Mukesh Patel School of Technology & Management Engineering

DEPARTMENT OF BASIC SCIENCES & HUMANITIES

Laboratory Journal

PHYSICS III

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Roll No. ___________________________

MUKESH PATEL SCHOOL OF TECHNOLOGY MANAGEMENT & ENGINEERING

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This is to certify that Mr./ Ms. ____has carried out the above mentioned term work for the subject Physics III in the Department of Basic Sciences & Humanities, MPSTME.

Subject faculty

EXPT 1

AIM: To study the different cubic lattices and determine the inter-planar spacing for different cubic lattices, Miller planes and directions.

APPARATUS:

1. Crystal models
2. Meter scales.

THEORY:

Crystals are made up of regular and periodic three dimensional pattern of atoms in space. The regularity in the arrangement of atoms allows us to visualize certain ‘building blocks’ of the crystal structure, called ‘unit cell’. A close stacking of the unit cells over each other gives rise to the full crystal. Because the arrangement of the atoms in the crystal has to be completely regular and perfect, only a limited number of cell patterns are possible. The simplest and the most-symmetric unit cell is the cubic one. Depending on the actual arrangement of the atoms, there can be three types of cubic unit cell. These are: (i) simple cubic (SC); (ii) body centered cubic (BCC); and (iii) face cantered cubic (FCC).

In a crystal there exists parallel direction and parallel planes. It is necessary to use some convention to specify these geometrical features. For this purpose, the system devised by Miller is widely used. If (h,k,l) are the Miller indices of a crystal plane, then the distance between two successive (hkl) planes, i.e., the interplanar separation, is given by

$$d_{hkl} = \frac{a}{\sqrt{h^2 + k^2 + l^2}},$$

Where ‘a’ is the length of one edge of the unit cell.

PROCEDURE:

DETERMINING INTERPLANAR SPACING

1. Take a simple cubic crystal model. Measure the length of the edge of the cube.
2. Calculate the length of the body diagonal and the face diagonal.
3. Find the numbers of (100) planes within one edge length, of (110) planes within one face diagonal length, and 0f (111) planes within one body diagonal length.
4. Calculate d_{100}, d_{110}, and d_{111}, and hence the ratio d_{100}:d_{110}:d_{111}.
5. Repeat the procedure with face centered cubic and body centered cubic models.

DETERMINING THE MILLER PLANES AND DIRECTIONS

A set of three integers h, k and l is used to indicate a particular crystalline plane. The set h,k,l written as (hkl) is called the Miller indices. The Miller Plane corresponding to the miller indices are drawn using the following procedure:

1. Evaluate the reciprocal of the three integers (hkl). These are the intercepts of the given miller plane to be drawn.
2. Identify the three axes on the unit cell. Plot the intercept of the given miller plane. Join the points to complete the plane on the unit cell.
3. In case if any of the integer is zero than the corresponding intercept will be infinite and for such a plane, draw a line parallel in that direction from the remaining intercepts and join the lines to form the given miller plane.

The following procedure is used to draw the direction of particular plane:

1. Choose the three axes with suitable origin on the unit cell.
2. Divide the miller integers with the largest among them. The set of three integers obtained is now the set of intercepts for the direction.
3. Plot the intercept for x-axis. From here move in y direction up to the y intercept value.
4. Then from y intercept move in z direction and plot the z intercept.
5. Now draw an arrow joining the origin to the z direction point. This arrow represents the direction of the particular miller plane.

OBSERVATION TABLE:

Determination of the ratio d_{100}: d_{110}: d_{111}.

Table I Measurements of a, √2a, √3a

Lattice	Sr. No.	Length of the cube edge (a) in cm	Mean 'a' in cm	√2a in cm (face diagonal)	√3a in cm (body diagonal)
SC	1				
	2				
	3				
BCC	1				
	2				
	3				
FCC	1				
	2				
	3				

Table II The inter planar spacing d_{100}, d_{110}, and d_{111}

Lattice	No. of (100) planes within one edge length (m)	D_{100} =a/m (cm)	No of (110) planes within one face diagonal length (n)	d_{110}= √2a/n (cm)	No of (111) planes within one body diagonal length (p)	d_{111}= √3a/p (cm)
SC						
BCC						
FCC						

RESULT:

Lattice	d_{100}	d_{110}	d_{111}	$d_{100}:d_{110}:d_{111}$	
				Experimental	Theoretical
SC					$1:1/\sqrt{2}: 1/\sqrt{3}$
BCC					$1:\sqrt{2}: 1/\sqrt{3}$
FCC					$1:1/\sqrt{2}: 2/\sqrt{3}$

CONCLUSIONS:

EXPT 2

AIM: To determine the band gap of a given semiconductor.

APPARATUS:

1. Semiconductor material (germanium p-n junction diode)
2. Micro ammeter
3. Power supply
4. Heating source
5. Thermometer
6. Connecting wires etc.

THEORY:

When the two blocks of p-type and n-type semiconductors are joined, a large concentration gradient exists across the junction for the majority carriers. Electrons tend to diffuse from n-type region into p-type region while holes tend to diffuse from p-type to n-type region, in an attempt to reduce the concentration mismatch in the regions. These give rise to the formation of depletion layer at the junction. The depletion layer is narrow region of width W about the junction and is devoid of mobile carriers. It has a distribution of fixed negative ions on the p-side and a distribution of fixed positive ions on the n-side of the junction. This distribution of immobile ions in the depletion layer gives rise to potential barrier (Vo) across the junction. The potential barrier prevents the diffusion of majority carriers across the junction. However, the barrier has the right polarity to promote the flow of minority carriers across the junction. As this flow is caused by a potential barrier it is called drift current. Drift current is very small as the minority carriers are very small. The minority carriers are generated through breaking of covalent bonds which depends only on the temperature. Therefore, the drift current is constant at a given temperature. Minority carriers can move across the junction only when the barrier potential exists across the junction. When the barriers potential is smaller they move slower, when it is larger they move faster. An externally applied voltage cannot change the magnitude of the drift current. It can only cause a decrease or an increase in the kinetic energy of the minority carriers. For this reason, the drift current due to minority carriers is called **reverse saturation current**. It is denoted by Is. It is of the order of Nano amperes for silicon p-n junction and microamperes in germanium p-n junction.

At equilibrium the drift current due to minority carrier is compensated by the diffusion current due to majority carriers and the net current across the junction is zero. When the pn junction is under reverse bias, the width of the depletion layer increases. An increase in the width will result in a decrease in the concentration gradient and a decrease in the diffusion current. The diffusion current totally disappears at the higher bias values, and the current through the junction is only due to the reverse saturation current.

$$I_S = AT^2 e^{\left(\frac{-E_g}{kT}\right)}, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

The dependence of reverse saturation current Is on temperature is given by

Where, T is the temperature in K,
E_g is the energy gap of the semiconductor,
k is the Boltzmann's constant,
A is a constant

$$\text{i.e., } \log_e \frac{I_S}{T^2} = -\frac{E_g}{kT} + \log_e A, \ldots\ldots\ldots\ldots(2)$$

$$\text{i.e., } \log_{10}\frac{I_S}{T^2} = -\frac{E_g}{2.303k}\left(\frac{1}{T}\right) + \text{const.............}(3).$$

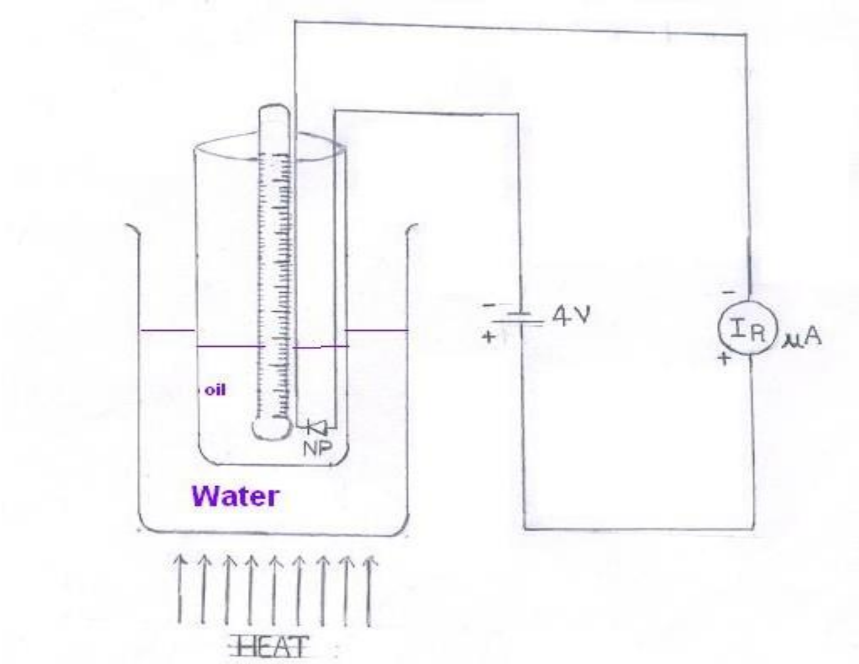
So the slope of the graph of log10IS/T^2 versus 1/T is given by the following relation

slope = - Eg / (2.303 x k) (4)

