LABORATORY MANUAL
M.SC. I SEMESTER
(PHYSICS)

Department of Pure & Applied Physics

Guru Ghasidas Vishwavidyalaya

(A Central University)

LIST OF EXPERIMENTS:

1. To determine the wavelength of Helium-Neon Laser by using Diffraction Grating.

2. To show the tunneling effect in tunnel diode using I-V Characteristics.

3. To determine the value of Planck's constant and work function using a photoelectric cell.

4. To determine the first excitation potential of Argon contained in the tube and hence to compute planks constant by Frank-Hertz Experiment.

Experiment no. 1

AIM: -

To determine the wavelength of Helium-Neon Laser by using Diffraction Grating.

APPARATUS REQUIRED: -

He-Ne Laser, Diffraction grating (3 windows: 100, 300,600 lines per mm), Screen holder, Graph paper.

Formula Used: -

When a monochromatic laser beam of wavelength λ is diffracted by a diffraction grating the nth order maxima formed at θn angle given by

Sinθn = mλN ...(1)

We calculate this value of Sinθn by

$$sin\theta_n = \frac{y_n^2}{\sqrt{y_n^2+D^2}} \quad ...(2)$$

Where y_n= distance between nth order of maxima from the central maxima

D = distance between screen & grating.

And

$$\lambda = \frac{Sin\theta}{mN}$$

Where N = number of line per mm of grating

m = order of maxima

Theory: -

Diffraction refers to various phenomena which occur when a wave encounters a sharp edged obstacle or a slit. A diffraction grating is an optical device with a periodic structure that differacts light into several beams travelling in different directions. The gratings we we will use in lab have three windows per slide. They are generally 100, 300, 600 lines per mm. We will need to calculate D for the 100, 300, & 600 lines per mm.

When laser light is incident on a diffraction grating and diffraction pattern is obtained on the screen formed by a graph paper. Different Sinθ can be obtained for different order of maxima

We have,

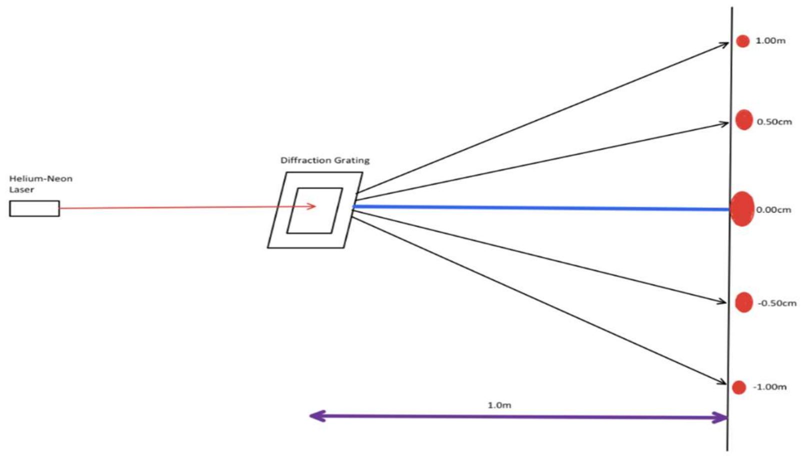
$$sin\theta_n = \frac{y_n^2}{\sqrt{y_n^2+D^2}}$$

And substituting Sinθ for different orders in formula,

$$\lambda = \frac{Sin\theta}{mN}$$ can be obtained

Diagram: -

Activity 4 (grating)



a) Above is a diagram of a HeNe Laser (632nm wavelength) shining through a diffraction grating of unknown line density (lines/mm); the diffraction pattern on a screen 1m away is as shown, bright red spots appearing in the positions as shown, with distances from the horizontal beam line indicated. Using the appropriate equation, and trigonometry, find the *line density* of the diffraction grating (remember that line density is not a quantity in the appropriate equation). Show all your calculations in your lab report.

Fig. (01)

Fig. (02)

Procedure: -

1. A plane transmission grating (100 lines per mm) is mounted on an upright next to laser and screen is mounted next to the grating.
2. When we switch on the laser, spectral spot is observed on the screen.

3. The central maxima and other maxima are identified as second order, third order…etc., on the either side of central maximum are marked.
4. The distance D between the screen and grating is noted.
5. The above procedure will be repeated for other values of N (like 300, 600).
6. We will calculate the value of wavelength by calculating mean value of λ for each window (100, 300 & 600).
7. After that we will calculate the mean value of wavelength again from three mean values of λ.
8. Obtained mean λ will be our experimental value of λ for He-Ne laser.

Observation Table: -

1) For N = 100 lines per mm

Serial No.	Order(m)	y(cm) R.H.S.	y(cm) L.H.S.	Mean y(cm)	D (cm)	$\boldsymbol{sin\theta} = \frac{y_n^2}{\sqrt{y_n^2+D^2}}$	$\boldsymbol{\lambda} = \frac{\boldsymbol{Sin\theta}}{\boldsymbol{mN}}$
1.	m = 1st						
2.	m = 2nd						
3.	m =3rd						
4.	m = 4th						
5.	m = 5th						

2) For N = 300 lines per mm

Serial No.	Order(m)	y(cm) R.H.S.	y(cm) L.H.S.	Mean y(cm)	D (cm)	$\boldsymbol{sin\theta} = \frac{y_n^2}{\sqrt{y_n^2+D^2}}$	$\boldsymbol{\lambda} = \frac{\boldsymbol{Sin\theta}}{\boldsymbol{mN}}$
1.	m = 1st						
2.	m = 2nd						
3.	m =3rd						

4.	m = 4th						
5.	m = 5th						

3) For N = 600 lines per mm

Serial No.	Order(m)	y(cm) R.H.S.	y(cm) L.H.S.	Mean y(cm)	D (cm)	$\sin\theta = \frac{y_n^2}{\sqrt{y_n^2+D^2}}$	$\lambda = \frac{Sin\theta}{mN}$
1.	m = 1st						
2.	m = 2nd						
3.	m =3rd						
4.	m = 4th						
5.	m = 5th						

Calculations: -

Obtain the value of λ by calculating mean values of λ from all three observations.

Result:- Wavelength of He-Ne laser is ………….Å obtained.

Standard value of He-Ne laser wavelength is λ = 6328 Å.

Percentage Error: -

Precautions:-

1. The screen must be placed perpendicular to the incident laser beam
2. The grating ruled surface be placed normal to the incident laser beam.
3. The experiment should be conducted with precautions to prevent the reflection of laser beams from any surface into the eyes, and direct exposure of the eyes to the laser beam should be avoided

Experiment no. 2

AIM :- To show the tunneling effect in tunnel diode using I-V Characteristics.

APPARATUS :-

- Regulated power supply
- Tunnel diode
- Connecting wires

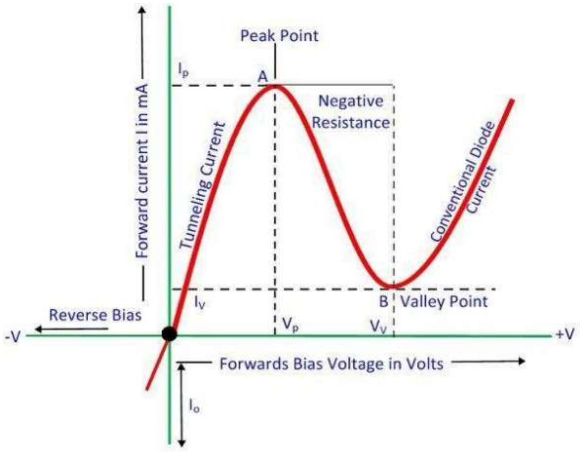
THEORY :- A Tunnel Diode is a type of semiconductor diode that exhibits negative resistance. Unlike conventional diodes which conduct current in any one direction , Tunnel diodes can conduct current in both forward and reverse biases.

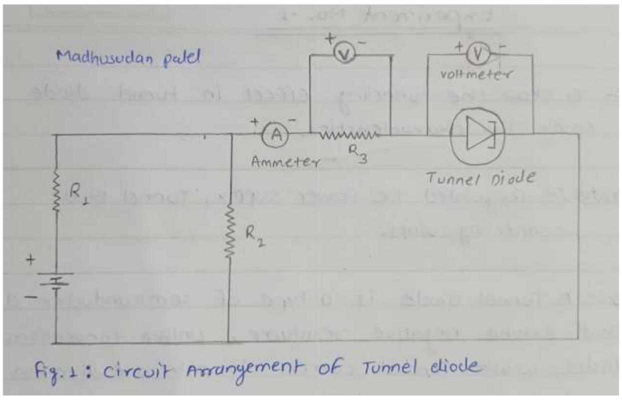
A Tunnel diode is a P-N Junction device which differs from other diodes as it is highly doped in comparison to other semiconductors. As a result of large no of impurity atoms, the space charge region at the Junction is so thin that electrical charges move easily through The Junchon by a process called 'Tunneling'.

This device permits both forward & Reverse Bias current, The diode is highly conductive when reverse Biased, and Even a small reverse Bias Can cause a large reverse tunnel current.When Forward Bias is Applied and increased, the tunnel current first increases rapidly to a Peak valve I_p. at a voltage V_p. Further increase in voltage beyond V_p Causes the tunnel current to fall rapidly to a minimum value I_v (valley current) at V_v the current then increases exponentially as in other diodes.

The area to the right of V_v, can therefore be compared with the forward Bias area of a Junction Diode.

<u>DIAGRAM</u> :-





(fig.1:- I-V Characteristics of Tunnel diodes.)

(fig.2:- Circuit Arrangement of Tunnel diode.)

<u>OBSERVATION TABLE</u> :-

S.NO.	Observed voltage (V_1) (in volt)	Voltage of tunnel diode (V_2) (in volt)	Current (in mA) $I = V_1/33$

<u>GRAPH</u> :-

Plot yourself with the help of observation table.

b/w forward voltage (V_2) and output current.

CALCULATION :-

Do it yourself.

Calculate slope from the curve for positive and negative resistance of the diode. You will get two resistance values , one +ve and one -ve .

RESULT :-

The characteristic curve of the tunnel diode has been plotted successfully. From the V-I characteristic curve , we get I_p =

V_p =

I_v =

V_v=

+ve resistance of tunnel diode =

-ve resistance of tunnel diode =

PRECAUTION :-

- Overheating of tunnel diode must be avoided.
- Tunnel diode is to be used in forward bias.
- Check the connecting wires before use.

Experiment:3

AIM: -

To determine the value of Planck's constant and work function using a photoelectric cell.

APPARATUS REQUIRED: -

A vacuum type photoelectric cell mounted inside a wooden box with a wide opening on the side opposite to the cathode, 6-volt DC supply, a voltmeter, a rheostat, a sensitive moving coil galvanometer with lamp and scale arrangement, a key, a mercury lamp and few light filters.

THEORY: -

When a photon of energy hv is incident on the emissive surface of the cathode, almost all of its energy is transferred to the electrons inside the metal. If this energy is greater than the threshold energy W_0, the electrons is emitted. W_0 is also called the work function of the metal. Above the threshold frequency, corresponding to the $W_0(= hv_0)$, photoelectrons have a range of energies from 0 to a certain maximum value, and this maximum energy increases linearly with increasing frequency. This is because, out of the total incident energy hv, a part W_0 is used up as the threshold energy and the rest is stored in the electrons as its kinetic energy.

Thus

$$hv = \frac{1}{2}mv^2 + W_0$$

$$= E_{max} + W_0 \qquad ......(1)$$

This equation is called Einstein's photoelectric equation.

As remains constant for a given photoelectric cell, E_{max} varies linearly with the frequency.

In this experiment, to find out the maximum kinetic energy E_{max} of the emitted electrons, we reverse bias the photoelectric cell i.e., its anode is made negative. It therefore, repels the emitted electrons and the current decreases. The negative potential on the anode is slowly increased till the stopping potential Vs is reached, when the current stops. When this happens

$$eV_s = E_{max} \qquad ......(2)$$

V_s is called the stopping potential or the cut off potential because it just stops the electrons from leaving the surface.

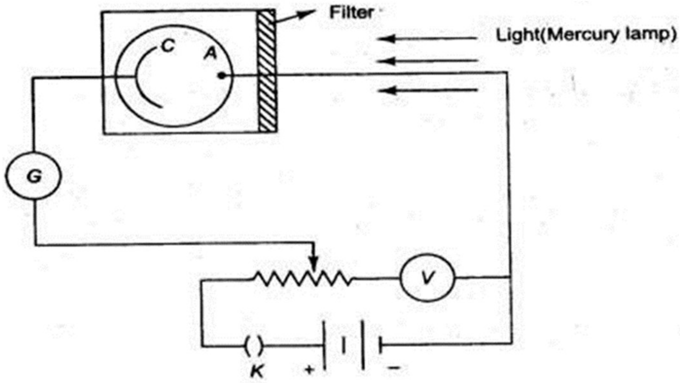
From eqn (1) and eqn (2) , we have

$$hv = eV_s$$

$$eV_s = hv - W_0$$

$$V_s = \frac{h}{e}v - \frac{W_0}{e} \qquad ......(3)$$

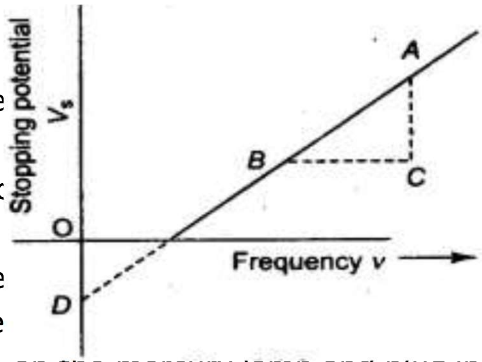
Thus, if we make a graph with the frequency v along the x-axis and the stopping potential V_s along the y-axis, it would be a straight line with slope equal to $\frac{h}{e}$ and negative intercept on y-axis equal to $\frac{W_0}{e}$.



Thus, the Planck's constant h and work function W_0 for a given photoelectric cell can be determined.

DIAGRAM: -

PROCEDURE: -



1. Make the connections as shown in the above figure ... ode and anode of the photocell.
2. Arrange the mercury lamp just in front of the photc ... hat the spot moves freely.
3. With no light falling on the photocell, insert the ... the voltmeter to zero and adjust spot in the galvanome ... ey.
4. Fit the violet filter in front of the photocell. Switch on the mercury lamp and plug in the key. The galvanometer will show deflection. Adjust the position of the mercury lamp so as to get maximum deflection. Do not move the lamp after this.
5. Increase the potential on anode slowly by the rheostat. The deflection in the galvanometer decreases. Go on increasing the negative potential applied to anode till the spot of light in the galvanometer comes back to zero position. Note down the potential.
6. Change the filter one by one from violet to red and repeat the experiment.
7. Make a graph with the frequency of the filter V alo0ng x-axis and the stopping potential V_s along y-axis.

OBSERVATION TABLE: -

S.NO.	COLOUR FILTER	WAVELENGTH λ (Å)	FREQUENCY $V_0 = C/\lambda\,(Hz)$	STOPPING POTENTIAL (V)
1.	Red	6300	$4.76*10^{14}$	
2.	Orange	6152	$4.87*10^{14}$	
3.	Yellow	5500	$5.45*10^{14}$	
4.	Green	5200	$5.76*10^{14}$	

5.	Blue	4700	$6.38*10^{14}$	

GRAPH: -

Plot a graph between frequency (X-axis) and stopping potential(Y-axis).

CALCULATION: -

The graph between the frequency along the x-axis and the slopping potential along y-axis is a straight line. Slope of line = $\frac{AC}{BC} = \cdots$

$$\frac{h}{e} = \text{slope}$$

Therefore, Planck's constant h = e x slope

= $1.6*10^{-19}$ x ...

= ... J/s

Negative intercept on y-axis = OD = ... V

Work function W_0 = OD = ... eV

PERCENTAGE ERROR: -

$$= \left| \frac{\textbf{theoretical value} - \textbf{experimental value}}{\textbf{theoretical value}} \right| \times 100$$

=...

RESULT: -

1. The Planck's constant, h = ... J/s
   Actual value= ...
   % error= ...
2. Work function, W_0 for the given photoelectric cell= ... eV

PRECAUTION: -

1. **Handle the Apparatus Carefully:** The photoelectric cell, mercury lamp, and other equipment are delicate and can be damaged easily. Handle them with care to avoid any damage.

2. **Avoid Ambient Light**: Perform the experiment in a dark room or cover the setup to avoid interference from ambient light. This ensures that only light from the mercury lamp hits the photoelectric cell.

3. **Proper Calibration:** Ensure that the voltmeter, galvanometer, and other measuring instruments are properly calibrated before starting the experiment. This helps in obtaining accurate readings.

4. **Safety Measures:** Mercury lamps can get very hot and pose a burn risk. Always switch off the lamp and allow it to cool before handling. Also, since you're working with electrical equipment, ensure that your hands are dry to avoid electric shock.

Experiment – 4

Aim:-

To determine the first excitation potential of Argon contained in the tube and hence to compute planks constant by Frank-Hertz Experiment.

Apparatus:-

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

Theory:-

From the early spectroscopic work it is clear that atoms emit radiation at discrete frequencies; is related to the change of energy levels through ν from Bohr's model, the frequency of the radiation . It is then to be expected that transfer of energy to atomic electrons by any mechanism should ν h=E 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 VG2K between the cathode and the grid G2. The grid G1 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 G2. 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 VG2K. As Voltage increases, the electron energy goes up and so the electron can overcome the retarding potential VG2A 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 VG2K 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, loose 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 five fold or even larger multiplicity in the excitation of the first level i.e. one can get 5 peaks (dips) or more. 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.

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 VG1K : 1.3 – 5V continuously variable.
→ Power Supply For VG2A : 1.3 – 15V continuously variable.
→ Power Supply For VG2K : 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.

Experiment Setup:-

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).

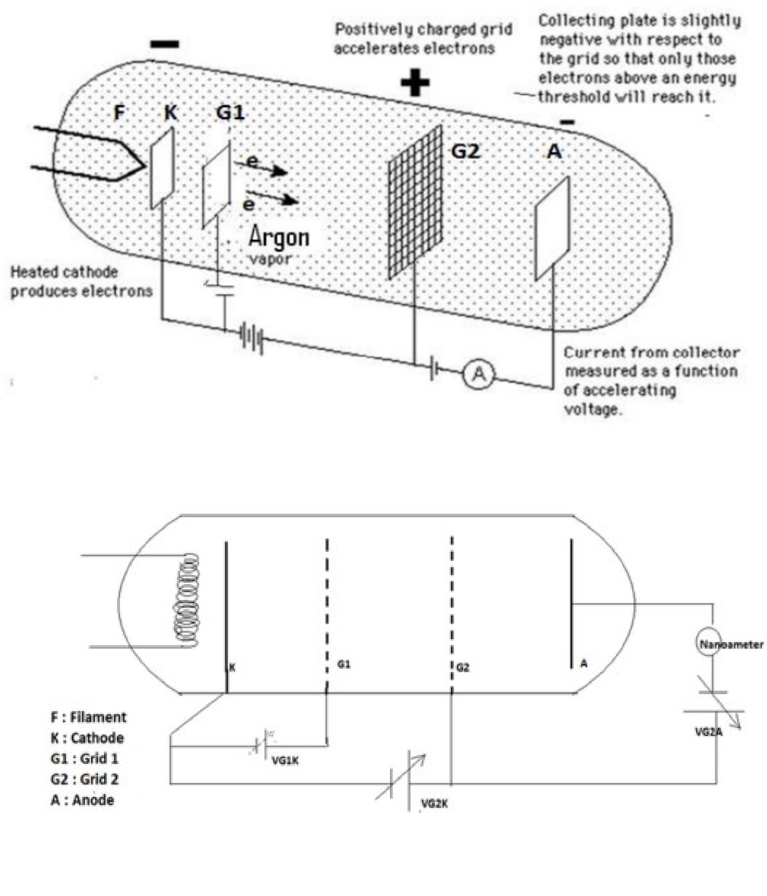


Fig.(1)

Formula Used:-

If Vn is the potential corresponding to nth peak and V1 is the potential corresponding to 1st peak then

Mean 1^{st} excitation potential(Vs) = $\frac{Vn-V1}{n-1}$

Where (n-1) is the number of dips between $1^{st}$and n^{th} peak.

$E = eVs = hv \qquad (v = \frac{c}{\lambda})$

$$h = e\frac{\{\frac{(Vn-V1)}{n-1}\}\lambda}{c}$$

where, λ is Wavelength of Argon ,c is speed of light ,e is charge of electron.

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 $VG1K$ and adjust the VG1K knob until voltmeter reads 1.5V.

5. Turn Voltage display selector to VG2A and adjust the VG2A knob until the voltmeter reads 7.5V.

When you have finished step 1-5, you are ready to do the experiment. Rotate VG2K knob and observe the variation of plate current Ip with the increase of VG2K . 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, VG2K vs. Plate current (Ip). For better resolution, the reading may be taken at an interval of 1V (1/2 division). Plot the graph with output current Ip on Y-axis and accelerating voltage VG2K at X-axis.

Observation Table:-

VG1K = 1.5V
VG2K = 7.5V

S.No.	Acceleration potential VG2K (Volts)	Plate Current Ip (nano Amperes)
1.		
2.		

3.		
..		
..		
..		

Results:-

1. Graph with output current on Y-axis and accelerating voltage VG2K 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.

Graph:-

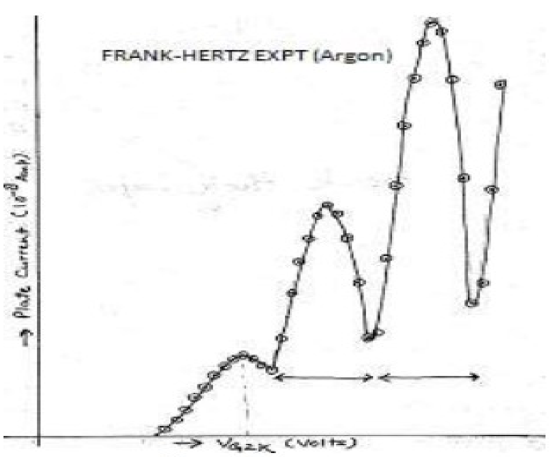
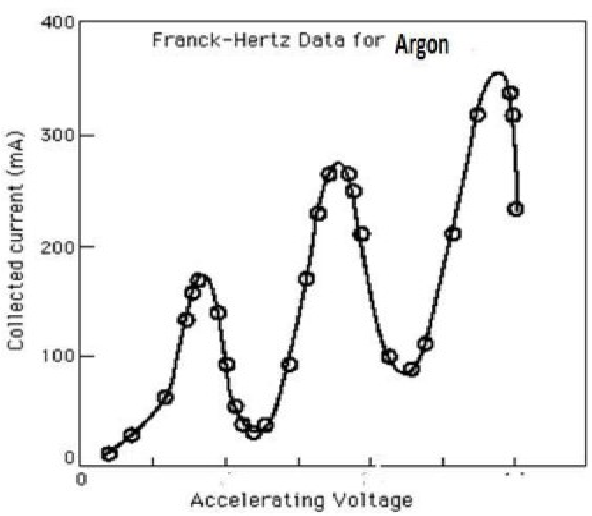


Figure 2



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 VG1K , VG2A and Filament Voltage during experiment, please first adjust the value of VG2K to ‘Zero’.

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

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}.