

FRANCK - HERTZ APPARATUS

Introduction : The Franck - Hertz experiment was provided the evidence for the existence of discrete energy states within an atom. They studied the excitation of atoms from low level energy to high level energy by means of colliding slow electron with the atom of a gas. The present apparatus uses a gas filled triode for experiment, with necessary point measurement using two digital meters, well regulated power supplies, solid state signal processing and, a scan oscillator to observe the spectrum amplitude upon a cathode ray oscilloscope screen. The brief introduction of apparatus is given below.

* Voltage supply for experiment.

1. DC regulated 0 - (- 5V) for anode - grid circuit as V1.
2. DC regulated 0 - 50V for grid - cathode circuit as V2.
3. Fixed 4Volt / 1Amp supply for heater.

* Metering.

1. Three and half digit digital LED display for measurement of,
Mode select V1, to take reading of anode - grid supply,
Mode select V2, to take reading of grid - cathode supply.
2. Three and half digit digital LED display for measurement of,
Feeble current in grid - anode circuit.

Note : This current is amplified and displayed upon display as μA .

* Scan oscillator to run grid - cathode supply at high frequency.

1. Voltage : - 3 to + 52V, at rate of 200 cycle per second rate.
2. Available at X output as sawtooth attenuated by 1 : 10 ratio.

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3. The amplified current signal at Y output $\geq 1V$.

4. Observable pips - dips = 3 (possibly 4).

5. CRO unblank signal (rear side) 0 / + 5V / , to unblank CRO as

0 = CRO trace blank 10 μ S.

+5V = Trace unblank 4.9 mS.

* Operating voltage / condition.

Input : 220V \pm 10%, 50Hz AC 25VA max.

RH : \leq 85% , (40°C).

Heating time : 5 minute minimum.

Theory : When energy is supplied to atoms and molecules, they absorb energy. It is noticed that the energy absorbed has definite values in case of a particular type of atoms or molecule. It is different for different atoms. Atoms and molecules on absorbing the energy becomes 'excited'. In excitation of atoms or molecules, the electrons absorb energy and pass on to the 'higher states'. It can be said 'that the electron is excited to first, second, third state' etc. However if more energy is applied then a state reaches, when the electron of the atom or molecule detaches from its parent atom, this state is defined as ionisation. Thus excitation of atoms or molecules is a process in which the electron of the system absorb energy and pass on to the higher energy state. Evidently excitation energies depends upon the atoms and the shell of the electron.

According to Bohr's theory' when an electron in an atom absorbs energy from an external source. it rises from its present orbit to a higher orbit and, the atom is then said to be in an 'excited state'. This state lasts only for a very short time.

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Operational theory : The diagram of experiment is shown in fig 1. A specifically designed electronic triode valve of specific spacing between different electrodes and filled with low pressure experimental gas (Argon). The space between the cathode (K), and grid (G), is sufficient, so that the emitted electrons suffer a number of collisions with the vapour atoms or molecules present between K and G. The grid G, is made positive with respect to cathode K. This potential ($V_{gk} = V_2$), accelerates electrons between K and G. This potential V_2 , is measured with a high impedance digital voltmeter. The anode (A) is given a small retarding potential ($-V_{ag} = V_1$) negative with respect to grid (G). The feeble current (in order of 10^{-7} amp), between A and G is measured by a digital microammeter (actually the current is amplified).

The variation of current with $V_{gk} = V_2$, is shown in fig 2. When the filament (heater H,H) get heated, the electrons emitted from cathode (K) . When V_{gk} increased from zero value, the electrons gains kinetic energy and head towards grid (G). Since the retarding potential negative V_{ag} , is small, therefore current rises with increased value of V_{gk} . Suddenly a fall of current (dip) is observed at certain value of V_{gk} . At this stage V_{gk} , becomes a critical potential V_c (pip). The electrons acquire sufficient energy at this potential V_c and, suffer inelastic collision with the atoms of vapour (gas). Most of the energy of electrons will be transferred in this process to the atoms of vapour (gas) and, the speed of electrons falls i.e. the colliding electrons are absorbed and re - emitted with almost zero energy. As the electrons has very little or less energy, they can not penetrate the retarding field and, fall in current is observed. The point of V_{gk} at where the excitation takes place is called as peak current point I_p (pip). and

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where current falls back is called valley current or I_v (dip). The voltage at I_p is equal to critical voltage V_c and can be treated as V_{c1} .