Eg = - 2.303 x k x slope (5)

Eg = - (2.303 x 1.38 x 10^{-23}) x slope / 1.6 x 10^{-19} (6)

DIAGRAM



PROCEDURE:

1. Fill half of a glass test tube with oil. Immersed the diode inside the oil in the test tube together with a thermometer and put the whole arrangements in water bath. Take care that the diode and the thermometer bulb should be a near proximity. Also both of them should be fully immersed in water.
2. Connect the circuit as shown in figure 1. Note down room temperature.
3. Now adjust the reverse bias voltage to a large value (e.g. 4volts) such that the current through the junction is only due to reverse saturation current. Note down the reverse saturated current.
4. Increase the temperature of the water bath with the help of the heating system. Note down the saturation reverse current IS at various temperatures up to 85^{0}C.
   Plot the graph of log10 IS/T^2 versus 1/T. Hence; determine the value of energy gap by using the formula given in equation (6)

OBSERVATION TABLE:

Reverse bias voltage = 4 volts

Table I Measurement of I_S at different temperature.

Obs. No.	t ^{0}C	I_s (μA)	T (K)	T^2	1/T (K^{-1})	I_s/T^2	$\log_{10} I_s/T^2$
1	Room temp						
2	30						
3	35						
4	40						
5	45						
6	50						
7	55						
8	60						
9	65						
10	70						
11	75						
12	80						

RESULT: Energy gap of semiconductor = Eg =..................................eV

CONCLUSIONS:

EXPT 3

AIM: To determine the Hall Coefficient of a given semiconductor.

APPARATUS:

1. Hall effect apparatus
2. Hall probe
3. Electromagnet

THEORY:

The Hall Effect can be described as the appearance of EMF across the width of a conductor when a current flow along its length & simultaneously a magnetic field is applied along its height i.e. perpendicular to the plane of the conductor. If a current I is passed along the length of the conductor of thickness t and placed in a magnetic field B perpendicular to the plane of the conductor i.e. along t, a potential difference V_H is developed across the width of the conductor and is represented by

$$V_H = (R_H \times B \times I) / t$$

Where, R_H is Hall-coefficient of a semiconductor crystal in cc/ Coulomb and B is expressed in Gauss & Current (I) in Amp.

For a given plate, R_H & t are constant. So for constant I the above relation can be expressed as

$$R_H = (K \times t)/I$$

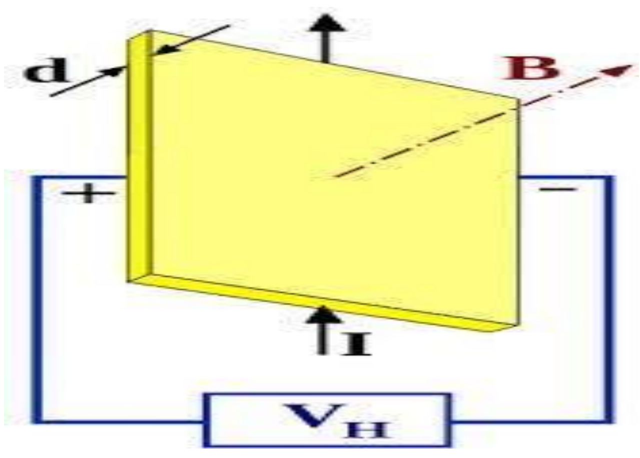
Where $K = V_H / B$

From the slope of V_H vs. B graph for a constant I, the value of R_H can be calculated.

FORMULA: $\mathbf{R_H = [V_H \times t \times 10^8] / B \times I}$

V_H is the observed voltage difference in Volts (V)
I the current running through the conductor in Ampere (A)
B is the magnetic field in Gauss
t = thickness of the sample = 0.015 cm

DIAGRAM:



Schematic diagram for measurement of Hall coefficient of a crystal

PROCEDURE:

1. Set the Pole gap 10 mm.
2. Connect the electromagnets with the Hall Effect kit.
3. Switch on the kit.
4. Keep Hall Effect probe in between the poles of magnets.
5. Set the probe current to 70 mA.
6. Start increasing the magnet current from 50 mA to 500 mA & simultaneously note down the Hall Voltage (V_H).
7. Follow the step 6 in reverse order, i.e. decrease the magnet current from 500 mA to 50 mA & note down the Hall Voltage (V_H).
8. Follow step 6 & 7 for probe current 100 mA.
9. Plot a graph between Magnetic Field (B) & Hall Voltage (V_H) and find the value of Hall Coefficient.

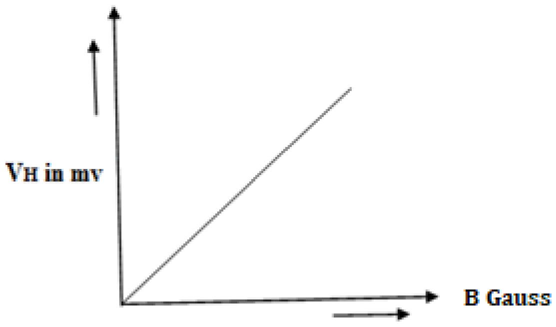
OBSERVATION TABLE: **Pole gap=10mm** **Thickness of given crystal is t= 0.015cm**

	Probe current **I = 70mA**				Probe current **I = 100mA**			
Magnet current I_m in mA	Magnetic Field B in Gauss for increasing (I_m)	Hall Voltage V_H in mV	Magnetic Field B in Gauss for decreasing (I_m)	Hall Voltage V_H in mV	Magnetic Field B in Gauss for increasing (I_m)	Hall Voltage V_H in mV	Magnetic Field B in Gauss for decreasing (I_m)	Hall Voltage V_H in mV
50	280		330		280		330	
100	480		580		480		580	
150	710		820		710		820	
200	930		1040		930		1040	
250	1150		1260		1150		1260	
300	1380		1470		1380		1470	
350	1600		1690		1600		1690	
400	1800		1880		1800		1880	
450	2030		2070		2030		2070	
500	2230		-		2230		-	

CALCULATIONS:

Probe current I= 70 mA		**Probe current I=100 mA**		**Mean R_H cc/Coulomb**
K from graph	**R_H in cc/Coulomb**	**K from graph**	**R_H in cc/Coulomb**	

RESULT: Hall-coefficient of the given crystal is________________________________.



R_H=Slope x t x 10^8 / I

CONCLUSIONS:

EXPT 4

AIM: To find the radius of curvature of a given plano-convex lens using Newton's ring.

APPARATUS: A monochromatic source of light (source of sodium light), a Plano-convex lens, an optically flat glass plates, a convex lens, a traveling microscope.

THEORY:

A parallel beam of monochromatic light is incident normally on a combination of a Plano-convex lens L and a glass plate G, as shown in Fig.1. A part of each incident ray is reflected from the lower surface of the lens, and a part, after refraction through the air film between the lens and the plate, is reflected back from the plate surface. These two reflected rays are coherent; hence they will interfere and produce a system of alternate dark and bright rings with the point of contact between the lens and the plate as the centre. These rings are known as Newton's ring.

The condition for constructive and destructive interferences are given as for normal incidence **cos r = 1** and for air film **μ = 1.**

1. **Central dark spot:** At the point of contact of the lens with the glass plate the thickness of the air film is very small compared to the wavelength of light therefore the path difference introduced between the interfering waves is zero. Consequently, the interfering waves at the centre are opposite in phase and interfere destructively. Thus a dark spot is produced.

2. **Circular fringes with equal thickness:** Each maximum or minimum is a locus of constant film thickness. Since the locus of points having the same thickness fall on a circle having its centre at the point of contact, the fringes are circular.

3. **Fringes are localized:** Though the system is illuminated with a parallel beam of light, the reflected rays are not parallel. They interfere nearer to the top surface of the air film and appear to diverge from there when viewed from the top. The fringes are seen near the upper surface of the film and hence are said to be localized in the film.

4. **Radii of the mth dark rings:** $r_m = \sqrt{m\lambda R}$.

5. The radius of a dark ring is proportional to the radius of curvature of the lens by the relation, $r_m \ \alpha \ \sqrt{R}$.

6. Rings get closer as the order increases (m increases) since the diameter does not increase in the same proportion.

7. In transmitted light the ring system is exactly complementary to the reflected ring system so that the centre spot is bright.

