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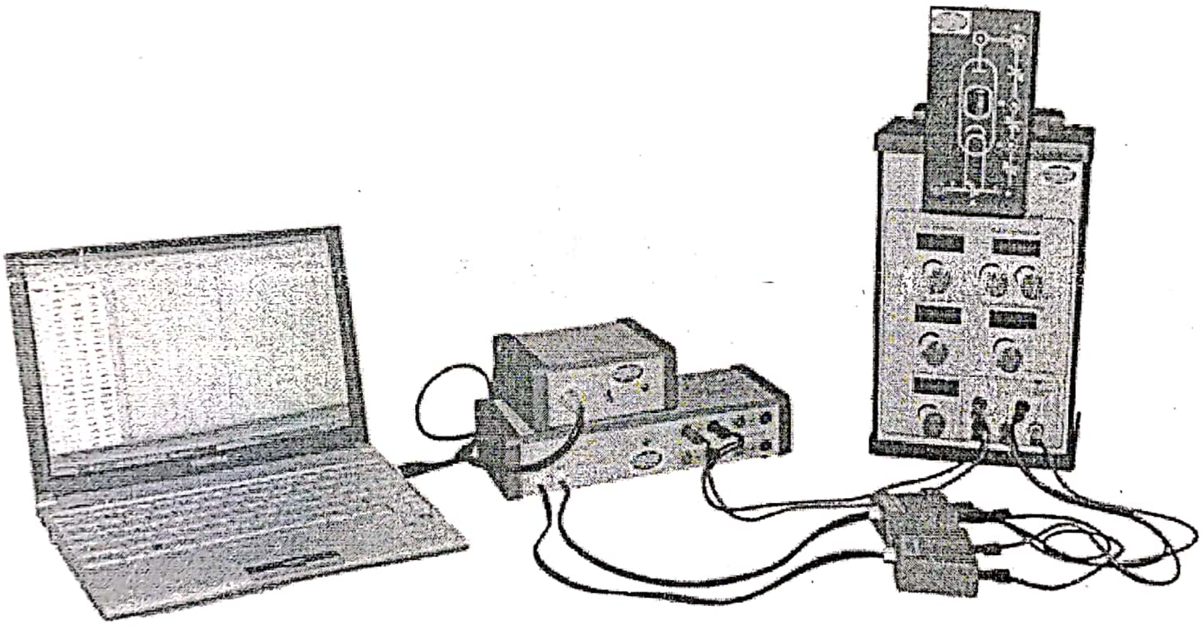
FRANCK-HERTZ WITH NEON TUBE

Instruction Manual



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Aim:

1. To determine the current strength in a franck-hertz tube as a function of anode voltage U.
2. To determine the excitation energy from the positions of current strength minima or maxima by difference formation.

INTRODUCTION:

The Franck-Hertz tube is a tetrode with an indirectly heated barium oxide cathode, a mesh-type control electrode, a mesh-type anode, and a collecting electrode (see Fig. 1). The electrodes are in a plane-parallel configuration. The distance between the control grid and the anode grid is about 5 mm, and the distances between the cathode and the control grid and between the anode and the collecting electrode are both about 2 mm. The tube is supplied already filled with neon gas at a pressure chosen to give an optimum characteristic curve, which is in the region of several hPa.

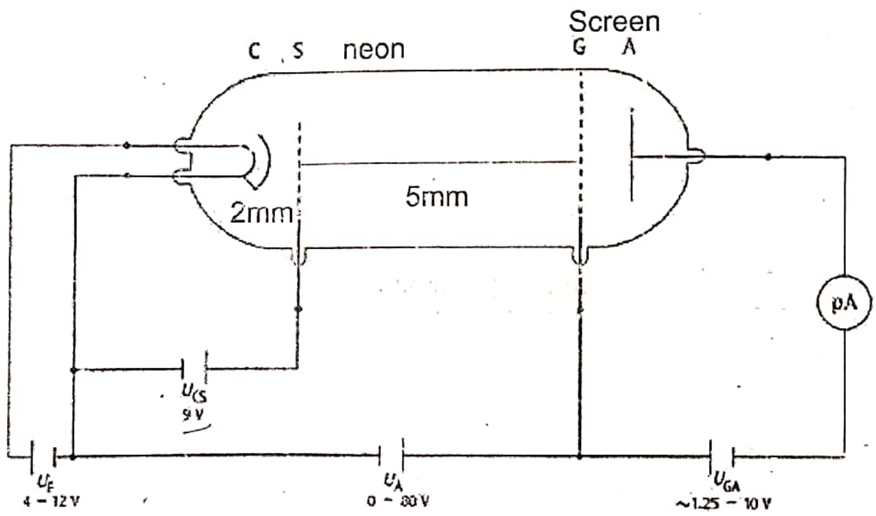

Fig.1 Schematic of set up for measuring the Franck-Hertz curve for neon (C cathode, S control gird, screen, G grid and a target electrode)

