Experiment #5

"To determine the work function of metal by using Richordson's equation"

Apparatus:

- → Two ammeters
- → two Voltmeters
- → L.T Supply
- → connecting wires
- → H.T Supply
- → Hot tungsten Filament
- → Resistor

Procedure: Make connections as shown in figure. Keep the anode potential or plate Voltage constant. Now increase the Filament Voltage in regular steps and note down the corresponding readings of Filament current I_F. Calculate value of Filament resistor R_t using ohm's law. After this, calculate time by formula

$$t = \frac{R_t - R_o}{\alpha R_o}$$

Plot the graph between $1/T$ and $\log I_p/T^2$ while $T = t + 273$. From graph, calculate the value of work function ϕ.

Theory:

Ohm's Law

The current flowing through

a conductor is directly proportional to the potential difference across ends provided the physical state such as Temp etc. of the conductor remains constant."

It implies that

$$V = IR$$

Resistivity and its dependance upon Temperature.

It has been experimentally seen that the resistance R of wire is directly proportional to its length L and inversely proportional to its cross-sectional area A. Expressing mathematically we have

$$R \propto \frac{L}{A}$$

$$R = \rho \frac{L}{A} \quad \text{—— (1)}$$

Where ρ is the constant of proportionality known as Resistivity. Specific resistance of material of the wire. It may be noted that resistance is the characteristic of a particular wire whereas the resistivity is the property of the material of which the wire is made. from eq (1) we have

$$\rho = RA/L$$

The above eq gives the definition

of resistivity as resistance of meter cube of material. The SI Unit of resistivity is ohm-meter (Ωm)

Conductance is another quantity used to describe the electrical properties of materials. Infact conductance is resiprocal of resistance.

Conductance = 1/Resistance (R)

The SI unit of conductance is mho/Siemen. Likewise conductivity, σ is the reciprocal of resistivity.

$$\sigma = 1/\rho$$

The SI unit of of conductivity is $ohm^{-1}m^{-1}$ or mhm^{-1}

The resistivity of a substance depends upon the temperature also. It may be explained by recalling that the resistance offered by a conductor to the flow of electric current is due to collisions, which the free electrons encounter with atoms of lattice. As the temp of the conductor rises, the amplitude of vibration of the atoms in the lattice increases and hence, the probability of their collision with free electrons also increases. One may say that the atoms then offer a bigger target, that is, the collision cross-section of atoms increases with

with temp. This make the collisions between free electrons and the atoms in the lattice more frequent and hence, the resistance of the conductor increases.

Experimentally the change in resistance of a metallic conductor with temp is found to be linearly over a considerable range of temp. above and below 0°c. over such a range, the fractional change in resistance per kelvin is known as the temperature coefficient of resistance.

$$\alpha = \frac{R_t - R_o}{R_o t} \quad \text{---} (2)$$

where R_o and R_t are resistance at temp 0°C and t°C As resistivity ρ depends upon the temp from eq (1)

$$R_t = \rho_t L/A \quad \text{and} \quad R_o = \rho_o \frac{L}{A}$$

put values of R_t and R_o in eq(2) we get

$$\alpha = \frac{\rho_t - \rho_o}{\rho_o t}$$

where ρ_o is the resistivity of a conductor at 0°C and ρ_t is resistivity at t°C.

The emission of electrons from a metal surface when exposed to light of particular frequency is called photoelectric effect The emitted electrons are known as photoelectrons.

Work function:
The work function represents the energy needed to remove the least ~~one~~ tightly bound electrons from the Surface.
When a photon is incident on metal surface, a part of photon energy (work function) is used by electron to break away from the metal and the rest appear as K.E of electron that is,
Incident photon Energy − Work function = Max K.E of photoelectron

$$hf' - \phi = \frac{1}{2}mv^2_{max}$$

This is also known as Einstein's photoelectric equation.

Thermionic Emission: Thermionic emission is the thermally induced flow of charge carriers from a surface or over a potential energy barrier. This occur because the thermal energy given to the carrier overcomes the work function of the material the Charge carrier can be electrons or ions, and in order literature are sometimes referred as thermions. After emission, a charge that is equal in magnitude and opposite in sign to the total Charge emitted is initially left behind is neutralized by charge supplied by the battery as the emitted charge carrier move away from the emitter and the finally the emitter will be in same state as it was before emission.

Factors affecting the rate of thermionic emission:

(1) **Surface of metal:** Rate increases as the size of surface increases, larger surface area allow more electrons to be emitted.

(2) **temperature of metal:** Rate increases as temp of metal increases. Higher temp allows more electrons to gain sufficiencet K.E to break free from the nucleus (the metal surface).

Types of metal: Rate depends on type of metal. If temp remains constant, different types of metals require different amount of energy to eject electrons.

Nature of metal surface: Rate increases when metal is coated with metal oxide. Metal oxide such as Barium oxide and Strontium oxide emit electrons at lower temp.

Richardson's Equation

Following J.J Thomson's identification of the electron in 1897, the British physicist owner willans Richardson began work on the topic that he later called the thermionic emission. He received a noble prize in physics in 1928 for his work on the thermionic phenomenon and especially for the discovery of law named after him.

This eq. Later called Richardson-Dushman equation and this equation relates the current density of a thermionic emission to the work function and Temp. (T) of the emitting material.

$$j_s = AT^2 \exp(-W/kT)$$

Where j_s is the current density of the emission (mA/mm²), A is Richardson's constant and $A = 1202\ mA/mm^2K^2$. m is the mass of electron, e is elementary charge and h is Plank's constant.