8. Under white light we get colored fringes.

The radius of curvature of the lens (R) = $[D^2_{n+m} - D^2_n] / 4\, m\, \lambda$

Where, D_{n+m} is the diameter of the $(n+m)^{th}$ dark ring and

D_n is the diameter of the n^{th} dark ring.

PROCEDURE:

1. Level the traveling microscope with its axis vertical. Arrange the set-up as shown in Fig.1 and

focus the microscope on the air-film. Newton’s Rings will be clearly seen.

2. Adjust the glass plate G1 for maximum visibility of the point of contact of lens L with the glass plate G and hence for maximum visibility of Newton’s Rings. In this orientation, G1 is at 45 to the incident beam of light.

3. Move the microscope to the right of the central dark spot (say order ‘n’, this is because the central ring is often broad and may not necessarily will be zero order) and set it on the extreme tenth (n+10 order) distinct dark ring so that the cross-wire perpendicular to the direction of movement of the microscope passes through the dark ring and is tangential to it. Record the microscope position from the horizontal scale along with its number with dark ring around the central dark spot as the first dark ring. Move the microscope to left and record the position of the next dark ring. Repeat it till you reach to the tenth dark ring on the left. From these measurements, evaluate the diameters of different rings.

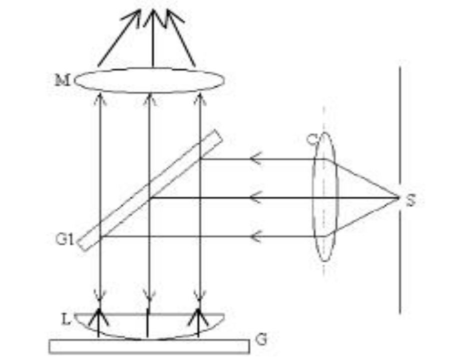
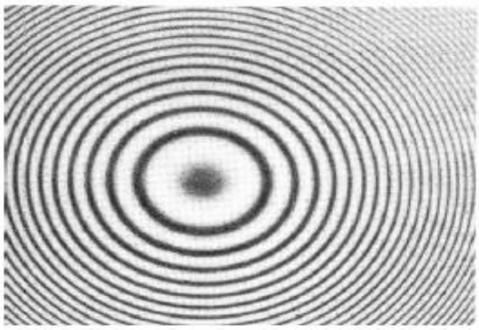


Fig. 1 Experimental set-up to observe Newton's ring



g g

OBSERVATIONS:

S. No.	No of the ring	Left end reading (a) mm	Right end reading (b) mm	Diameter $D_n = \lvert (a- b) \rvert$ mm	$(D_n)^2$ mm^2	$(D_{n+m})^2 - (D_n)^2$ mm^2
1	14					$(D_{14})^2 - (D_6)^2 =$
2	12					$(D_{12})^2 - (D_4)^2 =$
3	10					
4	8					
5	6					
6	4					

Mean value of $(D_{n+m})^2 - (D_n)^2 =$ mm^2 (for m = 8)

λ = 5893 x 10^{-7} mm

The radius of curvature of the lens (R) = $[D^2_{n+m} – D^2_n] / 4.m.\lambda =$ mm

Result: The radius of curvature of the lens (R) = cm

CONCLUSIONS:

EXPT 5

AIM: To determine the wavelength of Sodium yellow line using diffraction grating.

APPARATUS:

1. Plane transmission grating
2. A spectrometer, a spirit level, and a magnifying glass

FORMULA:

$\lambda = (d \sin \theta_m) / m$ ………………… (1)

Where λ is wavelength of light

d is grating element

m is the order of spectrum

θ_m is the angle of diffraction corresponding to m^{th} order.

THEORY:

When waves encounter obstacles or small apertures whose dimensions are comparable to their wavelength, they bend round the corners of the obstacles or apertures. Such bending of waves round obstacles is called diffraction. When light is allowed to pass through a single narrow slit, the diffraction effect is observed in the form of a pattern consisting of central bright band which may be much wider than the slit width, flanked by alternating dark bands and bright bands of decreasing intensity.

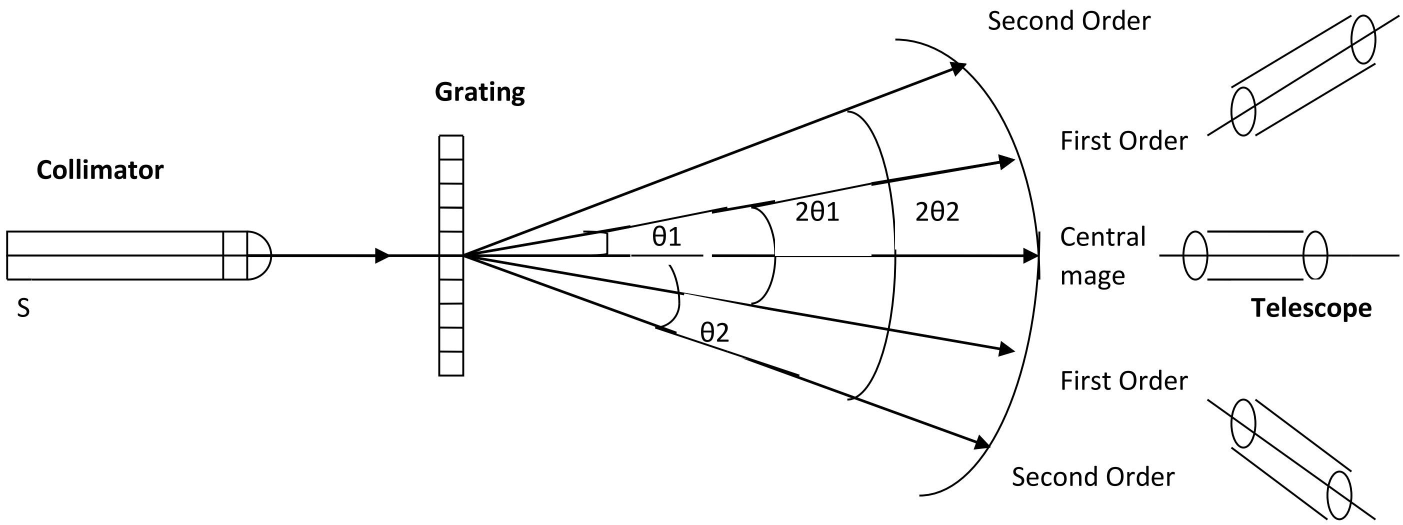
To make the diffraction pattern bright enough, light should be made to pass through several parallel slits rather than through a single slit. An arrangement, which consists of a large number of parallel and very closely spaced slits of the same width and separated by equal distance, is known as a diffraction grating.

The most important feature of a grating is its spacing "d". It is the distance from the center of the slit to the center of the adjacent slit. When light passes through a diffraction grating. The diffraction pattern consists of a series of bright narrow lines on a dark background. The angle of diffraction (θ) for which the maxima (bright lines) occurs are governed by the relation:

$$d \sin\theta = m \lambda \quad \ldots\ldots \quad (m = 0, 1, 2 \ldots)$$

Each bright line in the diffraction spectra is called a maxima and the number "m" corresponding to each maxima is called order. The brightest maxima is of the zero order (i.e, m = 0) which is seen opposite to the center of the grating. It is located at the center of the diffraction pattern. First order maxima (m = 1) are visible on both sides of it at equal distance. Still less bright second order maxima are located symmetrically about the central maxima.

DIAGRAM:



PROCEDURE:

1. Adjust the grating on the prism table with its plane normal to the axis of the collimator.
2. Adjust the telescope in line with the collimator receive the image of the slit on the crosswire.
3. Rotate the telescope slowly to the right till the image of the slit corresponding to the first order coincided with the crosswire.
4. In this position, the reading of the two windows is noted. Rotate the telescope further right to the image belonging to the second order on the crosswire.
5. Note down, the reading of the two windows in this position. Bring the telescope back in the line with the collimator to receive the image of the slit on the crosswire.
6. Now, rotate the telescope slowly to the left side of the collimator and repeat the procedure to take readings for the images of the slit corresponding to the first order and second order.
7. The difference between the reading in left side and right side for different orders gives the value of the double of the angle of diffraction for different orders.
8. Find out the value of λ using equation 1.

