Elements of Modern Physics Lab

(B.Sc. IV Sem.)

Physics / Electronics

Department of Pure & Applied Physics

Guru Ghasidas Vishwavidyalaya

(A Central University)

B. Sc. IV Semester

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Experiment list

1. Measurement of Planck's constant using black body radiation and photo-detector
2. To determine (1) wavelength and (2) angular spread of He-Ne laser using plane diffraction grating
3. To show the tunneling effect in tunnel diode using I-V characteristics.
4. To determine the slit width of single slit by using semiconductor laser.
5. To determine the slit width of double slit by using semiconductor laser.
6. To determine the diameter of circular aperture using laser diode source
7. To determine work function of material of filament of directly heated vacuum diode/frank hertz exp.

EXPERIMENT- 1

AIM-

To study the Photoelectric effect and determine the value of Planck's constant 'h'.

APPARATUS-

D.C. Power supply, Nanometer, Photocell with housing and mount, Optical bench, Mercury vapor lamp fitted in wooden box, Choke of mercury lamp, A set of optical filters (4900Å, 5400Å, 5800Å)

THEORY-

Light striking a metal surface stimulates electrons causing them to be emitted from the surface. We know that the energy from the light is $h\upsilon$. This energy, when absorbed by an electron will cause the electron to move from metal surface, will free the electron from metal's electrostatic pull (the work function ϕ) and imparts kinetic energy to the electron.

Thus, Maximum Kinetic energy = $h\upsilon - \phi$

Or $$h\upsilon = \phi + \frac{1}{2}mv^2 \qquad (1)$$

Where h is Planck's constant, υ is frequency of incident radiation, ϕ is work function and is constant for a material, m is mass of electron and v is velocity of electron.

Above equation (1) is known as Einstein Photo-Electric equation. It gives us the following information:

1. There should be a minimum frequency υ_0 called the threshold frequency at which photo energy becomes equal to work function and the photo electric effect ceases below this frequency.
2. The number of electron emitted by the photo metal is directly proportional to the received intensity.
3. Kinetic energy of the Photoelectrons is directly proportional to the frequency of incident radiation.

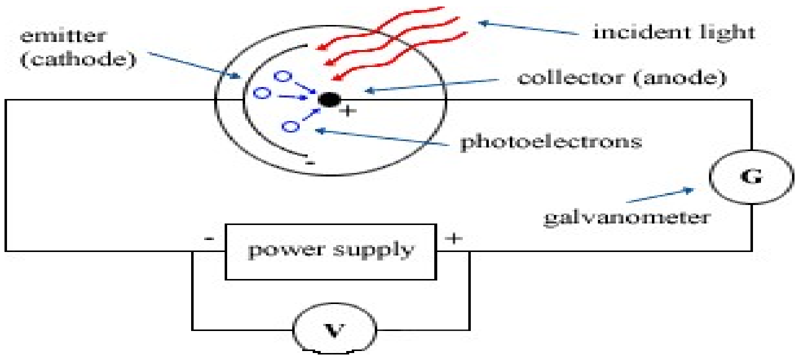


Figure: Circuit shows Photoelectric effect.

In the experiment, Light strikes an electron emitter (cathode) in the tube and the emitting electrons move to anode creating a current. Filters are placed in front of photoelectric tube which will allow a particular frequency of light to reach the emitter. A negative voltage is applied to anode creating a repulsive force against the incoming electrons (Anode is normally at a higher potential than the cathode, attracting the electrons. By making Anode more negative, the electrons begin to be repelled.)When the repulsive force is strong enough to block the electrons then the current will stop. This potential is known as the stopping potential (eV).

Thus equation (1) becomes $h\upsilon = \phi + eV$

If $\lambda_1 and \lambda_2$ be the wavelengths of light used to illuminate the cathode and $V_1 \& V_2$ be their respective stopping potentials then,

$$h\upsilon_1 = \phi + eV_1$$
$$h\upsilon_2 = \phi + eV_2$$
$$h(\upsilon_2 - \upsilon_1) = e(V_2 - V_1) \qquad (2)$$

We know that $\upsilon = \frac{c}{\lambda}$

Therefore above equation (2) becomes,

$$hc\frac{(\lambda_1 - \lambda_2)}{\lambda_1 \lambda_2} = e(V_2 - V_1)$$
$$\Rightarrow h = \frac{e(V_2 - V_1)\lambda_1\lambda_2}{c(\lambda_1 - \lambda_2)}$$

Therefore, for any two wavelengths (i.e. for a pair of filter) λ_i and λ_j we can write:

$$\therefore h_{ij} = \frac{e(V_j - V_i)(\lambda_i \lambda_j)}{c(\lambda_i - \lambda_j)} \text{ Joule sec} \qquad (3)$$

We shall use this formula to find value of Planck's constant.

Mercury vapor lamp –It is a gaseous lamp that consists of two bulbs, one within the other. The inner bulb is called the arc tube, which is made of quartz and the outer bulb serves to protect the arc tube. The arc tube contains argon gas and a small amount of pure mercury. Mercury lamps need a certain voltage to start up the arcs, which have an electrode on each end. Once there is a full voltage running from the starting electrode to the main electrode, the argon gas begins to become ionized by the electrons and an arc is formed between two electrodes, like a bridge. The heat produced from the arc vaporizes the mercury droplets, which become ionized as well. The mercury vapor now carries current within the arc. The current continues to increase to its full potential, which can be found in a mercury vapor lamp and hence serves as a resistor. So as the current is increasing, the ballast reduces the supply voltage simultaneously to keep the mercury-vapor lamp running under stable operation. As a result of the decreased voltage, a glow between the two electrodes is emitted within the arc tube. A mercury vapor lamp lasts longer than electric lights of similar wattages. But, mercury vapor lamps require five to seven minutes for it to reach its full brightness.

Photo-Electric effect- If light is incident on certain metals, the electrons are emitted. These electrons are known as photo-electrons and the metal is known as photo-metal. The emission of electrons by the action of light (Photo) is called photo-electric effect.

