white light source to determine the wavelength limits for visible light.

3

PART I: DETERMINATION OF DIFFRACTION GRATING CONSTANT, d

Wavelength of sodium doublet	λ	=	5890 Å and 5895 Å average 5893 Å
Order of the spectrum	m	=	....
Angle of spectrum line *(Uncalibrated)*	θ_{left}	=	....
Angle of spectrum line *(Uncalibrated)*	θ_{right}	=	....
Average angle	θ_{ave}	=	....
Diffraction Separation	d	=	....

....

Tehoretical value of d

Diffraction Separation	d_{TV}	=	....

% Error for d = ...

4

PART II: UNKNOWN DISCHARGE TUBE

Discharge Tube Number : . . . .

Color	θ_{left} *(uncalibrated)*	θ_{right} *(uncalibrated)*	$\theta_{average}$	λ ( )

PART III: DISPERSION MEASUREMENT

COLOUR	θ_1 *(uncalibrated)*	θ_2 *(uncalibrated)*	θ_{ave}	λ_{ave} ( )

5

PART IV: WHITE LIGHT SPECTRUM

COLOUR	θ_{left} *(uncalibrated)*	θ_{right} *(uncalibrated)*	$\theta_{average}$	λ ( )
Red End				
Violet End				

RESULTS:

Gas in the Discharge Tube is (*check the appropriate box*) :

☐ **Argon** ☐ **Xenon** ☐ **Hydrogen**

☐ **Helium** ☐ **Mercury** ☐ **Neon**

Dispersion of the spectrometer:

$D = \tan\Theta / \lambda$ = ...

....

Limits of the visible range :

.... $<$ λ (   ) $<$ ....

Consult to the resources for this experiment from PHYS LAB Website:

PHYL202 Intro

Presentation #6

PHYL202 Lab Book

The Balmer Lines of Hydrogen and the Rydberg Constant

Pre-Lab Report

Lab section:

Name & Surname:

Table #:

***Before the Lab* complete this page YOURSELF! Hand it in *in the first 5 min*. of the session PERSONALLY!**

You MUST justify your answers and show all steps. NO COPYCAT answers, or NO credits!

Please read the relevant presentation on PHYS LAB Website.

In this experiment spectrum of the hydrogen gas is going to be studied by using a spectrometer and a diffraction grating.

Q1. Write down the final and initial state numbers for each color that we are going to observe. i.e. n_i and n_f for red, green and violet spectrum lines. **Justify your answers, show calculations if needed or no credits!**

Q2. Write down the formula for wavelength in terms of Rydberg constant R, n_i and n_f.

($3^{rd\ and}$ 4^{th} Questions are on the next page!)

Q3. How can you be sure that n_f=2 for every case you observe. **Justify your answers, show calculations if needed or no credits!**

Q4. Do the dimension analysis for Rydberg constant by using the expression for it. **Show your derivation / formulae below <u>explicitly or no credits</u>!**

$$R = \frac{me^4}{8ch^3\varepsilon_0^2}$$

1

Lab Report

Lab section:

Name & Surname:

Table #:

***Complete this report YOURSELF except DATA taking parts! Use a pencil for plots only and a pen for the rest!* Show your work clearly, NO COPYCAT analysis allowed, or NO credits!**

OBJECTIVE : To observe the Balmer line spectra series of Hydrogen and to determine the Rydberg constant for hydrogen using a grating spectrometer.

THEORY : Elements emit light at characteristic wavelengths when they are excited through heating, electrical discharge, etc. In 1885, Balmer observed some of the lines in the Hydrogen spectrum and noticed that a group of them could be described by

$$\lambda = B\frac{n_2}{n_2 - 4}.$$

When Bohr put forward his model for the Hydrogen atom, it was easy to show that the Balmer lines are produced by the photon emissions when excited hydrogen atoms decay to the second energy level from upper levels. Since Bohr model gives the relationship between the wavelength of the emitted light when an electron moves from an energy level n_i to n_f and the principal quantum numbers n_i and n_f:

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

where R is the Rydberg constant that can be expressed as

$$R = \frac{me^4}{8\varepsilon_o^2 h^3 c}$$

where m is the mass of the electron. You may show that the Balmer lines are obtained when n_f=2 and n_i=n.

PROCEDURE :

1. Adjust the zero position of the spectrometer so that it is equal to the absolute zero. Align the collimator and the telescope such that you can see the slit clearly and sharply through the telescope. Next, adjust the cross-hair so that it is on the slit. Then, fix the telescope and rotate the body until the zero positions of the body and the telescope are aligned. Finally, fix the body and release the telescope to move freely.
2. Mount the diffraction grating carefully on the spectrometer.

3. Using the discharge tube containing hydrogen gas as the light source, determine the wavelengths of the Balmer lines in the hydrogen spectrum. Calculate the Rydberg constant for each of the determined wavelengths. Calculate the actual value of the Rydberg constant using the equation above and compare with your average experimental result.

3

HYDROGEN SPECTRUM LINES

A) For Red Spectrum Line

Angle of spectrum line θ_{left} = ...

Angle of spectrum line θ_{right} = ...

Average angle θ_{ave} = ...

B) For Green Spectrum Line

Angle of spectrum line θ_{left} = ...

Angle of spectrum line θ_{right} = ...

Average angle θ_{ave} = ...

C) For Violet Spectrum Line

Angle of spectrum line θ_{left} = ...

Angle of spectrum line θ_{right} = ...

Average angle θ_{ave} = ...

4

CALCULATIONS:

Description / Symbol			Calculation (show each step)	Result
Diffraction Grating Constant	d	=	. . . .	. . . .
Wavelength for the Red Line	λ_{red}	=	. . . .	. . . .
Wavelength for the Green Line	λ_{green}	=	. . . .	. . . .
Wavelength for the Violet Line	λ_{violet}	=	. . . .	. . . .

5

A) For Red Spectrum Line

Initial state n_i = ...

Final state n_f = ...

Rydberg constant R_{red} = ...

. . . .

B) For Green Spectrum Line

Initial state n_i = ...

Final state n_f = ...

Rydberg constant R_{green} = ...

. . . .

C) For Violet Spectrum Line

Initial state n_i = ...

Final state n_f = ...

Rydberg constant R_{violet} = ...

6

RESULTS:

Description / Symbol			**Calculation (show step by step)**	**Result**
Average value of Rydberg constant	R_{EV}	=	. . . .	. . . .
Calculated value of Rydberg constant	R_{CV}	=	. . . .	. . . .
% Error for *R*		=	. . . .	. . . .

Consult to the resources for this experiment from PHYS LAB Website:

PHYL202 Intro **Presentation #7** **PHYL202 Lab Book**

Pre-Lab Report

Lab section:

Name & Surname:

Table #:

***Before the Lab* complete this page YOURSELF! Hand it in *in the first 5 min*. of the session PERSONALLY!**

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Please read the relevant presentation on PHYS LAB Website.

In this experiment Stefan-Boltzmann Radiation Law is going to be studied by using a tungsten lamp and a radiation sensor. Video presentation on Moodle must be watched before answering the questions.

Q1. Write down the Radiation Rule. Define the elements in it and explain what it tells us.

Q2. Take the logarithm of it. Match it with the most general line equation: $y = mx + n$. **Show your calculations below explicitly or no credits!**

(3^{rd} Question is on the next page!)

Q3. You know that radiation is proportional to the 4th power of temperature. Thus, we need to determine the temperature of the tungsten filament. How are we going to determine the temperature? By a thermometer? **Justify your answers, or no credits!**

Q4. Show dimension **analysis** for Stefan-Boltzmann constant σ **explicitly. Show your calculations below <u>explicitly or no credits</u>!**

1

Lab Report

Lab section:

Name & Surname:

Table #:

***Complete this report YOURSELF except DATA taking parts! Use a pencil for plots only and a pen for the rest!* Show your work clearly, NO COPYCAT analysis allowed, or NO credits!**

OBJECTIVE : The aim of this experiment is to determine the rate of temperature dependency in the Stefan-Boltzman Radiation Law.

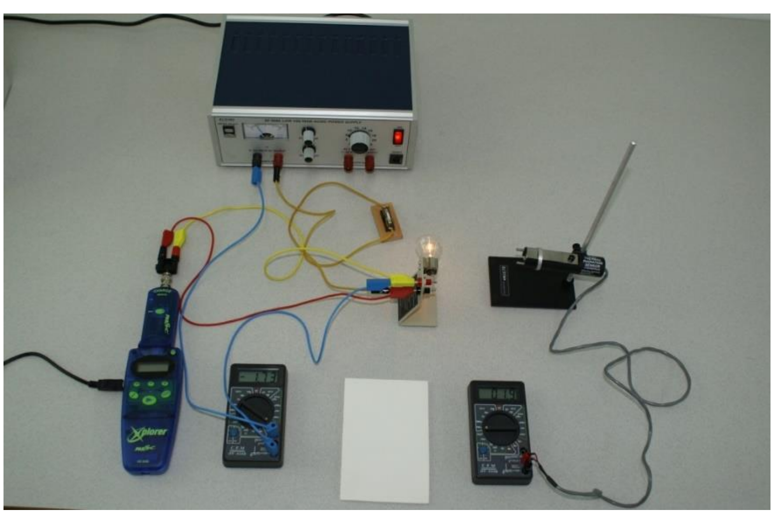
THEORY : Radiation from an object is observed to be dependent on its temperature. The distribution of photon frequencies can be understood in terms of quantum physics where the radiation occurs in the form of energy packets or photons. It has been observed that the wavelength at which the maximum intensity occurs (Wien's displacement law) or the total radiated power integrated over all wavelengths per unit area depends only on the temperature of the object. The latter is the subject of our experiment and is called the Stefan-Boltzman Radiation Law. It states that the total integrated radiated power per unit area from an object depends on the fourth power of its temperature:

$$R = \sigma T^4,$$

where σ is the Stefan-Boltzman constant ($\sigma = 5.6703 \times 10^{-8}$ W/m^{2}K^4).

The object that produces the radiation in this experiment is an incandescent tungsten bulb. The actual part that radiates is the tungsten filament. Since the resistance of metals increases as a function of temperature ($R = R_0(1+\alpha(T - T_0))$ where temperature coefficient of resistivity for tungsten is $\alpha = 4.5 \times 10^{-3}$ K^{-1}), we can determine its temperature by measuring its electrical resistance through Ohm's law: $R = \dfrac{V}{I}$.

We will use an infrared detector that is sensitive over a wavelength region between 0.5 to 40 μm. We will be measuring the total power radiated over this range only, but this should give us a value proportional to the total power radiated. Its output is in millivolts.



APPARATUS:

Stefan-Boltzman Lamp (a 12 V bulb), fuse and switch set, radiation sensor, reflecting heat shield, multimeter set to 200-millivolt range, multimeter set to 10-A range, Data Logger and the charge sensor, Pasco 24-V power supply, various leads and stand for the radiation sensor.

Spring 2024

PROCEDURE :

1. Multimeters and the power supply are placed on the workbench at their proper settings. If you notice something is not set right, please inform your instructor, otherwise DO NOT MAKE ANY CHANGES IN THE SETTINGS. Make sure that the heat shield is placed between the bulb and the sensor, reflective side facing the sensor.
2. You will determine the resistance of the tungsten filament at room temperature first. For this purpose adjust the power supply current to its minimum value, 0.2 A. You will be reading the current value from the multimeter set to 10-A range and the potential across the filament from the data logger set as a voltmeter.
3. Calculate the resistance using the Ohm's law. This will be your R0. Your instructor will give you the value of the room temperature. Make sure that all your temperature values are in Kelvin.
4. Make sure that the metal ring on the detector has been pushed all the way to the front, otherwise the detector readings might be faulty.
5. While increasing the current very slowly, record the current, the potential drop across the lamp, and the sensor output at each current setting. **DO NOT EXCEED 2.6 AMPERES!**
6. Calculate the resistance of the tungsten filament at each current setting using the Ohm's law and divide these values by the value at room temperature that you have determined in step 2.
7. Using the temperature coefficient of resistivity for tungsten, $\alpha = 4.5 \times 10^{-3}$ K^{-1}, and $R / R_0 = (1 + \alpha(T - T_0))$, determine the temperature of the tungsten filament at each current setting.
8. Plot your radiation sensor output versus temperature data on a log-log paper. Draw a straight line that passes through all the data points symmetrically, that is, either all the points fall on the straight line or equal number of points fall each side of the line.
9. A power law expression produces a linear plot when plotted on a log-log graph paper. Determine the slope of this straight line by picking two points far apart from each other. Slope is the ratio of the actual vertical distance to the actual horizontal distance on the graph. Since plotting on a log-log graph paper is equivalent to taking the base-10 logarithm of the values and then plotting them on a regular paper, slope is calculated through:

$$m = \frac{\log y_2 - \log y_1}{\log x_2 - \log x_1} = \frac{\log\left(\dfrac{y_2}{y_1}\right)}{\log\left(\dfrac{x_2}{x_1}\right)}$$

   where x and y values are direct readings from the graph.
10. Compare your result with the actual value of n = 4. What is your percentage error?

3

Draw the circuit diagram:

Write down the formula to calculate the temperature from the resistance (see step 7):

....

.... T = ...

T_o = ...

I_o = 0.2 Amp. V_o = ...

R_o = ... α = ...

4

Current I ( )	Potential Across the lamp V ( )	Radiation Sensor output V_{Rad} ( )	Resistance of the filament $R=V/I$ ( )	R / R_o	Temperature of the filament T ( )

5

6

A) From the graph, choose two SLOPE POINTS other than data points,

SP_1 : (;)

SP_2 : (;)

B) Calculate,

Description / Formula	Calculations (show each step)	Result
n = SLOPE =	………………………………………………	………………
	………………………………………………………………………	
% error =	………………………………………………	………………

Consult to the resources for this experiment from PHYS LAB Website:

PHYL202 Intro

Presentation #8

PHYL202 Lab Book