OBSERVATIONS:

Grating has 12,500 or 15000 lines / inch   CR=MSR+ (VSR x LC) $1^0=60'$; $0.5^0=30'$

d=2.54/12500 =________________cm   OR   d = 2.54 /15000 =________________cm

Order (m)	**Window**	**Spectrum on left side (a)**			**Spectrum on right side (b)**			**$2\theta_m = \lvert a-b \rvert$**	**θ_m in deg.**	**$\lambda = (d\sin\theta_m)/m$ in Å**
		MSR	**VSR**	**CR**	**MSR**	**VSR**	**CR**			
1	**W1**									
	W2									

RESULT: The wavelength of yellow line of sodium (λ) = ________________Å

CONCLUSIONS:

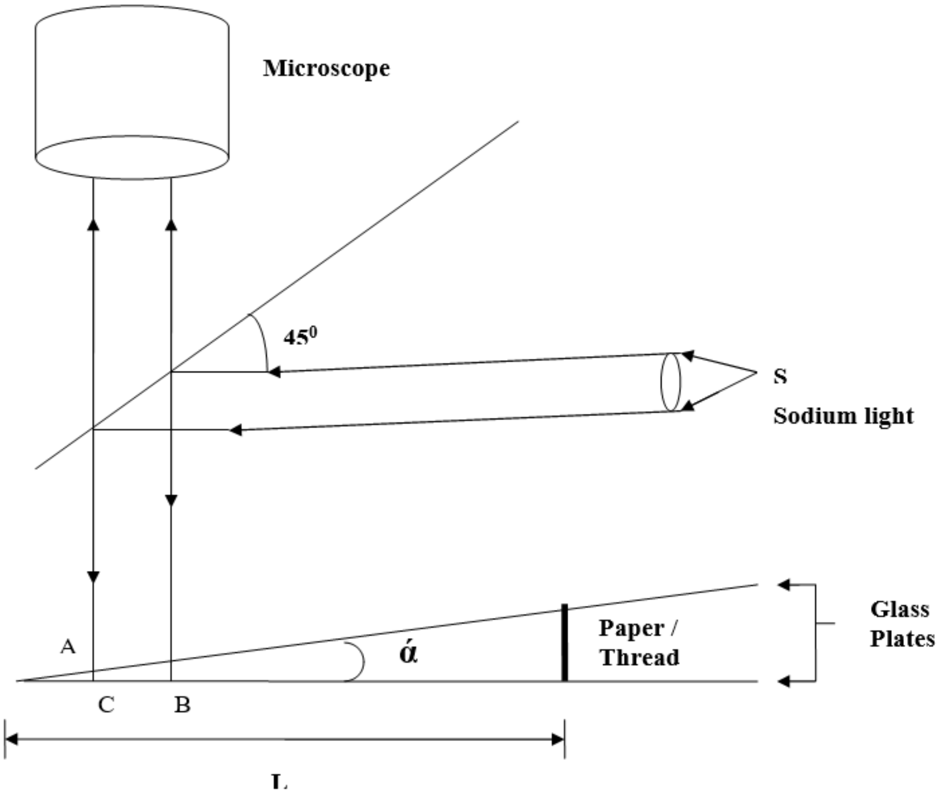
EXPT 6

AIM: To find the thickness of wire/hair using wedge shaped interference pattern

APPARATUS:

1. Monochromatic source of light (source of sodium light),
2. Microscopic slides Optically flat glass plates
3. Traveling microscope

THEORY: The fringes shown in the diagram, at A, C are caused by interference of the light beams reflected at A. C is the point at the bottom of the microscope slide immediately below A across the air film. The next fringe (at B) will be formed when the air has immersed in thickness by an amount.



Experimental arrangement for air-wedge.

Fringe pattern

PROCEDURE:

1. Arrange the apparatus shown in the figure with the specimen inserted under one end of the microscope slide on the glass plate until the parallel interference fringes, formed in the wedge shape, is visible in the microscope.
2. Find the distance to cover a given number of interference fringes.

OBSERVATION:

λ = 5893**Å** = 5893 x 10^{-7} mm

Fringe number ' n '	**Microscope reading 'mm' Y_1**	**Fringe number 'mm' 'n'**	**Microscope reading 'mm' Y_2**	**$\lvert Y_2 - Y_1 \rvert = Y$ 'mm'**
0		16		
4		20		
8		24		
12		28		
			Y_M =	

CALCULATIONS:

$$X = \frac{Y_M}{16}$$

The thickness of Specimen (t) is given by

$$t = \frac{\lambda L}{2X}$$

Where L = Distance of object from edge to the wedge = ____________________ mm

RESULT:

The thickness of the specimen 't' is = ______________ mm

CONCLUSIONS:

____

____

____

____

____

EXPT 7

AIM: To find out the beam divergence and spot size of the given laser beam.

APPARATUS:

1. Optics bench
2. Measurement unit
3. Laser light source
4. Photo detector
5. Two fixed stands
6. One sliding stand
7. Convex lens
8. Lens holder

FORMULA:

$\lambda = (d \sin \theta_m) / m$ ………………… (1)

Where λ is wavelength of light

d is grating element

m is the order of spectrum

θ_m is the angle of diffraction corresponding to m^{th} order.

THEORY:

The laser (light amplification by stimulated emission of radiation) is a device that produces a strong beam of coherent photons by stimulated emission. A laser beam is coherent, very narrow and intense. The directionality of the LASER beam is expressed in term of the full angle beam divergence, which is twice the angle that the outer edge of the beam makes with the center of the beam. The divergence tells us how rapidly the beam separates when it is emitted from the laser. According to the laser physics and technology, beam divergence of a laser beam is a measure for how fast the beam expands far from the beam waist. A laser beam with a narrow beam divergence is greatly used to make laser pointer devices. Generally, the beam divergence of laser beam is measured using beam profiler. The light emitted by a laser is confined to a rather narrow cone. But, when the beam propagates outward, it slowly diverges or fans out. For an electromagnetic beam, beam divergence is the angular measure of the increase in the radius or diameter with distance from the optical aperture as the beam emerges. Below in the fig.1 the divergence of laser beam is shown. Depending on the type of laser and diameter of beam waist, the angle of divergence of beam may differ.

Fig.1 The divergence of laser beam for two different lasers

DIAGRAM:

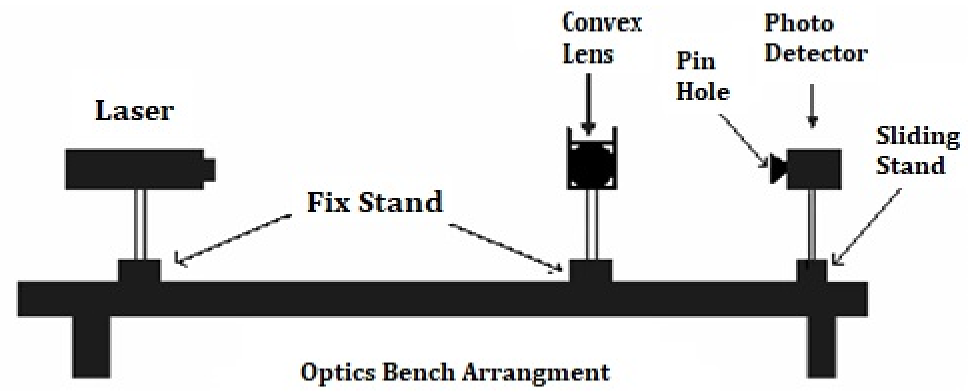


Fig.2a Experimental set up for laser beam divergence.

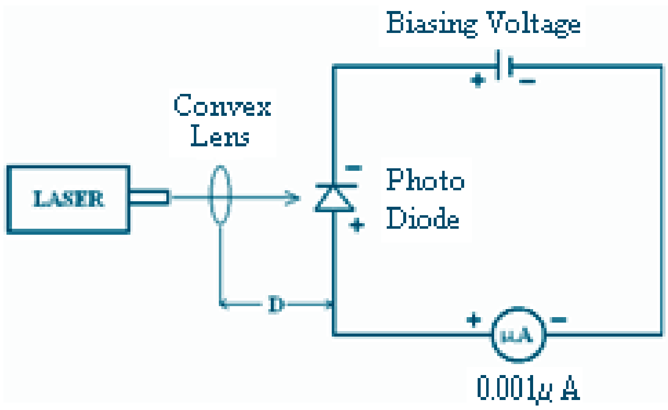


Fig.2b Schematic diagram of laser beam divergence experiment.

PROCEDURE:

1. Arrange the optical bench setup as shown in Figure 2 a.
2. Take measurement unit and patch cords and make circuit shown in Figure 2 b.
3. Connect mains cord and switch on the measurement unit.
4. Read diode current (I) in LCD, if display shows any current set the voltage variable knob at some biasing voltage such that the current becomes zero.
5. Turn on the Laser and focus it on the center of the diverging lens.
6. Now adjust the photo detector, laser and lens, so that the spot of Laser should be on the detector pinhole surface.

