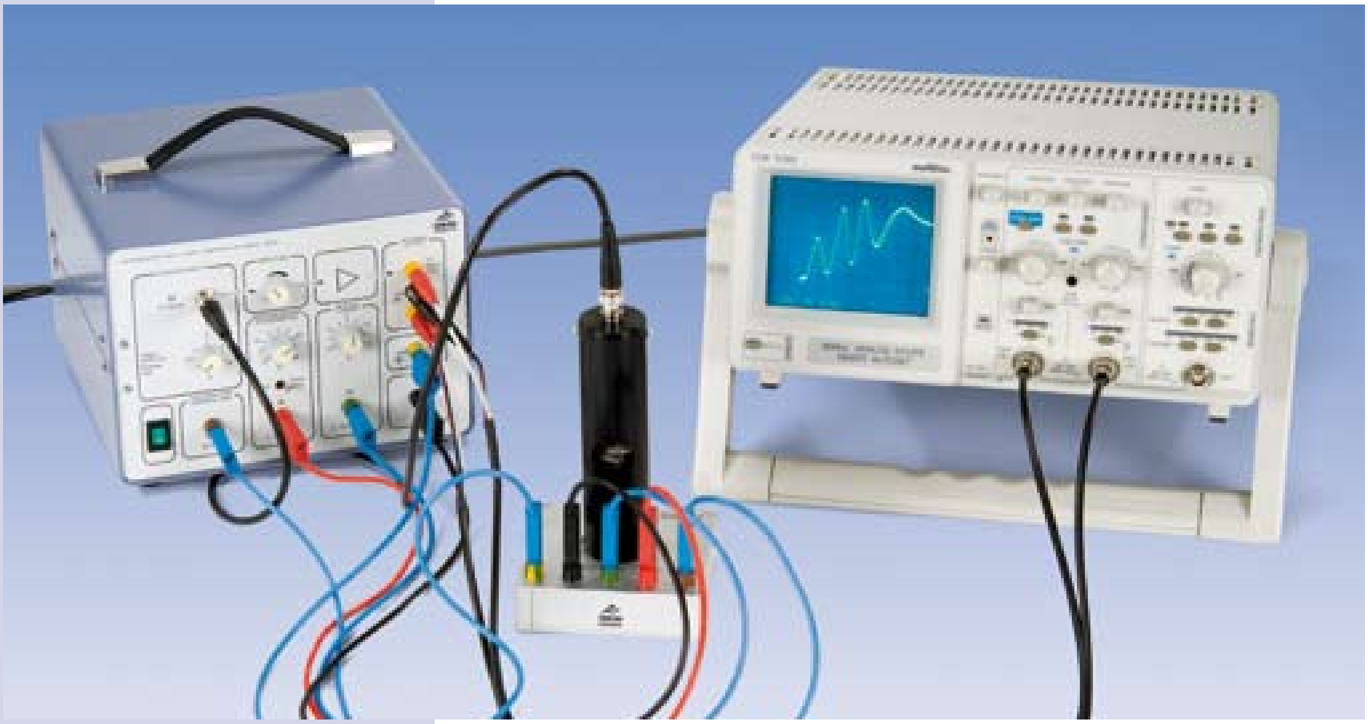
UE502040

Franck-Hertz Experiment for Neon



EXPERIMENT PROCEDURE:

- **Measure target current *I* as a function of the voltage *U* between cathode and grid.**
- **Compare the distribution of current maxima with the excitation energies of neon atoms.**
- **Observe the light emitted by the excited neon atoms.**
- **Determine the number of light-emitting levels for various accelerating voltages.**

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OBJECTIVE

Record and evaluate the Franck-Hertz curve for neon and observe emission of light.

SUMMARY

The Franck-Hertz experiment for neon involves observing how energy is transferred from electrons as a result of inelastic collision while pass-ing through neon gas. The transfer of energy occurs in discrete steps corresponding to the excitement by such collision of distinct energy level transitions in the neon atoms. The excited atoms then emit visible light.

REQUIRED APPARATUS

Quantity	Description	Number
1	Franck-Hertz tube with Ne filling	**U8482220**
1	Power supply unit for Franck-Hertz experiment, for 230 V AC	**U8482130-230** or
	Power supply unit for Franck-Hertz experiment, for 115 V AC	**U8482130-115**
1	Analog oscilloscope, 2 x 35 MHz	**U11175**
1	Digital Multimeter	**U11809**
1	High-frequency patch cord, 1 m	**U11255**
2	High-frequency patch cords, BNC / 4-mm-plug	**U11257**
1	Set of 15 safety patch cords, 75 cm	**U13802**

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BASIC PRINCIPLES

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:

An evacuated glass tube that has been filled with neon gas to a pressure of 10 hPa contains a heated cathode C, a control grid S, a grid G and a target electrode A arranged in that sequence (see Fig. 1). Electrons are emitted from the cathode and are accelerated by a voltage U towards the grid. Having passed through the grid they reach the target and thus contribute to a target current I if their kinetic energy is sufficient to overcome a decelerating voltage U_{GA} between the grid and the target.

The $I(U)$-characteristic (see Fig. 2) has a similar pattern to the original Franck-Hertz experiment using mercury gas but this time the intervals between minima where the current falls to almost zero for a specific voltage $U = U_1$ 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 observe 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 I rises once more.

For a higher voltage $U = U_2$ the target current also drops drastically and it is possible to see two zones of illumination. The electrons can in this case retain enough energy after an initial collision to excite a second neon atom.

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

EVALUATION

The $I(U)$-characteristic exhibits various maxima and minima and the interval between the minima is about $\Delta U = 19$ V. This corresponds to excitation energy of the 3p energy level of a neon atom (see Fig. 3) so that it is highly likely that this level is being excited. Excitement of the 3s-level cannot be neglected entirely and gives rise to some fine detail in the structure of the $I(U)$-characteristic.

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 U is increased by about 19 V.

NOTE

The first minimum is not at 19 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 (U21877) when the maximum voltage U is used.

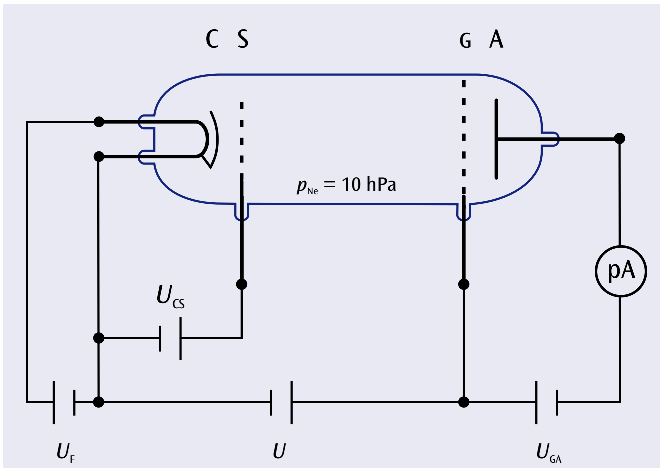

Fig. 1: Schematic of set up for measuring the Franck-Hertz curve for neon

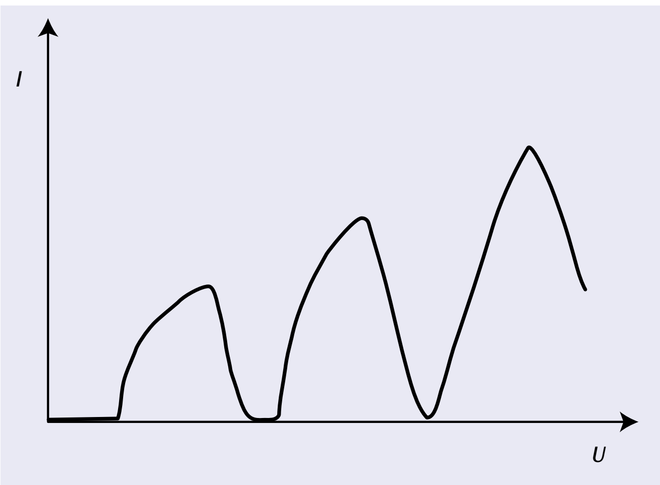

Fig. 2: Target current I as a function of the accelerating voltage U

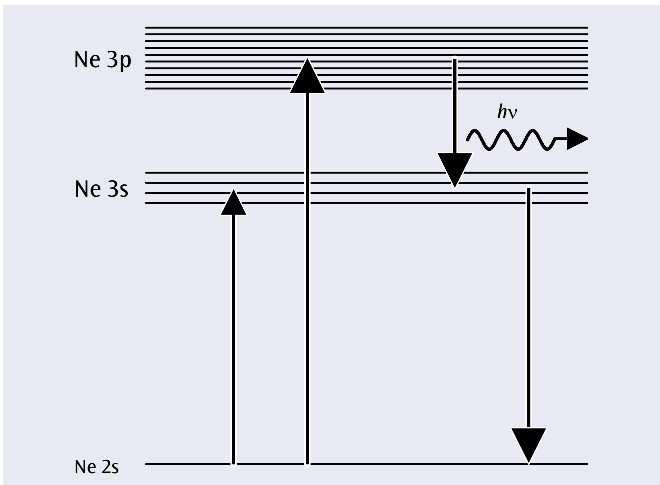

Fig. 3: Energy levels in neon atoms

Phys 232 – Franck-Hertz Experiment

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Pre-lab Assignment

Question 1: Suppose that a 70 V electric potential difference is maintained between two parallel plates that are separated by 5 mm. An electron is released from rest next to the lower potential plate. What is the speed of the electron when it reaches the higher potential plate? How long does the electron take to reach the higher potential plate?

Question 2: Briefly summarize Bohr's model of the atom by stating Bohr's postulates.

Experiment

This experiment uses a sealed tube from which the air has been evacuated. The tube has in turn been filled with a small amount (low pressure) of neon gas. Also, inside the tube are various electrodes. As shown in Fig. 1 on the previous page, there is a cathode C from which electrons are liberated by thermionic emission. These electrons are accelerated between the grids S and G. Between the grids, the electrons collide with neon atoms and exchange energy. Finally, electrons that have sufficient energy to overcome the stopping potential between the second grid G and the anode A are collected and generate a detectable electron current which is the proportional to the Franck-Hertz signal.

The voltages for the neon tube are all supplied by a single control unit. Make the necessary connections using appropriate banana cables and BNC (coaxial) cables. **Make sure that all of the connections are made properly before turning on the control unit**. **An improper connection could irreparably damage the neon tube**!

You will acquire your signal using an oscilloscope. In typical operation, an oscilloscope displays the input voltage as a function of time. For this measurement you will use the oscilloscope in the so-called xy-mode in which the voltage input to CH2 is plotted as a function of the voltage input to CH1. Setup the oscilloscope such that you display the Franck-Hertz signal (proportional to the anode current) as a function of the accelerating (grid) voltage.

Tune the various parameters (heater/filament/cathode voltage, stopping potential, signal amplitude control/amplifier gain, accelerating voltage) to get the best possible signal. Then experiment to investigate and then answer the following questions:

- What neon excitation energy are you observing? Give your answer in electronvolts and in Joules.
- What is the effect of tuning the heater voltage? Do your observations seem reasonable? Explain why.
- What is the effect of tuning the stopping potential? Do your observations seem reasonable? Explain why.
- Why is the stopping potential necessary? What happens when the stopping potential is set to zero?
- What is the effect of tuning the amplitude control? Do your observations seem reasonable? Explain why.
- Look at the exposed part of the Franck-Hertz tube. Can you see a visible emission? What causes this glow?
- *Carefully* observe what happens to the glow as you vary the range of the accelerating voltage? Start with a low accelerating voltage and slowly increase it using small increments. Neatly sketch in your lab notebook what you observe. Give a physical explanation for you observations.
- When the neon atoms de-excite photons or light is emitted. From your measured excitation energy calculate the wavelength you expect for the emitted light.
- Does your calculated wavelength match the colour of light that you observe? If not, what's the resolution of this apparent contradiction? (See the comment below.)

Finally, a schematic of the electron energy levels of neon is given on the course website in the supplemental material for this experiment. From this diagram and the reading, explain why the excitation energy you measured does not correspond to a wavelength that matches the colour of light that you observed.

Day 2

You may complete most of the above on day 1 of the experiment. On day 2 of this experiment, you will investigate the wavelength of light emitted by excited gases. You will use a spectrometer and the Vernier software Logger Pro to examine intensity of visible light emitted as a function of wavelength. First, you will study the light emitted by the neon atoms inside of the Franck-Hertz tube. Compare your observations to the neon energy level diagram found within the "additional reading" available in the supplemental material posted on the course website.

You will also be provided with a mercury light source. Just as in the Franck-Hertz apparatus, the mercury atoms are excited by electrons accelerated through a potential difference. Use the spectrometer to determine which wavelengths are found in the emitted light. Again, compare your observations to the energy level diagram supplied in the "additional reading". **Do not stare into the light emitted by the mercury lamp. The spectrum emitted light contains some ultraviolet (UV) light which can be harmful to your eyes.** When using to mercury source, keep it underneath a "blackout" felt and probe the emitted light by pointing the free end of the fibre of the spectrometer beneath the felt sheet.

Finally, you will also be provided with a hydrogen lamp. To prepare yourself, read about the energy levels of the hydrogen atom and find an expression that will allow you to calculate the difference in energy between distinct energy levels. Based on this expression, predict which transitions are expected to result in the emission of visible light. What are the initial and final energy levels and the corresponding wavelengths of the emitted light? Try verifying your predictions using the visible-light spectrometer.