[It was found that negative particles were emitted by illuminated metallic surfaces. After Anton von Lenard measured the particles to have same charge to mass ratio as electrons then the term photo electron was coined.]

Photocell- The photo-metal as cathode and another electrode as anode enclosed in a glass bulb is known as a photocell. The experimental electrons are emitted by the Photo-metal by the action of light and attract by the anode and thus a photo current flows in the circuit.

Stopping Potential- A minimum negative anode potential at a particular frequency to stop the faster emitted electrons is known as Stopping Potential. Thus stopping potential is directly proportional to the frequency of incident radiation.

PROCEDURE-

1. Put the Photo cell and source of light on the optical bench and align them.
2. Make proper connections of Planck's constant set up with the Photo-cell through the cable provided with the set up.
3. Switch 'ON' the Planck's constant set up and adjust the zero in the nanometer (Photo current meter) keeping the anode potential zero. Put a filter between the Photo cell and source of light.
4. Switch "ON" the Mercury bulb and adjust the slit to get some deflection in the photocurrent meter at zero anode potential.
5. Note this Photo current for zero anode potential and make table as shown below.

6. Apply a small negative potential on the anode say 50 mV with the help of knob, provided in the supply and measure the corresponding Photo current. Note this Photo current in the observation table.
7. Increase the negative anode potential (may be in step of 50 mV) and note the corresponding Photo current for same filter till it becomes zero.
8. Repeat the experiment for different light filters.
9. Plot a graph between negative anode potential on x axis and the corresponding Photo current on y-axis for different filters of wavelength of light.
10. Find the stopping potential for each wavelength from the graph.
11. Calculate the value of Planck's constant for each wavelength and find its mean.

OBSERVATION-

S.No.	Negative Anode Potential (Volt.)	Corresponding Photo-current (nA)		
		Blue Filter 4900 Å	Green filter 5400 Å	Red filter 5800Å
1	0.0			
2	0.050			
3	0.100			
4	0.150			
5	0.200			
6	0.250			
7	0.300			
8	0.350			
9	0.400			
10				

Graph:

Plot a graph between Negative Anode Potential (on X-axis) and the corresponding Photocurrent (on Y-axis) for different wavelengths of light and obtain the values of stopping potential for each wavelength

Stopping potential for red filter V_1 = ...V.

Stopping potential for green filter V_2 = ...V.

Stopping potential for blue filter V_3 = ...V.

Calculations:

Electronic charge $=1.6x10^{-19}$ Coulomb

Velocity of light(c) = $3x10^{8}$ m/sec

Using equation (3) we can find different values of Planck's constant

$$h_{12} = \frac{e(V_2 - V_1)(\lambda_1\lambda_2)}{c(\lambda_1 - \lambda_2)} J\sec = ... J\sec$$

$$h_{23} = \frac{e(V_3 - V_2)(\lambda_1\lambda_3)}{c(\lambda_2 - \lambda_3)} J\sec = ... J\sec$$

$$h_{13} = \frac{e(V_3 - V_1)(\lambda_1\lambda_3)}{c(\lambda_1 - \lambda_3)} J\sec = ... J\sec$$

Mean 'h'= $\frac{h_{12} + h_{23} + h_{13}}{3}$

$= \textbf{...............} J\sec$

MAXIMUM PERCENTAGE ERROR:-

Percentage error = (Observed value ~ Standard value) x 100 / Standard value

(Standard Value of Planck's constant (h) = 6.6262 x 10^{-34} Joule sec)

MAXIMUM PROBABLE ERROR:-

Taking logarithmic differentiation on both sides of following equation and then put the values of V′ and corresponding errors in the estimation of V′.

$$h_{ij} = \frac{e(V_j - V_i)(\lambda_i\lambda_j)}{c(\lambda_i - \lambda_j)} Joule\sec$$

PRECAUTIONS-

1. Experiment should preferably be performed in a dark room.
2. The entire cathode surface should be uniformly illuminated since the same emitting surface may possess different emitting sensitivities at different portions of the surface.
3. Observation should be taken by altering anode potential in small steps(0.05volt)
4. Corresponding to zero anode potential the deflection of light spot on scale should be adjusted to its maximum value.
5. The experiment should be performed with at least three filters.
6. The stopping potential should be measured by the graph to avoid error that exists due to nonlinearity of the matter.
7. A smooth straight line passing through most of the data points should be plotted.
8. The slit of the photocell should be kept close after completing the experiment.
9. The stopping voltage should decrease as wavelength increases.

Experiment 2

Aim: Determination of number of lines per cm of grating and wavelength of semiconductor laser diode.

Objective: To determine the number of lines per cm of laser grating and determine the wavelength of semiconductor laser diode.

Apparatus used:

Semiconductor laser, Plane transmission grating along with its holder, and screen.

Formula used:

The number of lines per cm on the grating is given by

$N = \sin\theta/m\lambda$

Where m represents the order of grating.

Theory:

Diffraction refers to various phenomena which occur when a wave encounters an obstacle or a slit. In classical physics, the diffraction phenomenon is described as the interference of waves according to the Huygens Fresnel principle. The **Huygens–Fresnel principle** (named after Dutch physicist Christiaan Huygens and French physicist Augustin-Jean Fresnel) is a method of analysis applied to problems of wave propagation.

A diffraction grating is an optical device which produces spectra due to diffraction. It has a large no. of lines grooved on it. The spectra consisting of different orders is governed by the relation-

$d\sin\theta = m\lambda$

where d is the grating element. It is given by $d = 1/N$

where N is the number of lines per cm.

$$N = 1/d = \sin\theta/m\lambda$$

When laser is used, a higher order spectra (upto fifth order) are readily observed.