   For e.g. If lens is of 10cm focal length, then position of Laser and photodetector should be near about 10cm from lens.
7. Now adjust the position of laser and detector so the laser spot focus on the Photo diode inside the detector through pinhole
8. Adjust the position of lens (by moving it on the optics bench towards laser or photo detector) so that maximum light falls on the detector.
9. Read the diode current (I) on the LCD of the measurement unit.

   Note: For observing value of current on LCD wait for some time to set the reading.
10. Set it for maximum value of current by adjusting (sliding) photo detector.
11. Note the reading of Spherometer fitted on sliding stand with the help of Main scale and circular scale in below observation table.
12. Now move the Spherometer perpendicular to laser beam in left side till the diode current (I) on the display show minimum reading.

13. Now move Spherometer in opposite direction (current will become maximum then start to minimize) till diode current (I) becomes minimum again.
14. The distance between positions of minimum current will give the diameter (d) of the laser spot, which is calculated using the formula given in observation table.
15. Note the distance between lens and detector, it will give the value of 'D'.
16. Repeat same procedure for other lenses with different focal length.
17. After calculating angular divergence of Laser for lenses take mean of it.

OBSERVATIONS:

For focal length *f* = 10 cm = 100 mm

Least count of Spherometer = pitch / number of divisions on the circular scale head …………….mm

Obs. No.	**D (mm)**	**Maximum Current 'x' (mm)**			**Minimum current left side 'a' (mm)**			**Minimum current right side 'b' (mm)**		
		MS	**CS**	**MS+(CSxLC)**	**MS**	**CS**	**MS+(CSxLC)**	**MS**	**CS**	**MS+(CSxLC)**
1										

Distance between lens and detector (D) = 10 cm = 100 mm

Reading of Spherometer when diode current is maximum (x) = ___________ mm

Reading of Spherometer when diode current is minimum on left side (a) = ___________ mm

Reading of Spherometer when diode current is minimum on right side (b) = ___________ mm

Diameter of the spot at photodiode, d = (b) – (a)

= _________ mm

Divergence of laser $\theta = \tan^{-1}\left(\frac{d/2}{D}\right)$

= ________ Degree

For focal length f = 15 cm = 150 mm

Obs. No.	D (mm)	Maximum Current 'x' (mm)			Minimum current left side 'a' (mm)			Minimum current right side 'b' (mm)		
		MS	CS	MS+(CSxLC)	MS	CS	MS+(CSxLC)	MS	CS	MS+(CSxLC)
1										

Distance between lens and detector (D) = 15 cm = 150 mm

Reading of Spherometer when diode current is maximum (x) = ___________ mm

Reading of Spherometer when diode current is minimum on left side (a) = ____________ mm

Reading of Spherometer when diode current is minimum on right side (b) = ____________ mm

Diameter of the spot at photodiode, d = (b) – (a)
= ________mm

Divergence of laser θ $= \tan^{-1}\left(\frac{d/2}{D}\right)$
= __________ Degree

RESULT:

1. The angular divergence of laser beam obtained from convex lens of focal length 10 cm = ______
2. The angular divergence of laser beam obtained from convex lens of focal length 15 cm =______

CONCLUSIONS:

____

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____

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EXPT 8

AIM: To determine the numerical aperture of a given optical fiber and hence to find its acceptance angle.

APPARATUS:

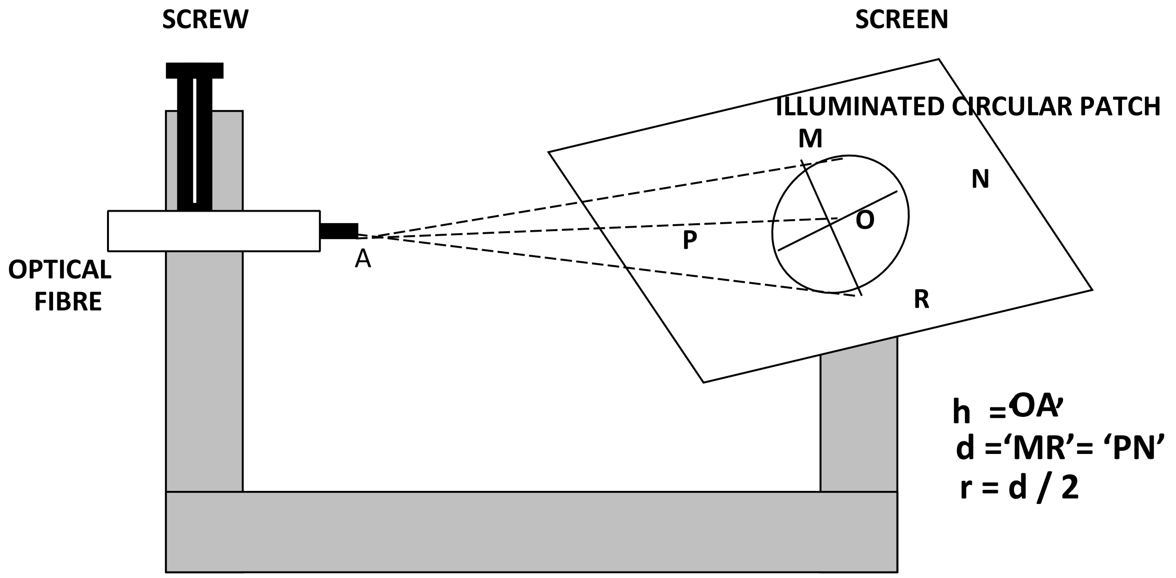
1. The fibre optics transmitter kit
2. Numerical aperture jig
3. One side open half meter optical fibre cable
4. Scale

THEORY:

Numerical aperture refers to the sine of maximum angle at which the light incident on the optical fibre end is totally internally reflected and is transmitted properly along the fibre. The cone formed by the rotation of this angle along the axis of the fibre is the cone of acceptance of the fibre. The numerical aperture of a fibre is simply equal to $(n_1^2 - n_2^2)^{1/2}$ where n_1 and n_2 are the refractive indices of core and cladding respectively.

Though the numerical aperture is a parameter associated with light entering an optical fibre, however to measure numerical aperture it is easier to investigate the characteristics of the light, leaving the fibre, which will provide a reasonable approximation of the numerical aperture.

DIAGRAM:



PROCEDURE:

1. Connect the power cord of transmitter kit to mains supply and switch it ON.
2. Select the Digital /Analog switch for Digital transmission. Keep Low – Hi switch in high position.
3. With the help of jumpers connect the Digital data generator to LED driver, and LED driver to LED (660nm).
4. Connect the optical fibre to LED. Insert the other end of the optical fibre into the numerical aperture measurement jig.
5. The inserted portion of the optical fibre should be perfectly straight. Adjust the fibre in such a way that its tip is approximately 5 mm above from the screen.
6. Now observe the illuminated circular patch in two mutually perpendicular directions. The radius of the circular patch is given by r = d / 2.
7. Measure the distance d between the tip of the fibre and the screen carefully.

8. The numerical aperture (N.A) is equal to $r/(r^2 + h^2)^{1/2}$. Calculate it.
9. Repeat the above procedure for different values d. Calculate the average value of numerical aperture.

OBSERVATIONS:

Refractive index of core (n_1) = 1.49

Refractive index of cladding (n_2) = 1.41

Numerical aperture (N. A) = $\sqrt{(n_1^2 - n_2^2)}$ =

Table 1: Measurement of numerical aperture

Obs. No.	'h' in mm	Diameter	r = d/2 in mm	$(r^2 + h^2)^{1/2}$ In mm	N.A.= $r / (r^2 + h^2)^{1/2}$	Mean N.A.

RESULT:

The numerical aperture of optical fibre is = ____________________

CONCLUSIONS:

____

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EXPT 9

AIM: To find out the magnetic field along the axis of a circular coil carrying current.

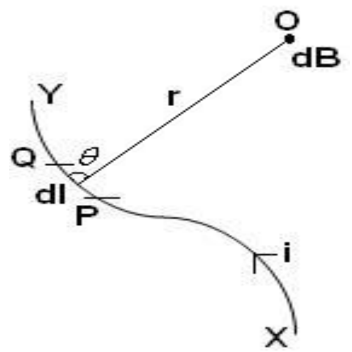
APPARATUS:

1. Tangent Galvanometer
2. Current carrying coil measurement unit
3. Magnetometer
4. Patch cords
5. Mains cord

THEORY:

A current carrying wire generates a magnetic field. According to Biot-Savart's law, the magnetic field at a point due to an element of a conductor carrying current is,

1. Directly proportional to the strength of the current, *i*
2. Directly proportional to the length of the element, *dl*
3.Directly proportional to the Sine of the angle θ between the element and the line joining the element to the point
4.Inversely proportional to the square of the distance *r* between the element and the point.