The connecting sockets for the heater, control grid and anode grid voltages are on the base of the instrument. The collector current is taken off through the BNC socket at the top end of the screening cylinder. An internal 10 kΩ limiting resistor is permanently built in between the connector sockets for the accelerator (control grid) voltage and the anode voltage. This protects the tube in case there is a spark discharge caused by applying too high a voltage. The voltage loss in this resistor when making measurements is negligible, as the anode current in the tube is smaller than 5 μA. (Thus the voltage loss in the protecting resistor is 0.05 V.)

TECHNICAL DESCRIPTIONS:

Filament voltage	:	6 - 9 V
Control voltage	:	9V
Accelerating voltage	:	Maximum 80 V
Counter voltage	:	1.2 - 10 V
Tube	:	130 x 26 mm dia. approx

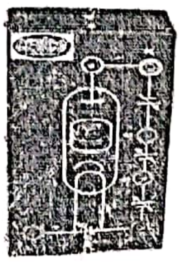

Fig.2

PRINCIPLE:

The electrons emitted from the indirectly heated cathode of tetrode filled with neon vapors are accelerated. The excitation energy of neon is determined from the distance between the equidistant maxima of the electron current in variable opposing electric field.

THEORY:

In the Franck-Hertz experiment neon atoms are excited by inelastic collision with electrons. The excited atoms emit visible light that can be viewed directly. Thus it is possible to detect zones where the light and therefore the excitation is more intense. The distribution of such zones between the cathode and the grid depends on the difference in potential between the two:

Electrons are emitted from the cathode and are accelerated by a voltage V towards the grid. Having passed through the grid they reach the target and thus contribute to a target current, if their kinetic energy is sufficient to overcome a decelerating voltage U_{GA} between the grid and the target.

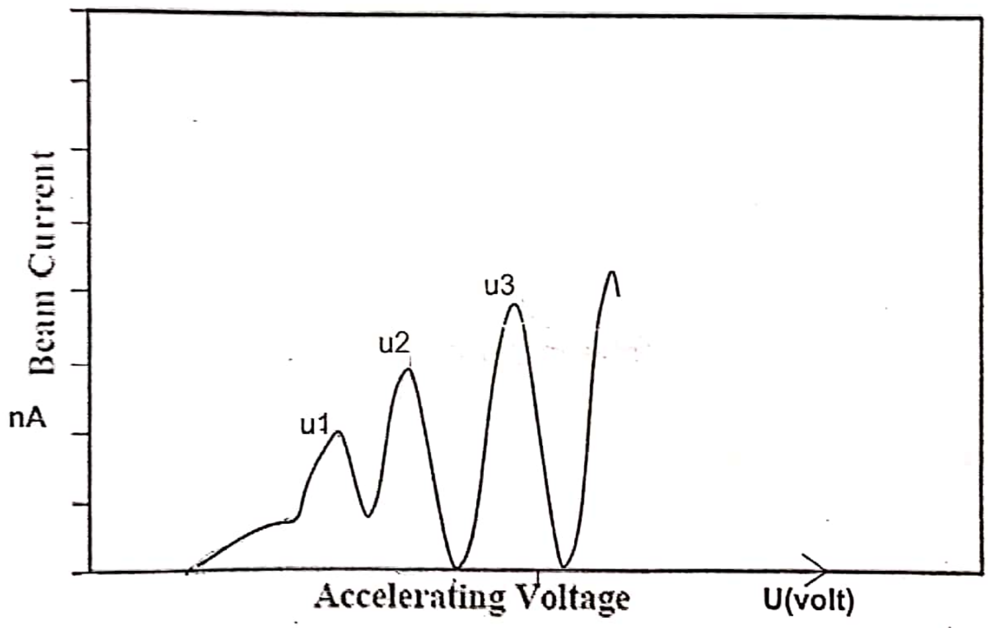

Fig.3

The I(U)-characteristic (see Fig. 3) has a similar pattern to the original Franck-Hertz experiment using neon gas but this time the intervals between minima where the current falls to almost zero for a specific voltage $V = V_1$, corresponding to the electrons reaching sufficient kinetic energy to excite a neon atom by inelastic collision just before reaching the grid are about 19 V. Simultaneously it is possible to a faint orange light close to the grid since the energy transition to the base state of a neon atom results in the emission of such light. The zone of illumination moves towards the cathode as the voltage U increases and the target current / rises once more.