Increasing V_{gk} , further cause to increase current again, till next V_c occurs, can be designated as V_{c2} . The presence of the first dip at grid potential $V_{gk} = V_c$, shows that the electrons are throughout accelerated between grid and cathode. They acquire the critical energy for the inelastic collision only when they reach the grid - anode space. After first inelastic collision, they move at smaller distance between grid (G) and cathode (K). Thus another collision occurs at $V_{gk} = V_{c2}$. Hence the value of critical potential between point V_{c1} and V_{c2} is equal to V_c ($V_{c2} - V_{c1} = V_c$). Other dips - dips to signify critical potentials shall be observed for the value of $V = nV_c$, where n may be 1, 2, 3 or 4, depends upon successive peaks.

Franck - Hertz experiment shows that the electrons transfer energy to the atoms in discrete amounts and, that the atoms can not be excited if the accelerated electrons possess energy less than eV_c .

Limitations : Atoms have more than one excitation potentials and an ionisation potential. This method is not able to distinguish between both.

The actual value of excitation potential is slightly lower than the observed voltage, because the velocity of emission is not zero.

Flipping stage is fast enough (in ms order) so point measurement is difficult.

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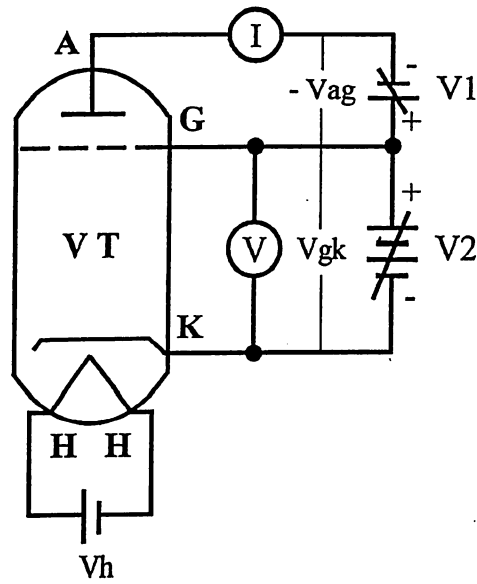


Fig 1 : Diagram of experiment. VT is gas filled electronic valve.

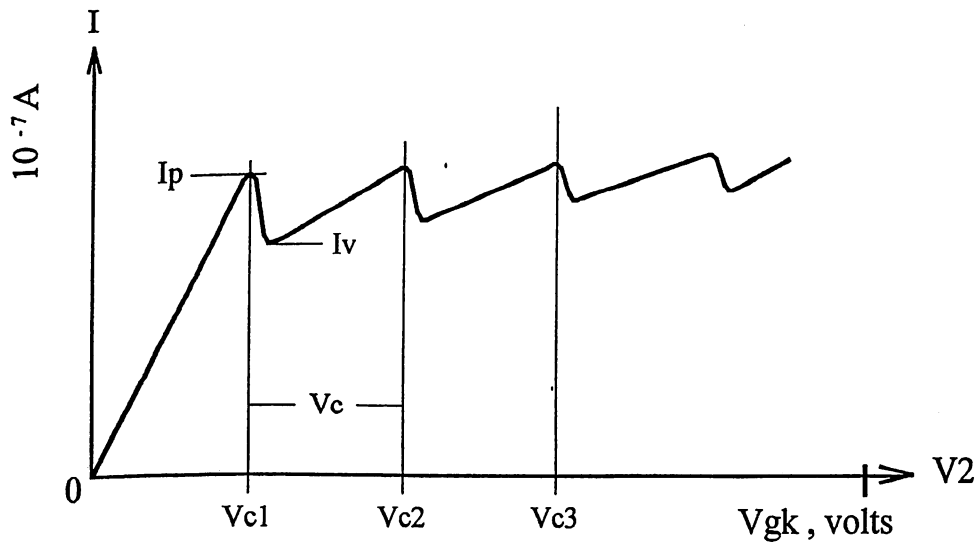
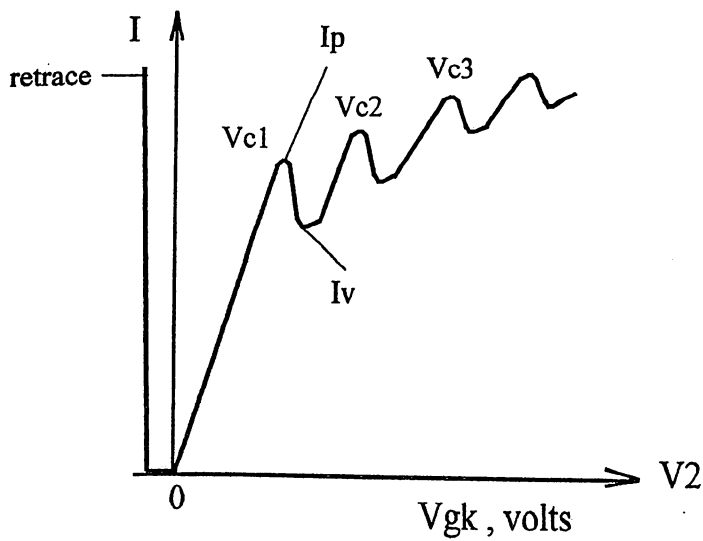


Fig 2 : Typical excitation potential V_c v/s I curve. Below CRO observation.



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Procedure 1: Experiment with manual operation.

The electronic tube is fitted in base inside the cabinet (close to right hand side cover).

1. Select OFF at MODE selector. Keep both supply controls at zero.

2. Switch on power. Wait about five minute to preheat the tube.

3. Now select the MODE, at V1. There will be some current displayed in uA meter.

Adjust the supply V1, till current becomes zero. This will adjust retarding potential

V_{ag} (about negative 2.0 - 2.5 volt). Leave V1 here.

4. Now select MODE to V2. Adjust V2 supply slowly and, note corresponding voltage / current from the given meters.

5. As first critical potential arrive, where first inelastic collision occurs, slowly adjust V2 and note voltage as V_{c1} , at where the current falls suddenly. This will give V_{c1} value.

6. Increase V2 further and note other critical voltage values with current. Plot curve between the voltage and current to obtain the values of nV_c . Observe the n is a number 1,2,3 etc for V_{c1} , V_{c2} , V_{c3} . The V_c is found from find out from the differential and mean value of critical potential value (about 11V).

Note : if uA read some current (+ve) adjust V1 to -3V. If uA still reads current, bring $V_1 = 0$ and, adjust it to zero by mean of screw driver adjustment in given hole '0'.

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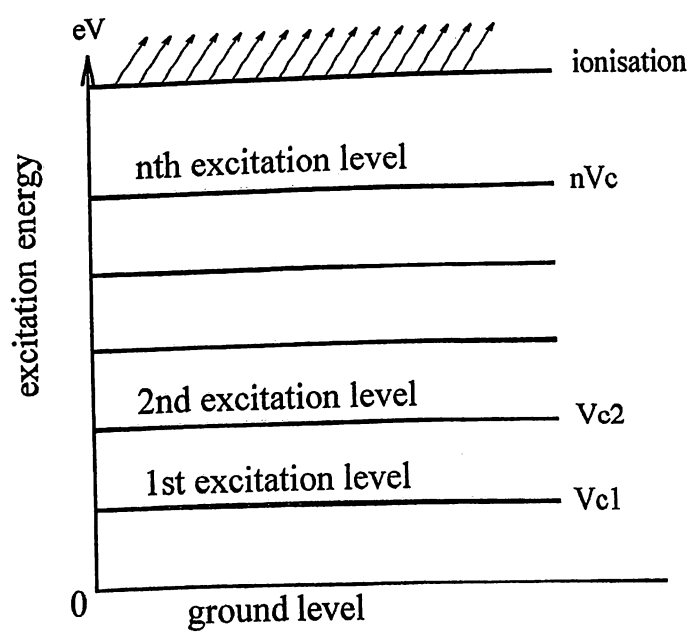
Procedure 2: Experiment with CRO.

Other app req : A CRO.

Connect CRO, X, Y and ground inputs to given 'scan output' terminals.

1. Select OFF at MODE selector. Keep both supply controls at zero.
2. Switch on power. Wait about five minute to preheat the tube.
3. Now select the MODE, at V1.
4. Adjust the supply V1, till voltmeter read - 2.5V. Leave it here.
5. Now select SCAN mode from MODE selector. A trace will appear upon CRO screen. Note there is retrace line visible at screen, which can be removed if CRO has a Z input with +ve unblank input. In this case the Z input should be connected with given unblank sockets at rear side of cabinate.

CRO constant : X - 1V div and Y - 0.5V/div.



Typical excitation and ionisation levels of atoms.