Thus, the magnetic field at O is dB, such that,

$$dB \propto \frac{i\,dl\,Sin\,\theta}{r^2}$$

Then,

$$dB = k\frac{i\,dl\,Sin\,\theta}{r^2}$$

where,

$$k = \frac{\mu_0}{4\pi}$$

is the proportionality constant and?

$$\mu_0 = 4\pi\times10^{-7}\,NA^{-2}$$

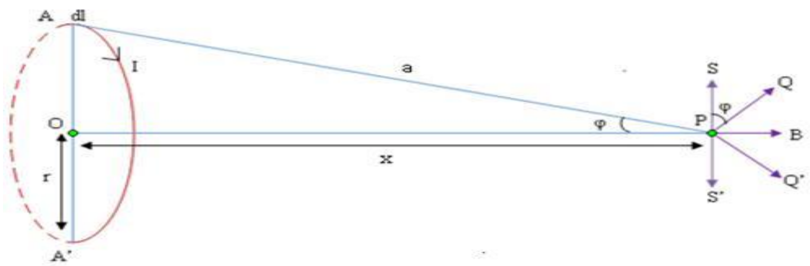
is called the permeability of free space. Then,

$$dB = \frac{\mu_0}{4\pi}\frac{i\,dl\,Sin\,\theta}{r^2}$$

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{i\;d\vec{l}\times\vec{r}}{r^3}$$

In vector form,

Consider a circular coil of radius r, carrying a current I. Consider a point P, which is at a distance x from the centre of the coil. We can consider that the loop is made up of a large number of short elements, generating small magnetic fields. So the total field at P will be the sum of the contributions from all these elements. At the centre of the coil, the field will be uniform. As the location of the point increases from the centre of the coil, the field decreases.



By Biot- Savart's law, the field dB due to a small element dl of the circle, centered at A is given by,

$$dB = \frac{\mu_0}{4\pi} I \frac{dl}{(x^2 + r^2)} \qquad (1)$$

This can be resolved into two components, one along the axis OP, and other PS, which is perpendicular to OP. PS is exactly cancelled by the perpendicular component PS' of the field due to a current and centered at A'. So, the total magnetic field at a point which is at a distance x away from the axis of a circular coil of radius r is given by,

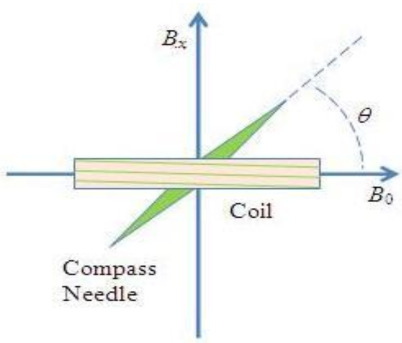
$$B_x = \frac{\mu_0 I}{2} \frac{r^2}{(x^2 + r^2)^{3/2}}$$

If there are *n* turns in the coil, then

$$B_x = \frac{\mu_0 n I}{2} \frac{r^2}{(x^2 + r^2)^{3/2}} \quad \text{......................... (2)}$$

where μ_0 is the absolute permeability of free space.

Since this field B_x from the coil is acting perpendicular to the horizontal intensity of earth's magnetic field, B_0, and the compass needle align at an angle θ with the vector sum of these two fields, we have from the figure



$$B_x = B_0 \tan\theta \qquad (3)$$

The horizontal component of the earth's magnetic field varies greatly over the surface of the earth. For the purpose of this simulation, we will assume its magnitude to be $B_0 = 3.5\text{x}10^{-5}$ T. The variation of magnetic field along the axis of a circular coil is shown here.

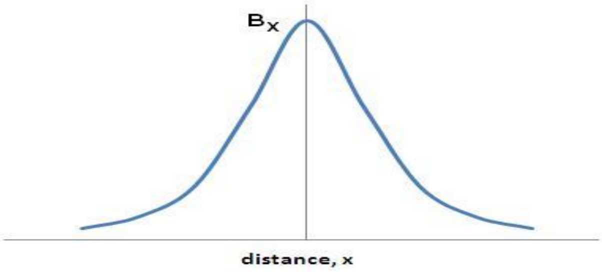
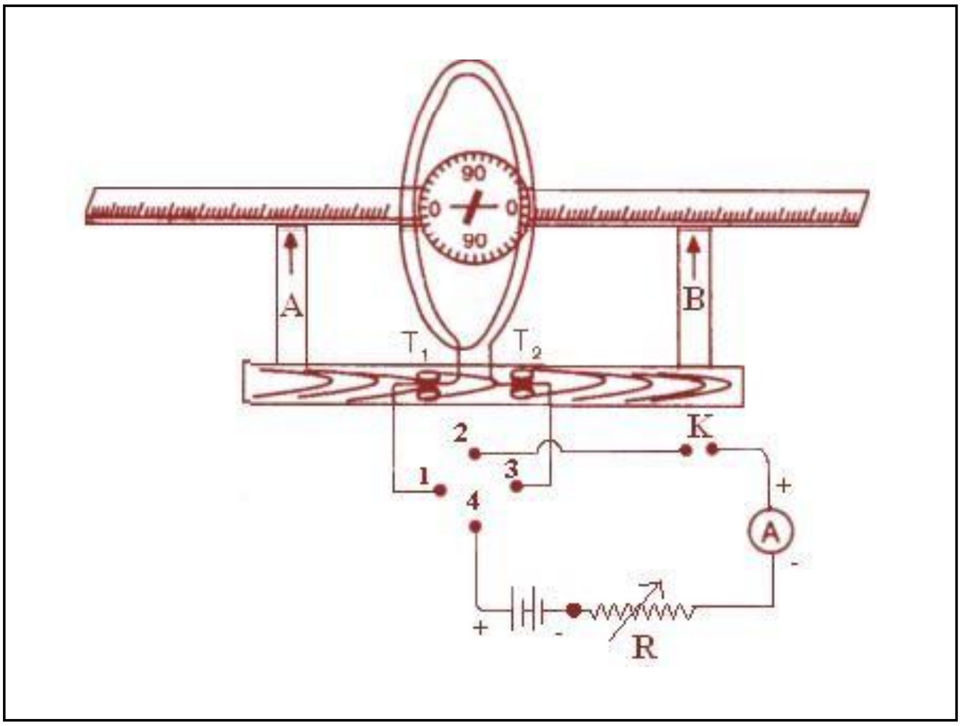


DIAGRAM:

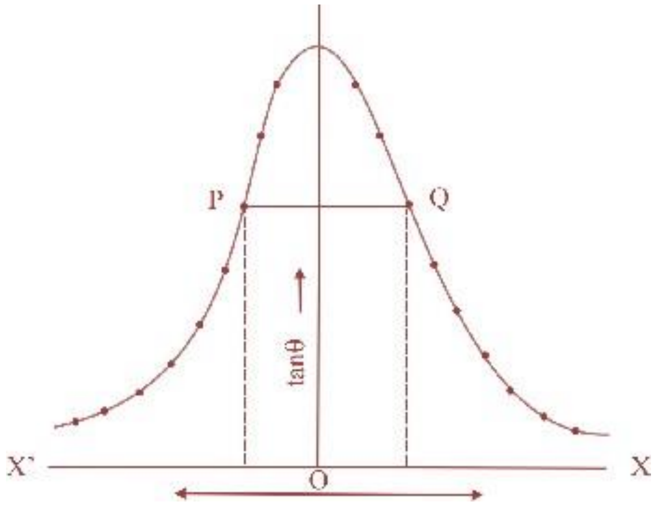


Circular Coil Apparatus

PROCEDURE:

1. Place the Tangent Galvanometer on the table such that the arms of magnetometer lie roughly in east and west direction.
2. Place the magnetometer at the centre of the coil in such a manner that magnetic needle lies at the center of the vertical coil in same direction.
3. Place the eye a little above the coil and rotate the Tangent Galvanometer in the horizontal plane till the coil, the needle and its image in the mirror of magnetometer, all lie in the same vertical plane.
4. In this manner the coil will be set roughly in the magnetic meridian.
5. Now rotate the Magnetometer so that the pointer read the position of 0-0.
6. Now take the current carrying coil measurement unit and place it nearthe instrument.
7. Connect C and 5 terminals of coil to the 6 and 7 terminal of reversingkey.
8. Connect DC power supply between the points 2 and 3 with samepolarity.
9. Connect DC Ammeter between the points 10 and 11 with same polarity.
10. Now short the terminals 4 and 5, 8 and 9, 12 and 13, 1 and 14 respectively.