For a higher voltage $V = V_2$, the target current also drops drastically and it is to see two zones of illumination. The electrons can in this case retain enough energy after an, initial collision to excite a second simulate meously.

As the voltages are further increased, other minima in the target current along with further zones of illumination can be observed.

The I(V)-characteristic exhibits various maxim and minima and the interval between the minim is about 6.U = 176eV. This corresponds t excitation energy of the 3p energy level of a neo atom (see Fig. 4) so that it is highly likely that thi level is being excited. Excitement of the 3s-leve cannot be neglected entirely and gives rise t some fine detail in the structure of the I(\ characteristic.

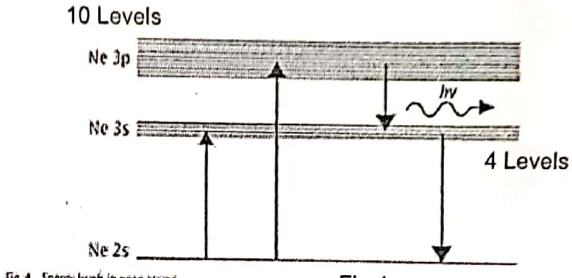

Fig.4 Energy levels in neon atoms

Fig.4

The zones of illumination are zones of greater excitation and correspond to drops in voltage in the I(U)-characteristic. One more zone of illumination is created every time V is increased by about 19V.

NOTE:

The first minimum is not at 16.5 V itself but is shifted by an amount corresponding to the so-called contact voltage between the cathode and grid.

The emission lines in the neon spectrum can easily be observed and measured using a spectroscope when the maximum voltage V is used.

FRANCK HERTZ BASE UNIT DESCRIPTIONS:

1. Handle for transport
2. Plate Current Display
3. Accelerating Voltage or Screen Grid (G_2) Voltage Display (0-80V)
4. Variable knob for accelerating voltage or Screen Grid (G_2) Voltage
5. Current gain adjustment knob
6. Current offset knob
7. Control Grid (G_1) Voltage Display (0-9V)
8. Variable knob for Control Grid (G_1) Voltage
9. Plate / Anode Voltage Display (~1.2-12V)
10. Variable knob for Plate Voltage
11. Filament Voltage Display (0-8.5V)
12. Variable knob for Filament Voltage
13. Accelerating Voltage or Screen Grid (G_2) Voltage Inputs from DAC1
14. Accelerating Voltage or Screen Grid (G_2) Voltage output to 10V Sensor
15. Plate/Anode Current output to 100nA Sensor
16. Ground
17. Toggle Switch for manual or Data Logging mode
18. ON/OFF Switch
19. Ground Out
20. Filament Voltage Output
21. G_2 Voltage output
22. Plate Voltage Output
23. G_1 Voltage output

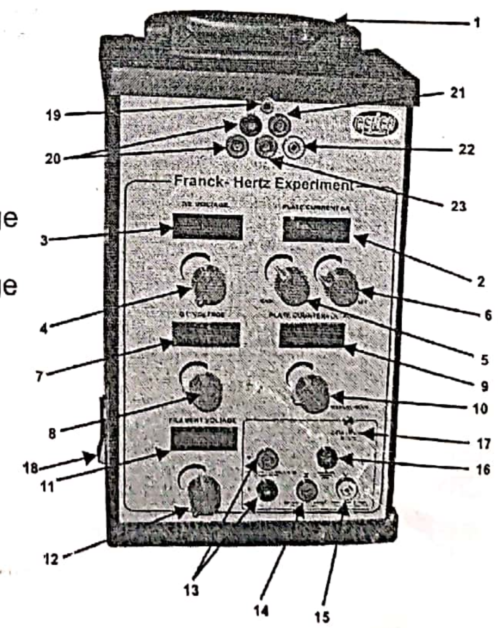

Fig.5

Note the same can be used on computer by adding

1. Voltage Sensor
2. Current Sensor
3. Data logger
4. Power Supply

② Using OFFSET set plate current to zero.

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PROCEDURE FOR FRANCK HERTZ EXPERIMENT: -

1. Place the Franck Hertz base unit on experimental table and mount the Neon tube unit on the 4mm socket provided on the top of the base unit.
2. Put the switch manual mode.
3. Set the all control knob (Scanning voltage, filament voltage, VG1K, VG2A, VG2K) at extreme anticlockwise position of the Franck Hertz base unit (1).
4. Connect the Franck Hertz base unit (1) plug to mains, switch ON the Unit. → ① Set GAIN to ≈ 50% position.
5. Now set the filament voltage at 8.2V to 8.5 V approx, and wait for 3-5 minute.
6. Set G1 Voltage 6V to 8V and Plate Counter Voltage 7V to 9V approximately.
7. Set the GAIN knob at maximum position (extreme clockwise direction) and zero the plate current using OFFSET knob. for fixed value of V_F, G_1, & U_{GA}, vary G_2 and note plate current
8. Repeat the experiment for different filament voltage, G1 or Plate counter voltage.

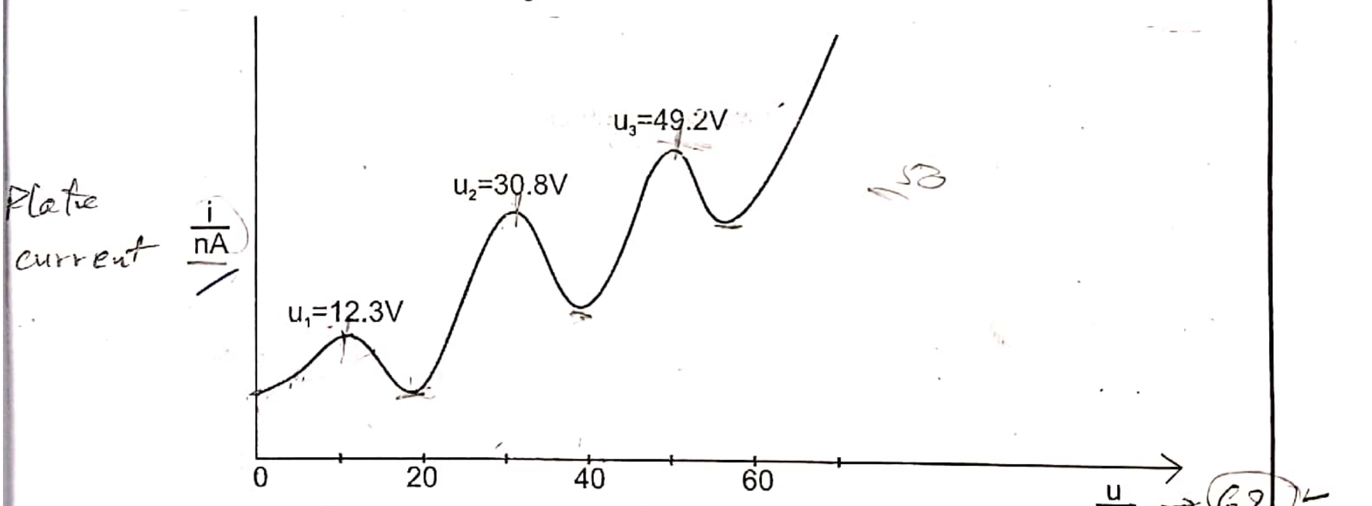
Plot I vs G_2

Franck Hertz Curve:

When filament voltage = 8.2 V

G1 = 6.6V

Plate counter voltage U1 = 7.2 V.



Mean Value $= \frac{18.5 + 18.4}{2} = 18.45V$

This energy is nearer to the excitation energies for the 3 p level of neon, which is expected between 18.3V and 19V. The excitation energies of 3S levels is between 16.7V to 17V. Thus the probability of excitation to the former by inelastic collisions of electron is more.

Important Note:

1. Some times due to double and multiple collisions of electrons and combinations of excitation of 3S level and 3P level, there may be small variations in plate current measured in nano-ampere. In such case we can take the mean of min and max. readings keeping G2 constant.
2. The maxima where the current becomes maximum, is slightly different for different tubes.