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Determination of Mass of Electron

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Abstract— We present an efficient way to compute the mass of the electron, a fundamental particle of matter. The main goal of our work is to find out the mass of electron without depending on its charge and specific charge. Still, in this modern era, the mass of the electron is found out complicatedly by using the conclusion of Millikan's oil drop experiment and JJ Thompson's experiment which contains some limitations. Our theory is mainly based upon Einstein's photoelectric effect and a simple equation of kinematics. From our experiment, we can measure the mass of the electron by just measuring the time taken by the electron to travel from cathode to fluorescent screen kept at a certain distance when radiation of suitable frequency is incident on a metallic surface. Our study is based on the assumption that when radiation of frequency a bit more than the threshold frequency is incident on suitable metal, the electron may move with velocity small enough that the time taken by photoelectrons to travel a certain distance can be measured precisely with quartz or atomic clock. We can then conclude whether the value of the mass of an electron that we are using from decades is actually correct or not

Index Terms— Anode, Cathode, Distance, Electron, Evacuated Tube, Fluorescent Screen, Frequency, Kinetic Energy, Mass, Photoelectric Effect, Radiation, Threshold, Time, Velocity, Voltage, Work Function.

1 Introduction

THE emission of the electrons or other carriers when light of certain frequency falls on metal is known as the photoelectric effect, and the emitted particles are known as photoelectrons. This is an area which is overlooked by everyone and is commonly studied in atomic physics. Up to now, using charge of an electron from Millikan's oil drop experiment and specific charge of an electron from J J Thompson's experiment, the mass of an electron is calculated as, M= e/(e/m). But in Millikan's experiment, the voltage used could have been weaker than it is now as today voltage is much stronger. Furthermore, he used electrons from oil drop only [1]. If he were to use electrons from a different source, he could have possibly encountered different values. In J J Thompson's experiment, it is very difficult to maintain the cross field. So, the value of the mass of electron may have certain errors. Our experiment is an improvement upon the previous research. All researchers are always built up around some assumption. So, our study is based on the assumption that when radiation of frequency a bit more than the threshold frequency is incident on suitable metal, the electron may move with velocity small enough that the time taken by photoelectron to travel a certain distance can be measured precisely with an atomic clock.

2 Theory

Before every experiment, we need a theoretical concept to support it. So, in this experiment, we begin from the photoelectric equation by separating mass in one side and other physical quantities on the other side.

Mathematically, from photoelectric effect,

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We have,

$$E = \phi + K.E$$

where, E= energy of incident radiation

ϕ= work function of the metal

$$h\nu = h\nu_0 + {}^{1}/_{2}\, mv^2$$

$$h(\nu - \nu_0) = {}^{1}/_{2}\, mv^2$$

So,

$$m = \frac{2h(\nu - \nu_0)}{v^2}$$

where, ν = frequency of incident radiation

ν_0= threshold frequency of taken metal which is constant quantity

h= value of plank's constant i.e. h=6.626 069 83(22) ×10−34Js.[2]

v= velocity of emitted electron

We can find the velocity of photoelectrons by a simple equation,

$$v = {}^{d}/_{t}$$

where, d= distance between cathode and fluorescent screen

t= time taken by an electron to cover distance 'd'

Therefore,

$$m = \frac{2h(\nu - \nu_0)t^2}{d^2}$$

Thus, by knowing the values of physical quantities mentioned in the above equation, we can easily and efficiently find out the mass of an electron.

3 Methodology

This method is based on the photoelectric effect. In this experiment, an evacuated tube containing cathode of pure metal with certain threshold frequency and an anode having a small hole is taken. Cathode and anode are connected in parallel with a voltmeter and in series with ammeter which then connected to a high voltage battery through a rheostat as shown in Fig.1.

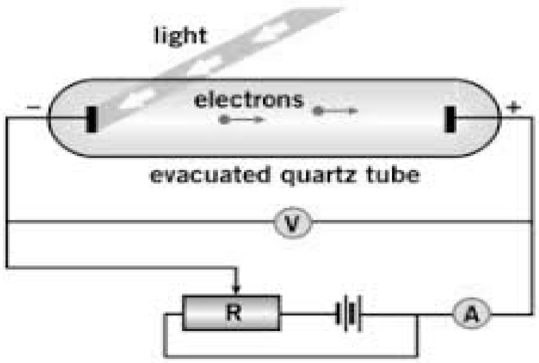

Fig. 1. Einstein photoelectric effect.

The light source of frequency just a bit more than the threshold frequency is incident on the cathode so that the velocity of emitted electrons will be less. In order to maintain the difference between the incident frequency and threshold frequency, we can use light with controlled frequency as per the threshold frequency of the metal used as different metal has different threshold frequency as shown in Table 1.

TABLE 1
THRESHOLD FREQUENCIES OF DIFFERENT METALS [3]

Metals	Threshold Frequency (Hz)
Sodium	8.174×10^{14}
Zinc	1.293×10^{15}
Copper	1.376×10^{15}
Platinum	1.785×10^{15}
Calcium	9.615×10^{14}

Hz = Hertz

As the velocity of the emitted electron is quite high and the distance from cathode to anode is too short, we get a very small value of time which is very difficult to measure. In order to overcome this difficulty, we can use a long-evacuated tube with a fluorescent screen at the end as shown in Fig.2. which helps us to increase the effective distance without increasing the distance between cathode and anode. As a result, it increases the time and can be easily measured with an atomic clock.

An atomic clock is a clock device that uses an electron transition frequency in the microwave, optical, or ultraviolet region of the electromagnetic spectrum of atoms as a frequency standard for its timekeeping element.[4] The best cesium frequency standards are so much more reproducible that the rate of rotation and revolution of earth that in 1967 the second was defined as 9,192,631,770 [5] periods of the resonance frequency of the cesium-133 atom. National standards agencies in many countries maintain a network of atomic clocks which are intercompared and kept synchronized to an accuracy of 10−9 seconds per day (approximately 1 part in 1014). After measuring all the physical quantities required and putting them in the given equation, we can find out the mass of an electron.

Fig. 3. Atomic Clock [6]

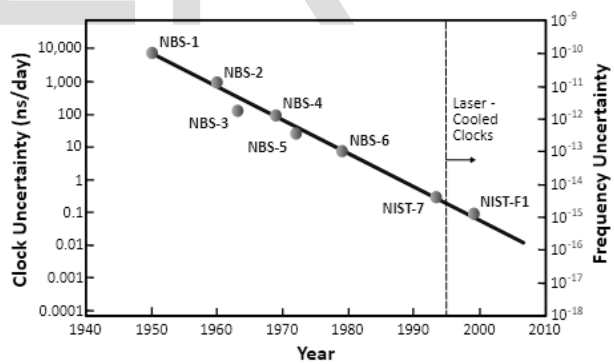

Fig. 4. Accuracy of atomic clock. [7]

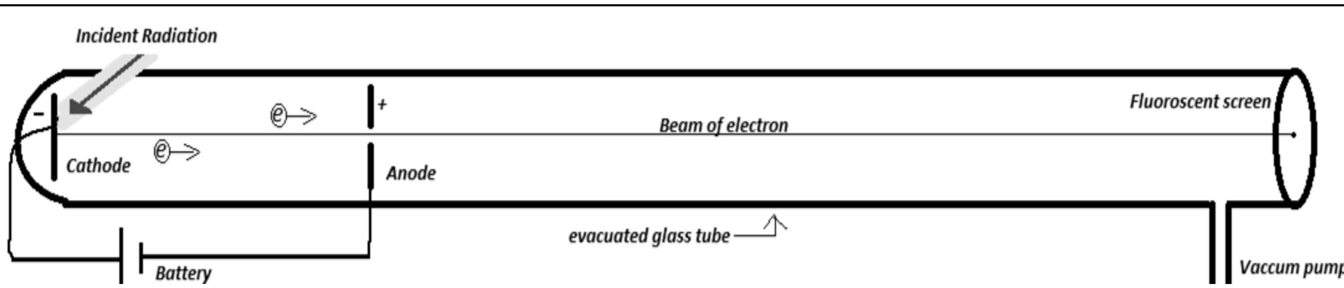

Fig. 2. Complete apparatus with an evacuated tube, a cathode, an anode, battery and fluorescent screen showing the mechanism of the experiment.

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4 Conclusion

By this technique, we can find the mass of the electron in the much simple, efficient and economical way. This is a new enhanced way of finding the mass of an electron, from a simple theory and experiment but there may be some room for improvements.

As our research may not provide the answers of all the queries but it will definitely provide the future lead in the field of photoelectric effect and the fundamental particles.

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