11. Connect the mains cord and switch on the power supply.
12. Select reversing key in one direction and switch on the DC power supply.
13. Observe the deflection of the needle of magnetometer.
14. Now slide the magnetometer along the axis of the coil and find the position where the maximum deflection is obtained. In this position the center of the needle co-insides the center of the vertical coil.
15. Now change the direction of current by reversing key and note down the deflection again. If the both deflections are nearly equal that means the coil is in magnetic meridian.
16. If the mean deflection of both cases is not nearly equal, then slightly turns tangent galvanometer till the deflection for the direct and reverse current become nearly equal.
17. Note the position of the deflection $\theta1$ and $\theta2$ in observation table by both ends of pointer keeping the current constant. Now reverse the current and again note the deflection of pointer for both ends and sayit $\theta3$ and $\theta4$.
18. Above readings are for origin (0-0) position.
19. Now note the value of the current shown by ammeter.
20. Shift the magnetometer by 1 cm in Left hand side of the coil and note down the deflection $\theta1$ and $\theta2$ in observation table by both ends of pointer keeping the current constant.
21. Now reverse the current and again note the deflection of pointer for
    i. both ends and say it $\theta3$ and $\theta4$.
22. Take the number of observations by shifting the magnetometer by 1 cm at a time for both forward and reverse current.
23. Similarly repeat the steps 20, 21 and 22 by shifting the magnetometer in the Right hand side of the coil keeping the constant current.
24. Now plot a graph taking positing (x) along the X- axis and tan θalong the Y- axis, it will be similar to graph shown in figure, below



    i. **Note:** For plotting the graph take left hand side reading as "-ve" and right handside reading as "+ve".
25. Find out the two inflexion point on the curve, the distance betweenthese two point will be the radius of the coil.
    1. i.e. a = PQ
26. Similarly perform all the steps for another no. of turns of coil

OBSERVATIONS:

No. of turns (n) = ... **Current I = ... A**

S. No	Distance	Left Side				Mean θ	Tan θ	Right Side				Mean θ	Tan θ
		Direct Current		Reversed Current				Direct Current		Reversed Current			
		θ1	θ2	θ3	θ4			θ1	θ2	θ3	θ4		
1													
2													
3													
4													
5													
6													
7													
8													

No. of turns (n) = ...,Current I = A, Radius (a) = m

Sr. No.	Distance x	Magnetic Field $\frac{\mu_0}{4\pi} \times \frac{2\pi n I a^2}{(a^2 + x^2)^{3/2}}$
1		
2		
3		
4		
5		
6		
7		
8		
9		

CONCLUSIONS:

EXPT 10

AIM: To study the magnetic field along the axis of Helmholtz coil.

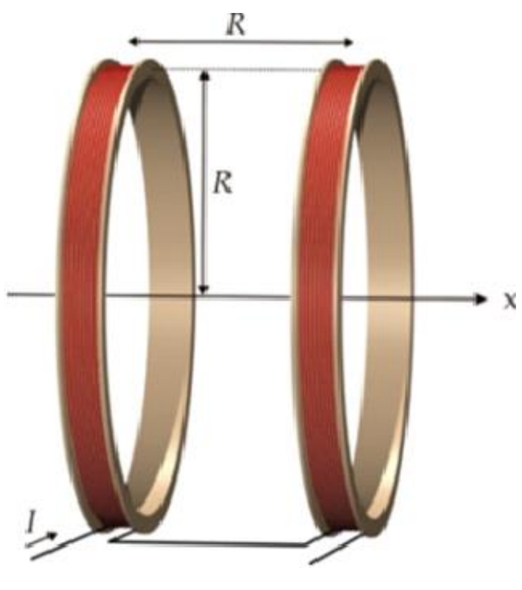
APPARATUS:

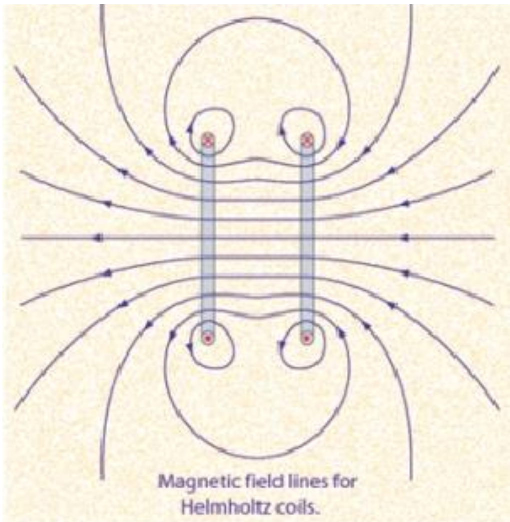
1. Power Supply DC 0-20V, 5 Amp
2. Digital Gauss Meter with Axial Probe
3. Coil N=390, Dia=140mm
4. Support Base
5. Support Rod
6. U Channel Big
7. U Channel Small
8. Deflection Compass with Base
9. Axial probe holder
10. Multimeter
11. Connecting Leads

THEORY:

A useful experiment for getting a fairly uniform magnetic field is to use a pair of circular coils on a common axis with equal currents flowing in the same logic. For a given coil radius, you can calculate the separation needed to give the most uniform central field. This separation is equal to the radius of the coils. The magnetic field lines for this geometry are illustrated in figure at right side.

The spatial distribution of the field strength between a pair of coils in the Helmholtz arrangement is measured. The spacing at which a uniform magnetic field is produced is investigated and the superposition of the two individual fields to form the combined field of the pair of coils is demonstrated.



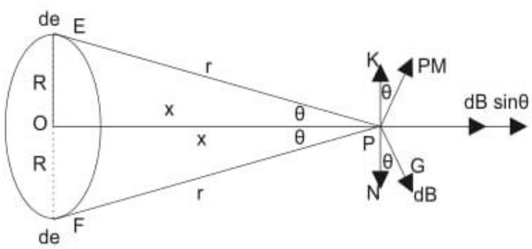


Magnetic field lines for Helmholtz coils.

Field at any point on the axis of current carrying coil.

Let E and F are two diametrically opposite element of coil through which current i is flowing. Field at P at distance x (=op) from the centre and at distance r from the element E is

$$dB = \frac{\mu 0}{4\pi} \frac{I(\vec{de} \times \vec{r})}{r^3} \quad \text{----------(1)}$$



or $$dB = \frac{\mu 0}{4\pi} \frac{I\, dl \sin 90 r}{r^3}$$ (angle between dl and r is 90°)

$$dB = \frac{\mu 0}{4\pi} \frac{I\, dl}{r^2} \quad \text{----------(2)}$$ along PM perpendicular to EP

The same field due to element F diametrically opposite to E acting along PG ⊥ to FP. The components dB cosθ get cancelled of all diametrically opposite elements.
The elements dB sinθ get added for all elements.
So field due to whole coil.

$$B = \int_0^{2\pi R} dB \sin\theta$$

$$= \frac{\mu_0}{4\pi} \int_0^{2\pi r} \frac{I\, dl}{r^3} \sin\theta$$

$$= \frac{\mu_0}{4\pi} \frac{I}{r^2} \times \frac{R}{r} \int_0^{2\pi R} dl$$

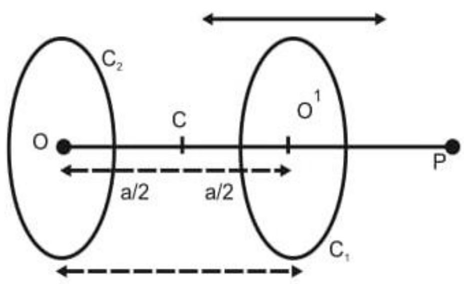
$$= \frac{\mu_0}{4\pi} \frac{IR}{r^3} (dl)_0^{2\pi R} = \frac{\mu_0}{4\pi} \frac{IR \times 2\pi R}{r^3}$$

$$= \frac{\mu_0 I}{2} \frac{R^2}{(R^2+X^2)^{3/2}} = \frac{\mu_0 I\, R^2}{2R^3 \{1+\frac{x^2}{R^2}\}^{3/2}}$$

$$B = \frac{\mu I}{2R \{1+\frac{x^2}{R^2}\}^{3/2}}$$

For N turns coil

$$B = \frac{\mu_0 NI}{2R \{1+\frac{x^2}{R^2}\}^{3/2}}$$



For two coils separated by distance 'a' then

$$O.P = X_1 = (X_0 - a/2) \quad \text{for coil - c}$$

and OP = x_2 =(X0+a/2) for coil c2

x_0 = distance of point P from the centre point C of two

when CP = X_0 then, $O^1P = x_0 - a/2$, and op = $x_0 + a/2 = x2$

$$\text{At } (x, r=o) = \frac{\mu_0 NI}{2R} \left(\frac{1}{(l+A_1^2)^{3/2}} + \frac{1}{(l+A_2^2)^{3/2}} \right)$$

$$A_1 = \frac{x_2}{R} = \frac{(x_0 + a/2)}{R}$$

$$A_2 = \frac{x_1}{R} = \frac{(x_0 - a/2)}{R}$$

When $x_0 = 0$, flux density has a maximum value when a<R and a minimum value when a>R. The curve plotted for these are as shown.