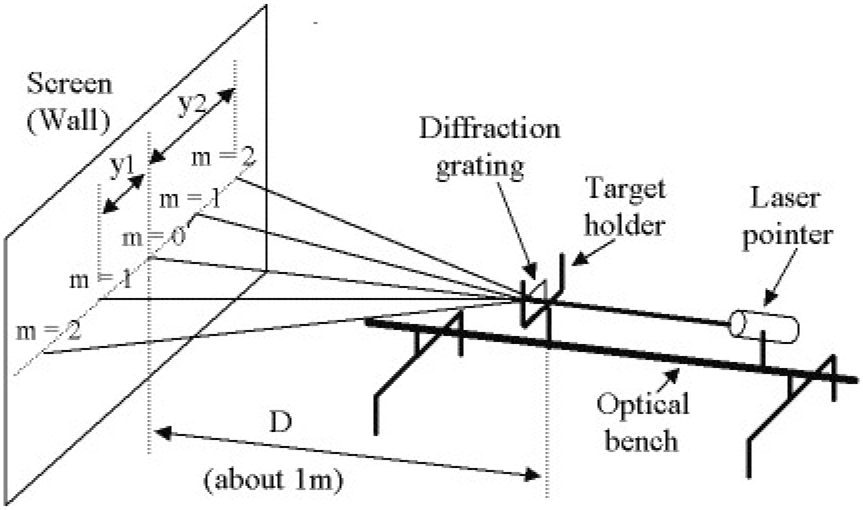


Figure: Experimental arrangement

Procedure:

1. Semiconductor laser is mounted on its saddle as shown in figure.
2. A plane transmission grating is mounted on an upright next to laser. A screen is mounted next to the grating.
3. The laser is switched on. The relative orientation of laser with respect to grating is adjusted such that spectral spot is observbed on the screen.
4. The screen is moved towards and away from the grating till about nine spots are clearly seen on the screen.
5. The central maximum and other maxima are identified.
6. The positions y of the spots belonging to first order, second order, ….. etc. on the either side of central maximum are marked.
7. The separation between central maximum and first order maxima is measured on either side. The readings are noted in Table -1.
8. The above procedure is repeated for other higher orders.
9. The distance *l* between the grating and screen is noted.
10. The number of lines per cm is computed.

Observation:

S. No.	Order	y(cm)		Mean y (cm)	*l* (cm)	θ = (y/*l*)(180/π)	Sin θ	N (per cm)	λ
		LHS	RHS						
1.	m = 1								
2.	m = 2								
3.	m = 3								
4.	m = 4								
5.	m = 5								

Mean value of N = ………

Mean value of λ = ……….

Result:

It is found that the grating has.................Number of lines per cm on it and wavelength of semiconductor laser is ………………

Precautions:

1. The grating ruled surface be place normal to the incident laser beam.
2. The screen must be placed perpendicular to the incident laser beam.
3. Use laser light very carefully it's harmful for our eyes.
4. Switch off the laser source after use.

EXPERIMENT-3

AIM-

To study the Voltage-Ampere Characteristics & Resistance Characteristics of a Tunnel Diode in Forward Bias.

APPARATUS –

A tunnel diode, two voltmeter, power supply and connection wire.

THEORY-

In the junction diode the forward -bias current characteristics is utilized in electronic-circuit applications. The Importance of the Zener Diode is its reverse-bias current characteristic this experiment we will be concerned with another class called "Tunnel Diodes" whose characteristic differ markedly from the first two.

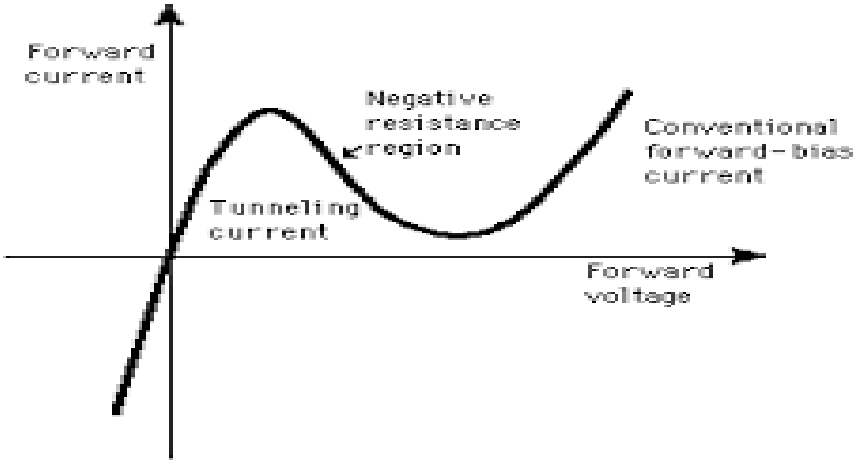
The characteristics of a solid-state diode depend on the semiconductor material from which from which the diode is constructed on the nature and extent of "doping" of that material and on the physical construction and geometry of the device. A tunnel diode is a PN Junction device which differs from the types previously studied in that it has a high concentration of impurities in its semiconductor elements. A a result of the large number of impurity atmos, the space-charge region at the junction is so thin that electrical charges move easily through the junction by a process called 'tunneling" Tunnel current added to the normal diffusion current radically alters the volt-ampere characteristic of the diode.

Figure shows a typical volt-ampere characteristic of a tunnel diode whose symbol in Fig. (1b). This device permits both forward and reverse-bias currents, the diode is highly conductive when reverse-biased, and even a small reverse bias causes a large reverse tunnel current. When forward bias is applied and increased, the tunnel current first increases rapidly to a peak value 1, at a voltage V. An increase in forward bias beyond V, causes tunnel current to fail rapidly to a minimum value 1, (Valley Current) at V current increase exponentially as in other diodes. The arca to the right V, can therefore be compared with the forward -bias area of a junction diode.

PARAMETERS:-

The tunnel diode under consideration having following parameters:

1. Peak point current I_p =
2. Peak point voltage V_p =
3. Valley point current I_v =
4. Valley point voltage V_v =



(Characteristics Curve of Tunnel Diode)

PROCEDURE

1. Connect the instrument to the Mains 230V AC.

2 Set R, fully anticlockwise position.

3. Switch ON the instrument using ON/OFF indicator switch.

4. Adjust R, very slowly & continuously until the voltage v_{m} or V_{y}) across the diode 15mV. Measure voltage V, across R,

5. Record the reading in Table (1)

6. Adjust R, for 20mV. Measure the voltage V, cross R, Record the results in Table (1)

7. Repeat the step 6 for different values of values in V_{2} in in the steps of 10mV & note down the Table. Do not exceed the max voltage V 500mV.

8. Calculate the current $I_{TD}=V_1/R_3$ for every value of V_2

9. Also calculate the resistance $R_{TD}=V_{TD}/I_{TD}$ every value of V_{TD}

10. Plot the V-I Characteristics from the data in Table (1)

11. Plot the Voltage V_{TD} versus Resistance R_{TD} for the Tunnel Diode.

Table-1

V_{TD} or V_2 (mV)	V_1 (Mv)	$I_{TD} = V_1/R_3$	$R_{TD}=V_2/I_{TD}$

Result-

EXPERIMENT No.4

Aim:

To determine slit width of single slit by using semiconductor Laser.

Apparatus:

Semiconductor laser, Single Slit, Screen, Scale, tape etc.

Theory:

If the waves have the same sign (are *in phase*), then the two waves constructively interfere, the net amplitude is large and the light intensity is strong at that point. If they have opposite signs, however, they are *out of phase* and the two waves destructively interfere: the net amplitude is small and the light intensity is weak. It is these areas of strong and weak intensity, which make up the interference patterns we will observe in this experiment. Interference can be seen when light from a single source arrives at a point on a viewing screen by more than one path. Because the number of oscillations of the electric field (wavelengths) differs for paths of different lengths, the electromagnetic waves can arrive at the viewing screen with a *phase difference* between their electromagnetic fields. If the Electric fields have the same sign then they add *constructively* and increase the intensity of light, if the Electric fields have opposite signs they add *destructively* and the light intensity decreases.

Diffraction at single slit can be observed when light travels through a hole (in the lab it is usually a vertical *slit*) whose width, *a*, is small. Light from different points across the width of the slit will take paths of different lengths to arrive at a viewing screen (Figure 1). When the light interferes destructively, intensity minima appear on the screen. Figure 1 shows such a diffraction pattern, where the intensity of light is shown as a graph placed along the screen.

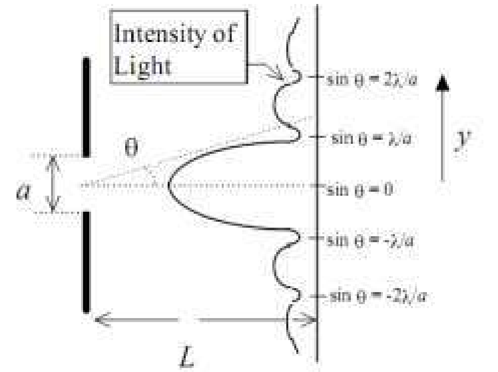


Figure 1: Diffraction by a slit of width a. Graph shows intensity of light on a screen.

For a rectangular slit it can be shown that the minima in the intensity pattern fit the formula

$a\sin\theta = m\lambda$

where *m* is an integer (±1, ±2, ±3…..), *a* is the width of the slit, λ is the wavelength of the light and θ is the angle to the position on the screen. The m^{th} spot on the screen is called the m^{th} order minimum. Diffraction patterns for other shapes of holes are more complex but also result from the same principles of interference.

Procedure:

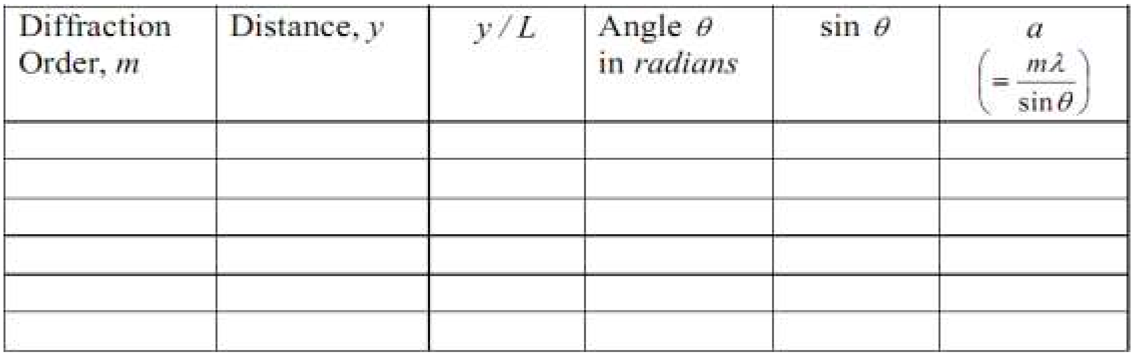
Diffraction at single slit

The diffraction plate has slits etched on it of different widths and separations. For this part use the area where there is only a single slit.

For two sizes of slits, examine the patterns formed by single slits. Set up the slit in front of the laser. Record the distance from the slit to the screen, *L*. For each of the slits, measure and record a value for *y* on the viewing screen corresponding to the center of a dark region. Record as many distances, *y*, for different values of *m* as you can. Use the largest two or three values for *m* which you can observe to find a value for *a*. The semiconductor laser has a wavelength of 670 nm.

Observations: **Table 1: Single slit**

L = ……. **λ = ………..**



Diffraction Order, m	Distance, y	y/L	Angle θ in *radians*	$\sin\theta$	a $\left(=\frac{m\lambda}{\sin\theta}\right)$

Result : Slit width = ……

Precautions:

Look through the slit (holding it very close to your eye). See if you can see the effects of diffraction. Set the laser on the table and aim it at the viewing screen.

DO NOT LOOK DIRECTLY INTO THE LASER OR AIM IT AT ANYONE! DO NOT LET REFLECTIONS BOUNCE AROUND THE ROOM.

Pull a hair from your head. Mount it vertically in front of the laser using a piece of tape. Place the hair in front of the laser and observe the diffraction around the hair. Use the formula above to estimate the thickness of the hair, *a.* (The hair is not a slit but light diffracts around its edges in a similar fashion.) Repeat with observations of your lab partners' hair.

EXPERIMENT No.5

Aim:

To determine slit width of double slit by using semiconductor Laser.

Apparatus:

Semiconductor laser, double Slit, Screen, Scale, tape etc.

Theory:

If the waves have the same sign (are *in phase*), then the two waves constructively interfere, the net amplitude is large and the light intensity is strong at that point. If they have opposite signs, however, they are *out of phase* and the two waves destructively interfere: the net amplitude is small and the light intensity is weak. It is these areas of strong and weak intensity, which make up the interference patterns we will observe in this experiment. Interference can be seen when light from a single source arrives at a point on a viewing screen by more than one path. Because the number of oscillations of the electric field (wavelengths) differs for paths of different lengths, the electromagnetic waves can arrive at the viewing screen with a *phase difference* between their electromagnetic fields. If the Electric fields have the same sign then they add *constructively* and increase the intensity of light, if the Electric fields have opposite signs they add *destructively* and the light intensity decreases.

Diffraction at double slit can be observed when two parallel slits each of width b separated by an opaque space of width c, the corresponding intensity distribution of the Fraunhofer pattern formed is (see Fig.4) given as,

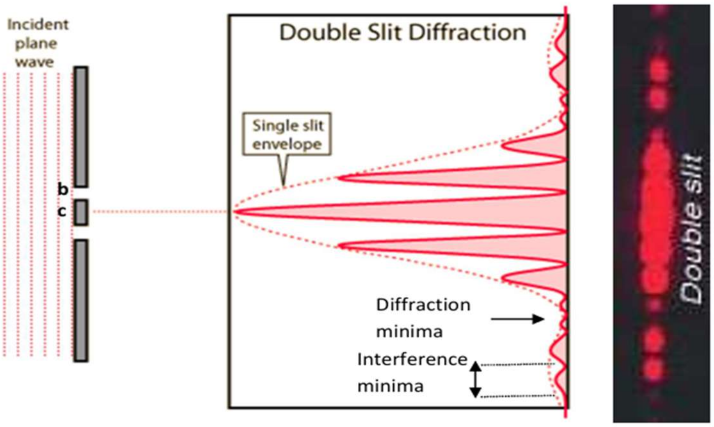


Figure. Schematics for Double-slit diffraction

$$I = I_0 \frac{sin^2\beta}{\beta^2}\, cos^2\gamma$$

where θ being the angle of diffraction,

$$\beta = \frac{\pi b \sin\theta}{\lambda} \qquad \gamma = \frac{\pi d \sin}{\lambda} \quad , \text{d =b+c}$$

$$b \sin\theta = m\lambda$$

Procedure:

Diffraction at double slit

1. Arrange the screen at least 2 meters away from the laser source. On the screen, attach a ruled paper with clips such that the ruled scale is horizontal. You may use graph paper in place of ruled paper, if you consider it convenient.
2. Turn the laser on and be extremely careful not to let your eyes in the direct or reflected line of the laser. Do not turn the laser off and on too frequently; instead use something to block the laser when it is not in use.
3. Adjust the height of the laser (and the screen) such that the laser spot is directly on the ruled line in the middle of the paper.
4. Examine the patterns formed by double slits. Set up the slit in front of the laser. Record the distance from the slit to the screen, *L*. For each of the slits, measure and record a value for *y* on the viewingscreen corresponding to the center of a dark region. Record as many distances, *y*, for different values of *m* as you can. Use the largest two or three values for *m* which you can observe to find a value for *a*. Thesemiconductor laser has a wavelength of 670 nm.

Observations: **Table 1: double slit**

L = ……. **λ = ………..**

Diffraction Order, m	Distance, y	y/L	Angle θ in *radians*	$\sin\theta$	a $\left(= \dfrac{m\lambda}{\sin\theta}\right)$

Result : Slit width = ……

Precautions:

Look through the slit (holding it very close to your eye). See if you can see the effects of diffraction. Set the laser on the table and aim it at the viewing screen.

DO NOT LOOK DIRECTLY INTO THE LASER OR AIM IT AT ANYONE! DO NOT LET REFLECTIONS BOUNCE AROUND THE ROOM.

Pull a hair from your head. Mount it vertically in front of the laser using a piece of tape. Place the hair in front of the laser and observe the diffraction around the hair. Use the formula above to estimate the thickness of the hair, *a.* (The hair is not a slit but light diffracts around its edges in a similar fashion.) Repeat with observations of your lab partners' hair.

Experiment No. 6

Aim : To demonstrate the Fraunhofer diffraction pattern and to determine diameter of circular apertures by using semiconductor laser diode.

Apparatus used:

semiconductor Laser, An optical bench, A single slit and a Circular aperture.

Formulae:

(1) The width of the single slit is given by

$$d/2 = \lambda/\sin\theta$$

where λ is the wavelength of light and θ is the angle of diffraction.

(2) The diameter D of the circular aperture is given by

$$D = 1.22\lambda f/d$$

Where d is the diameter of Air's disc and f is the distance from the circular aperture to the screen.

Theory:

Fraunhofer diffraction deals with the limiting cases where the light appoaching the diffracting object is parallel and monochromatic, and where the image plane is at a distance large compared to the size of the diffracting object. The more general case where these restrictions are relaxed is calledFresnel diffraction.

Fraunhofer diffraction is the special case where the incoming light is assumed to be parallel and the image plane is assumed to be at a very large distance compared to the diffracting object. Fresnel diffraction refers to the general case where those restrictions are relaxed. This makes it much more complex mathematically. Some cases can be treated in a reasonable empirical and graphical manner to explain some observed phenomena.

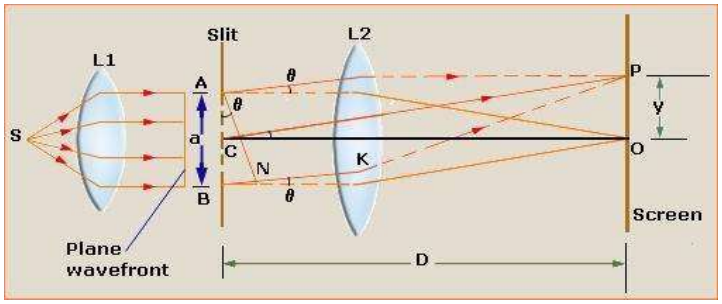


Figure: Condition for fraunhofer diffraction.

Diameter of circular apertures

Aim: To determine the diameter of circular apertures.

Apparatus Required:

A 0.5 M W He-Ne Laser, An optical bench and a Circular aperture.

Theory:

Circular Aperture Diffraction

When light from a point source passes through a small circular aperture, it does not produce a bright dot as an image, but rather a diffuse circular disc known as Airy's disc surrounded by much fainter concentric circular rings. This example of diffraction is of great importance because the eye and many optical instruments have circular apertures. If this smearing of the image of the point source is larger that that produced by the aberrations of the system, the imaging process is said to bediffraction-limited, and that is the best that can be done with that size aperture. This limitation on the resolution of images is quantified in terms of the Rayleigh criterion so that the limiting resolution of a system can be calculated.

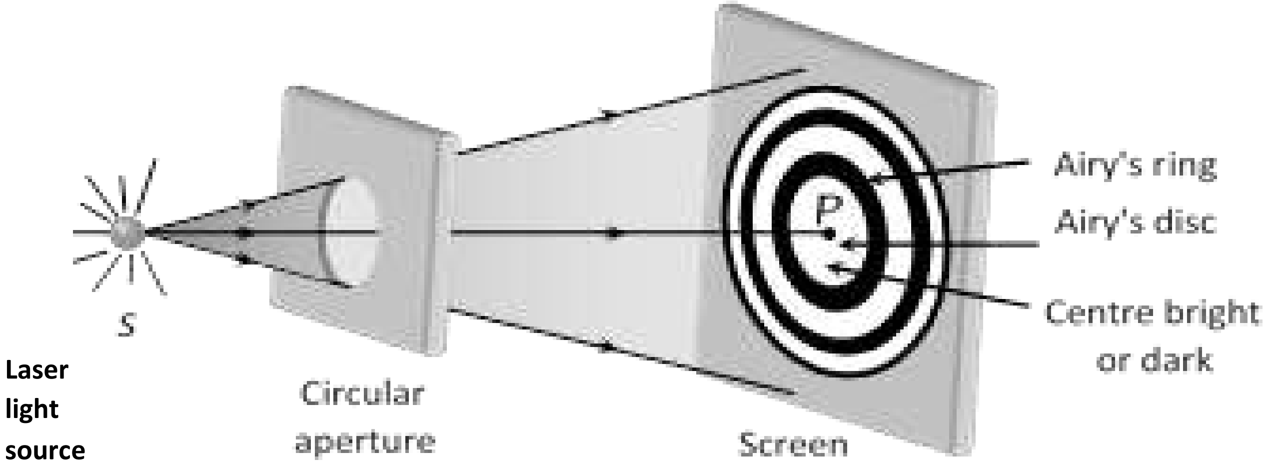
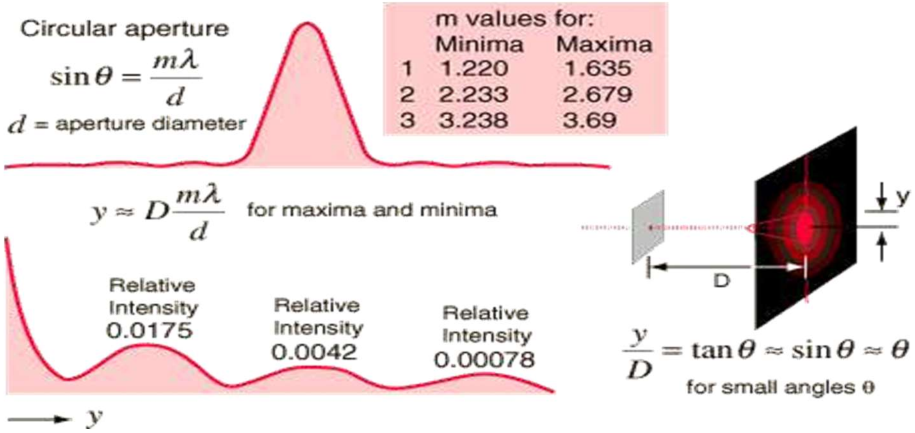


Figure: Experimental Arrangement



Procedure:

1. The circular aperture(slide) is mounted on the upright next to the laser.
2. The laser is switched on .The circular aperture and the orientation of laser are carefully adjusted such that the laser beam passes through the fine aperture.
3. A circular ring pattern consisting of a bright central Airy disk surrounded by circular ring is observed on the screen.
4. The position of the first minima on either side of the center are marked on the screen. The distance ‘d’ between the marks is measured and noted in Table-2
5. The distance ‘f’ between the screen (wall) and aperture is measured.
6. The diameter ‘D’ of the aperture is compared from the formula.

$$D = 1.22\lambda f/d$$

Observation:

λ = 6328 Å = 6.328×10^{-5}cm

Aparture	F (cm)/L (distance from apwrture to screen)	d(mm) dimeter of fringe formed in screen OR Cm	Dimeter of aparture D = 1.22λf/d
A			
B			
C			
D			

Results:

1. The diameter of the circular aperture is found to be ………mm.

Precautions:

1. The circular aperture ruled surface be place normal to the incident laser beam.
2. The screen must be placed perpendicular to the incident laser beam.
3. Use laser light very carefully it’s harmful for our eyes.
4. Switch off the laser source after use.

Experiment No -7

Aim:

To determine work function of material of filament of directly heated vacuum diode/frank hertz exp.

Apparatus:

Tetrode tube filled with experimental Argon gas, filament, power supply three variable voltage sources, nano ammeter.

Experimental Set-up:

The experimental set up involves a tube containing low pressure experimental gas fitted with four electrodes: an electron-emitting cathode (K), a mesh grid (G1) for minimizing space charge effects a mesh grid (G2) for acceleration, and an anode (A). The anode was held at a slightly negative electrical potential relative to the grid G2 (although positive compared to the cathode), so that electrons had to have at least a corresponding amount of kinetic energy to reach it after passing the grid and thereby making the dips in the plate current more prominent. Instruments were fitted to measure the current passing between the electrodes, and to adjust the potential difference (voltage) between the cathode (negative electrode) and the accelerating grids Fig (1).

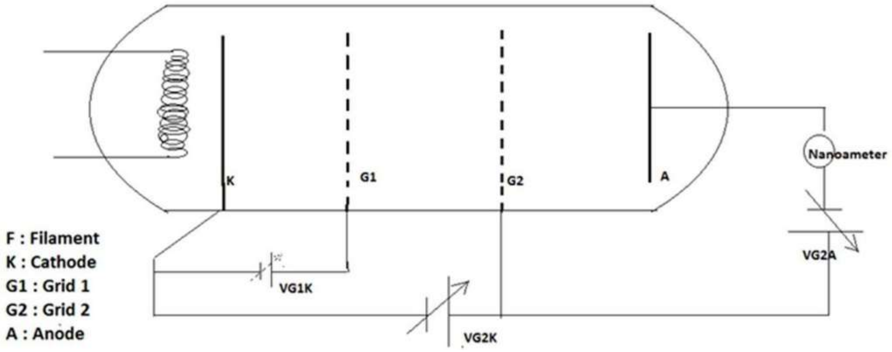


Figure – 1

Figure -2

Formula Used:

If V_n is the potential corresponding to nth peak and V_1 is the potential corresponding to 1st peak then

Mean 1st excitation potential = $\dfrac{V_n - V_1}{n - 1}$

Where (n-1) is the number of dips between 1st and nth peak.

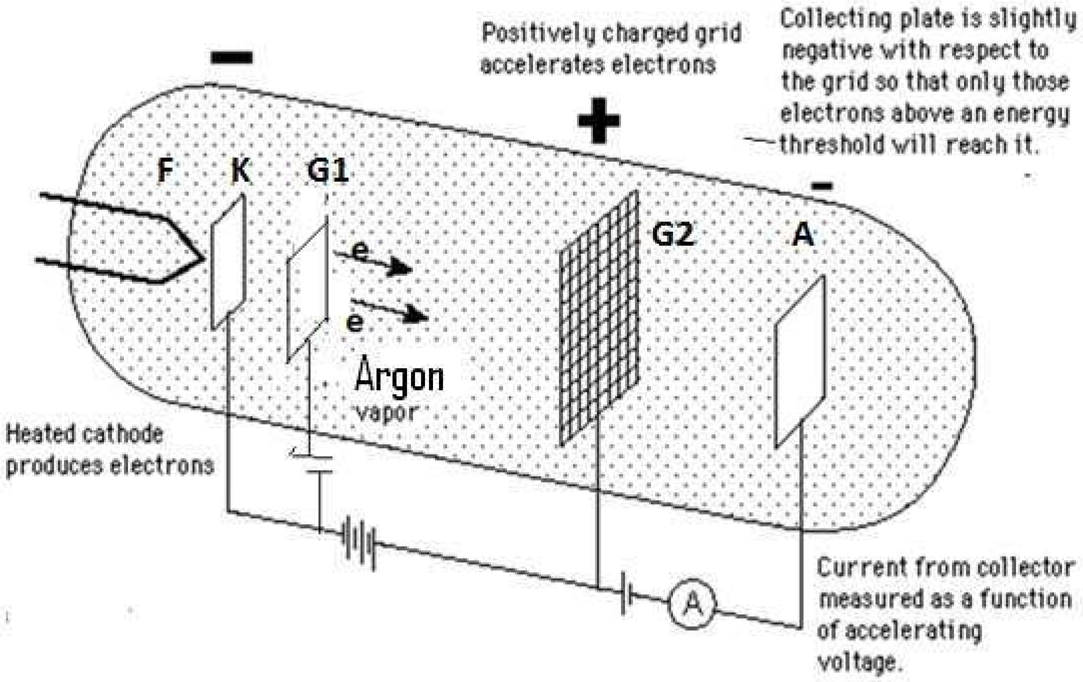
Introduction

From the early spectroscopic work it is clear that atoms emit radiation at discrete frequencies; from Bohr's model, the frequency of the radiation ν is related to the change of energy levels through $E = h\nu$. It is then to be expected that transfer of energy to atomic electrons by any mechanism should always be in discrete amounts. One such mechanism of energy transfer is through inelastic scattering of low- energy electrons.

Franck and Hertz in 1914 set out to verify these considerations.

(a) It is possible to excite atoms by low energy electron bombardment.
(b) The energy transferred from electrons to the atoms always had discrete values.
(c) The values so obtained for the energy levels were in agreement with spectroscopic results.

The Franck–Hertz experiment elegantly supports Niels Bohr's model of the atom, with electrons orbiting the nucleus with specific, discrete energies. Franck and Hertz were awarded the Nobel Prize in Physics in 1925 for this work.



Operating Principle:

The Frank-hertz tube in this instrument is a tetrode filled with the vapour of the experimental substance Fig.1 indicates the basic scheme of experiment.

The electrons emitted by filament can be accelerated by the potential V_{G2K} between the cathode and the grid G_2. The grid G_1 helps in minimizing space charge effects. The grids are wire mesh and allow the electrons to pass through. The plate (A) is maintained at a potential slightly negative with respect to the grid G_2. This helps in making the dips in the plate current more prominent. In this experiment, the electron current is measured as a function of the voltage V_{G2K}. As Voltage increases, the electron energy goes up and so the electron can overcome the retarding potential V_{G2A} to reach the plate (A). This gives rise to a current in the ammeter, which initially increases. As the voltage further increases, the electron energy reaches the threshold value to excite the atom in its first allowed excited state. In doing so, the electrons lose energy and therefore the number of decreases. This decrease is proportional to the number of inelastic collisions that have occurred. When the V_{G2K} is increased further and reaches a value twice that of the first excitation potential, it is possible for an electron to excite an atom halfway between the grids, lose all its energy, and then gain a new enough energy to excite another atoms resulting in a second dip in the current. The advantage of this type of configuration of the potential is that the current dips are much more pronounced, and it is easy to obtain fivefold or even larger multiplicity in the excitation of the first level i.e. one can get 5 peaks (dips) or more.

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Franck-Hertz Experiment Set-up, Model: FH-2558, consists of the following:

→ Argon filled tetrode
→ Filament Power Supply : 2.6 -3.3V continuously variable
→ Power Supply For V_{G1K} : 1.3 – 5V continuously variable
→ Power Supply For V_{G2A} : 1.3 – 15V continuously variable
→ Power Supply For V_{G2K} : 0 – 80V continuously variable
→ Multirange Analogue Voltmeter
    Range : 0-5V, 0-15V & 0-100V
→ Multirange Analogue Voltmeter
    Range : 0-1 (50 divisions)
    Range Multiplier : 10^{-6} , 10^{-7}, 10^{-8} & 10^{-9}

The instrument can lead to a plot of the amplitude spectrum curve by means of point-by-point measurement.

Procedure:

1. Before the power is switched 'ON' make sure all the control knobs are at their minimum position and Current Multiplier knob at 10^{-7} or 10^{-8} or 10^{-9} (whichever suitable) position.

2. Switch 'ON' the power.

3. Turn the manual- Auto Switch to manual and check that the Scanning Voltage Knob is at its minimum position.

4. Turn Voltage Display Selector to V_{G1K} and adjust the V_{G1K} knob until voltmeter reads 1.5V.
5. Turn Voltage display selector to V_{G2A} and adjust the V_{G2A} knob until the voltmeter reads 7.5V.

When you have finished step 1-5, you are ready to do the experiment.

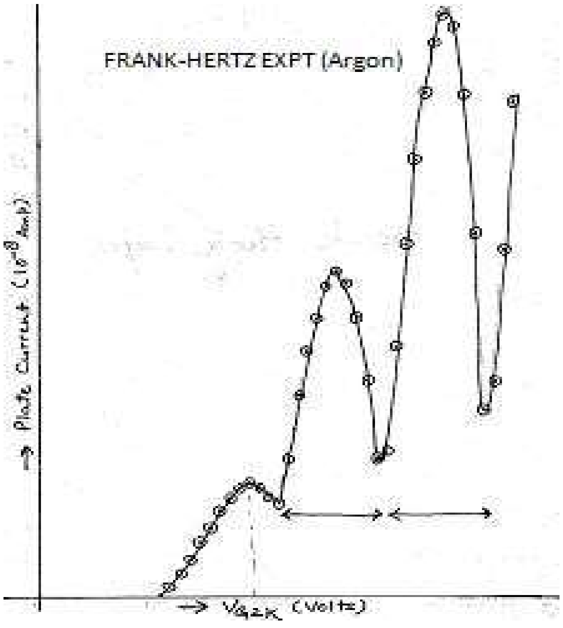
Rotate V_{G2K} knob and observe the variation of plate current I_p with the increase of V_{G2K}. The current reading would show maxima and minima periodically. The magnitude of maxima could be adjusted suitably by adjusting the filament voltage and the value of Current Multiplier. Now take the systematic readings, V_{G2K} vs. Plate current (I_p). For better resolution, the reading may be taken at an interval of 1V (1/2 division). Plot the graph with output current I_p on Y-axis and accelerating voltage V_{G2K} at X-axis.

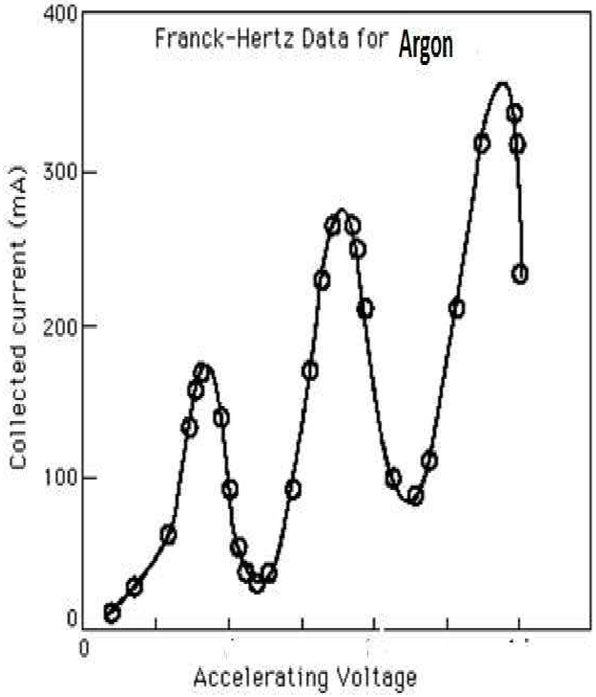
Observation Table :

V_{G1K} : 1.5V

V_{G2A} : 7.5V

S No.	Aceeleration Potential V_{G2K} (Volts)	Plate Current I_p (nano Amperes)
1.		





Results:

1. Graph with output current on Y-axis and accelerating voltage V_{G2K} at X-axis is plotted which shows series of dips in current at approximately 12.1 volt **(say)** increments (fig 2).

2. At low potential differences—up to 12.1 volts when the tube contained argon vapour—the current through the tube increased steadily with increasing potential difference. The higher voltage increased the electric field in the tube and electrons were drawn more forcefully towards and through the accelerating grid.

3. At 12.1 volts the current drops sharply, almost back to zero.

4. The current increases steadily once again if the voltage is increased further, until 24.2 volts is reached (exactly 12.1+12.1 volts.

5. At 24.2 volts a similar sharp drop is observed.

Precautions:

1. During the experiment (manual), when the voltage is over 60V, please pay attention to the output current indicator, if the ammeter reading increase suddenly, decrease the voltage at once to avoid the damage of the tube.
2. If you want to change the value of V_{G1K}, V_{G2A} and Filament Voltage during experiment, please first adjust the value of V_{G2K} to 'Zero'.

3. Whenever the filament voltage is changed, please allow 2-3 minutes for its stabilization .

4. When the Frank-Hertz Tube is already in the socket, please make sure the following before the power is switched 'ON' or 'OFF', to avoid damage to the tube.

5. Manual – Auto switch is on Manual and Scanning and Filament Voltage knob at its minimum position (rotate it anticlockwise) and current multiplier knob at 10^{-7}.