When

a = R the field is

Virtually same when

$$\frac{-R}{2} \quad <X> \quad \frac{R}{2}$$

when a=R ($x_0 = 0$)

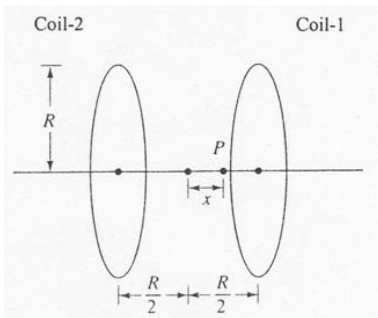
$$B = 0.716\ \mu_0 N \ \frac{I}{R}$$

When N = 390 I_0 =0.5A R = 0.070^m

$$B = \frac{0.716 \times 4\pi \times 10^{-7} \times 390 \times 0.5}{0.070}$$

$$= 2.51 \text{ MT}$$

HELMHOLTZ COILS



Helmholtz coils are constructed from two circular coils of wire, each perpendicular to the same axis, and each carrying the same current in the same direction. As shown in Figure right, the coils are separated by a distance R which is also the radius of each coil

We can use Equation 4 to find an expression for the B field at any point P on the axis of the coils. If the magnetic field strength due to coil 1 is B1 and that due to coil 2 is B2, then by superposition

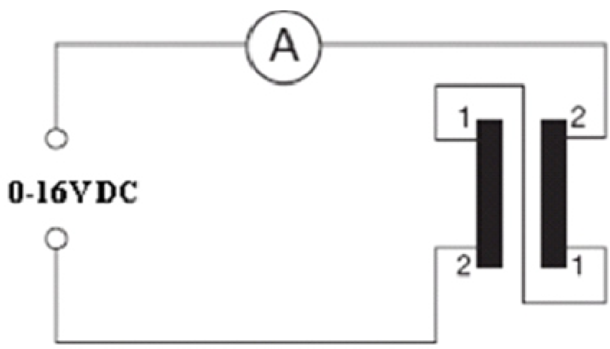
B = B1 + B2… .... (5)

In this configuration, it is convenient to specify xo not at the center of a single coil, but rather at the midpoint between the two coils. Therefore, in the equation for B1, xo must be replaced by xo – R/2, and for B2, xo must be replaced by xo + R/2. Also note that Bo as defined above does not correspond to the field at this new position xo

DIAGRAM:

PROCEDURE:

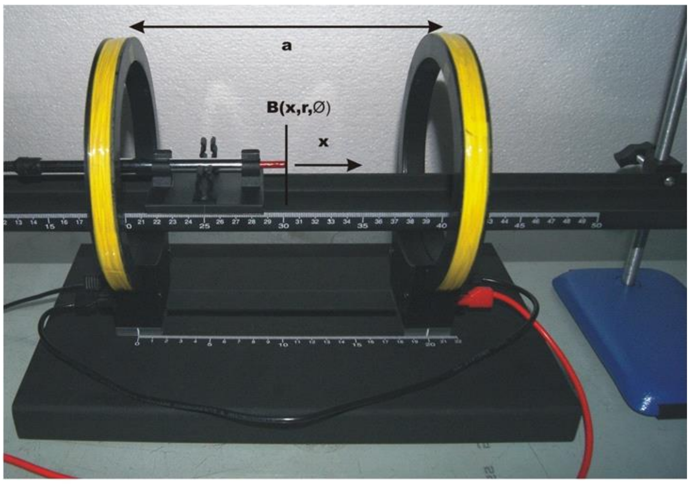
1. Connect the coils in series and in the same direction, see Fig. below the current 0.5 A (operate the power supply as a constant current source). Measure the Magnetic field with the axial Hall probe.



Wiring Diagram for Helmholtz Coil

2. The magnetic field of the coil arrangement is rotationally symmetrical about the axis of the coils, which is chosen as the x-axis of a system of cylindrical coordinates (x, r, Φ).
3. The origin is at the centre of the system. The magnetic field does not depend on the angle Φ, so only the components Bx(x, r) and Br (x, r) are measured.
4. Clamp the axial probe on to a support base, level with the axis of the coils.

HELMHOLTZ COILS ARRANGEMENT-I



Magnetic Field B along x-axis & Center x=0

1. Along the x-axis, for reasons of symmetry, the magnetic flux density has only the axial component Bx. Figure right shows how to set up the coils, probe and rules. Measure the relationship B (x, r = 0) when the distance between the coils $a = R$ and, for example, for $a = R/2$ and $a = 2R$

OBSERVATION:

Distance	x (Cm)	B at a=R/2 (Gauss)	B at a=R (Gauss)	B at a=2R (Gauss)
0	-20			
2	-18			
4	-16			
6	-14			
8	-12			
10	-10			
12	-8			
14	-6			
16	-4			
18	-2			
20	0			
22	2			
24	4			
26	6			
28	8			
30	10			
32	12			
34	14			
36	16			
38	18			
40	20			

The magnetic field along the axis of two identical coils at a distance 'a' apart is explained as

$$B(x, r=0) = \left(\frac{\mu_0 N I}{2R}\right)\left(\frac{1}{(1+Z_1^2)^{3/2}} + \frac{1}{(1+Z_2^2)^{3/2}}\right)$$

Where, $Z_1 = \frac{x+a/2}{R}$, $Z_2 = \frac{x+a/2}{R}$

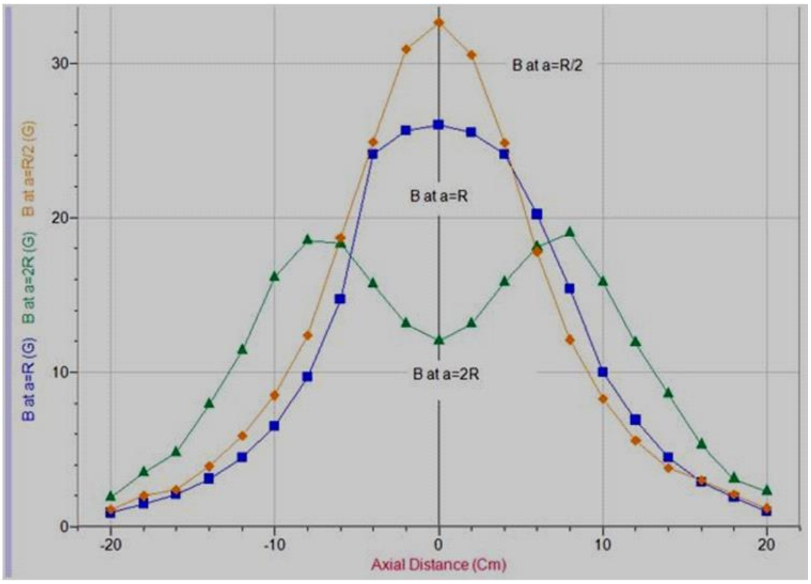
When x = 0, Magnetic flux density has a maximum value when a < R and a minimum value when a > R. The curves plotted from our measurements also shown as below in figure; when a = R, the field is virtually uniform in the range –R/2<x<+R/2

Magnetic flux density at the mid-point when a = R is defined as where $\mu = 4\pi \times 10^{-7}$ web amp^{-1} m^{-1}

$$\mathbf{B} = \frac{0.716 \times 4 \times 3.14 \times 10^{-7} \times 390 \times 0.5}{0.070}$$

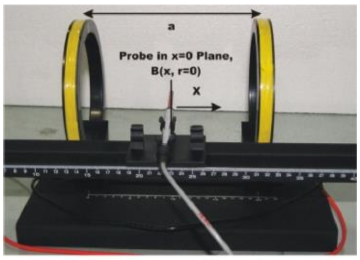
= 2.51x10^-3T=2.51mT

=25.1Gauss



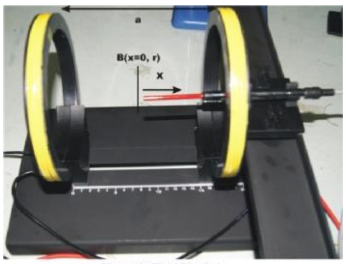
1. When distance a = R the coils can be joined together with the spacers.

   a. Measure Bx (x, r) as shown in Figure above. Set the r-coordinate by moving the probe and the x-coordinate by moving the coils. Observed the magnetic flux density must have its maximum value at point (x = 0, r = 0).



Magnetic Field B in Plane x=0

   b. Turn the pair of coils through 90° (Figure below). Check the probe: in the plane x = 0, Bx must = 0.



Magnetic Field B(x=0,r)

CONCLUSIONS:
