Department of Electrical Engineering

Final Term Assignment Summer 2020

Applied Physics

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16469

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Max Marks: 50
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Q1: a) What is meant by the term Work done? Derive equations for positive and negative work done. (5 Marks)

b) An object weighing 32 N is pulled with a force of 45 N with a rope which is making an angle of 45 degrees with the direction of motion of the object. The object moves 50 meters along the ground, calculate the work done in pulling the object? (5 Marks)

Q2 a) State and mathematically explain Coulomb's law. Apply Coulomb's law to discuss role of the material medium in between the charges. (5 Marks)

b) Explain using diagrams and mathematical expressions concept of electric flux. (5 Marks)

Q3) a) Describe the existence of magnetic force on electric current carrying conductor in a magnetic field. Obtain equation for the force. (5 Marks)

b) What is the force per meter length on a wire carrying 1.2 A current in a 0.75 T magnetic field? (5 Marks)

Q4) a) Give electrical classification of solids, give three examples for each type of material. (5 marks)

b) Distinguish between intrinsic and extrinsic semiconductors. Give example of each material used for these purposes. (5 marks)

Q5) What is photoelectric effect? How it is experimentally studied? What are the major features of photoelectric effect, describe by giving examples? (10 marks)

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Q1 (a) **Work :-**

In ordinary language the word "work" means almost physical or mental activity but in Physics it has only one meanings:

Work is said to be done only when a force (F) produces motion.

The work done by a force (F) on a body is defined as the product of the force (F) and the distance (s or d) moved by the body in the direction of the force (F).

The scaler or dot product of force and displacement is called work, so, work is a scaler quantity. and its SI unit is joule (j).

Work = Force x Distance moved in the direction of the force

$$W = FS$$

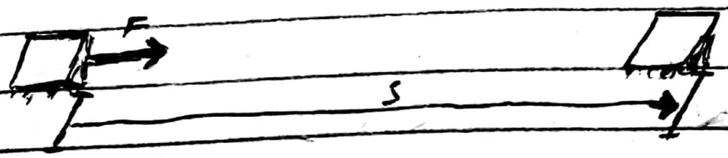


figure shows a constant force (F) applied to a body and displaces a body through a distance (s or d) in its own direction.

Examples :-

① when an engine moves a train along a railway line, it is said to be doing work.

② Horse pulling a cart is also doing work.

③ A man climbing the stairs of a house is doing work.

Equation for positive work:-

we know that

$$W = FS\cos\theta$$

In particular if $\theta = 0°$

$$W = FS\cos(0)°$$

~~W = FS cos 1~~

$$W = FS(1) \qquad \because \cos 0° = 1$$

$$\boxed{W = FS}$$

Equation for negative work:-

we know that

$$W = FS\cos\theta$$

In particular if $\theta = 180°$

$$W = FS\cos(180°)$$

$$W = FS(-1) \qquad \because \cos 180° = -1$$

$$\boxed{W = -FS}$$

Q1 (b)

Given data:

Weight of the object, $W = mg = 32N$

force applied $F = 45N$

Distance covered by the object $S = 50m$

Angle between the direction of the force and the direction of the displacement, $\theta = 45^\circ$

Required data:

Work done, $W = ?$

Solution:

Using the equation

$$W = FS\cos\theta$$

$$= (45N)(50m)(\cos 45^\circ)$$

$$= (45N)(50m)(0.707)$$

$$= 1590.75\ Nm$$

$$W = 1590.75\ Nm$$

Q2
(a) ~~Stat~~ Statement :-

This law states that two stationary point charges q_1 and q_2 repel or attract each other with a force which

(a) is directly proportional to the product $q_1 q_2$ of the magnitude of the charges,

(b) is inversely proportional to the square of the distance r between them,

(c) Acts along the line joining the charge

Mathematical form

Let q_1 & q_2 be two stationary point charges separated by a distance (r). According to the coulomb's law the force (F) between two stationary points charges is given by.

$$F_e \propto q_1 q_2$$

And

$$F_e \propto \frac{1}{r^2}$$

There fore

$$F_e \propto \frac{q_1 q_2}{r^2}$$

$$F_e = (\text{constant}) \frac{q_1 q_2}{r^2}$$

$$\boxed{\vec{F_e} = K \frac{q_1 q_2}{r^2} \hat{r}}$$

where K is the constant of proportionality known as coulomb constant.

$$K = \frac{1}{4\pi\varepsilon_0}$$

$$\vec{F_e} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \hat{r}$$

Applying coulomb's law in material mediam

Dielectric

A material in which all the electrons are tightly bound to the nuclei of the atoms is called a dielectric (or insulator).

Glass, plastic, mica, oil are examples of dielectrics.

When the medium surronding the charges is not a vacuum but is a non-conducting or dielectric medium then the colomb force between the charges is reduced. The effective coulomb force is now given by:

$$\vec{F_e} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \hat{r}$$

The quantity (ε) is called the permittivity of the material. A material medium with high permittivity reduces appreciably the force between the charges as compared with the vacuum value.

For air, $\varepsilon_{air} \approx \varepsilon_0$

Q2

(b) Electric flux (ϕ)

The electric flux (ϕ) is defined as the scalar or dot product of electric field intensity $\vec{E}$ and the plane surface area $\vec{A}$.

Mathematically we can write,

Electric flux, $\phi = \vec{E} \cdot \vec{A}$

$$\phi = EA\cos\alpha$$

where α is the angle between the direction of electric field intensity $\vec{E}$ and the direction of vector area $\vec{A}$. Physically electric flux represents the number of lines of electric force passing normally (perpendicularly) through a surface.

Condition for maximum flux:

When the surface area is perpendicular to the electric field intensity. Then $\vec{E}$ will be parallel to $\vec{A}$, so that $\theta = 0°$ under this condition flux passing through the surface is maximum. In other words under this condition maximum number of lines of force will normally pass through the surface.

Magnitude of electric flux is given by

$$\phi = EA\cos\theta \quad \because (\theta = 0°)$$

$$\phi = EA\cos 0° \quad \because (\cos 0° = 1)$$

$$\boxed{\phi = EA}$$

Condition for minimum flux:

When the surface area is parallel to the electric field intensity. Then $\vec{E}$ will be perpendicular to $\vec{A}$, so that $\theta = 90°$ under this condition flux passing through the surface is minimum. In other words under this condition no lines of force will pass through the surface.

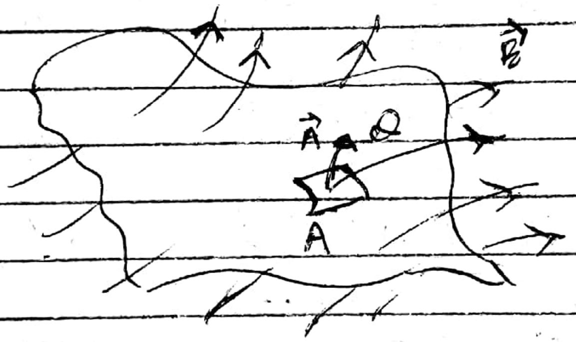
Magnitude of electric flux is given by:

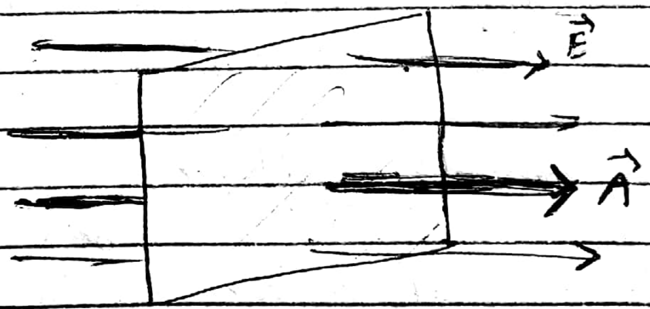
$$\phi = EA\cos\theta \quad \therefore (\theta = 90^\circ)$$

$$\phi = EA\cos 90^\circ \quad \therefore (\cos 90^\circ = 0)$$

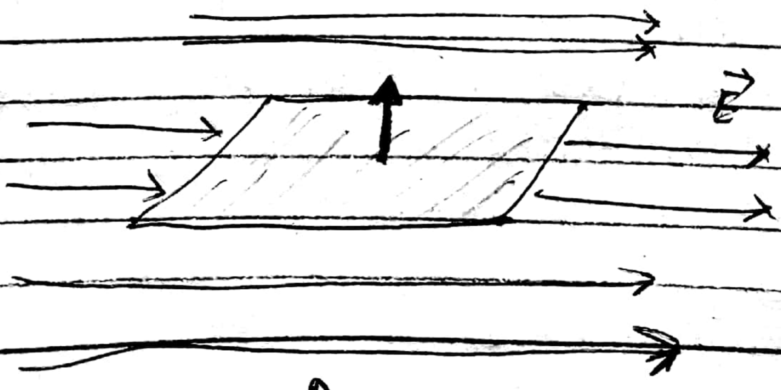
$$\boxed{\phi = 0}$$

Diagrams:-





A_1



A_2

Q3

(a) Force on a current carrying conductor in a uniform magnetic field:

consider a current carrying wire in a region of uniform magnetic field as shown in the figure. It is observed that the wire experiences a magentic force ($\vec{F}$) that is always perpandicular to the magnetic field ($\vec{B}$) and also the current (I). The direction of magnetic force is given by the right hand rule as:

"When the right-hand is held so that the fingers can be curled from the direction of the current into the direction of the magnetic field, the magnetic force points in the direction of the thumb".

It is experimentally observed that the magnitude of the magnetic force on a current carrying conductor depends on the following factors:

① The magnetic force on a current carrying conductor increases with increase in current and decreases in current through the conductor i.e. the magnetic force is directly proportional to current in the conductor.

$$F \propto I \quad \text{—— ①}$$

(2) The magnetic force increases with the increase in length of the conductor.

$F \propto L$ ——— (2)

(3) The magnetic force on a current carrying conductor increases with the increase in the intensity of of magnetic field & vice versa.

$F \propto B$ ——— (3)

(4) If the conductor makes an angle (α) with the direction of magnetic field then the magnetic force on it is proportional to $\sin\alpha$.

$F \propto \sin\alpha$ ——— (4)

Combine equations (1), (2), (3) and (4) we get

$F \propto ILB\sin\alpha$

$F = (\text{constant})\, ILB\sin\alpha$

$F = kILB\sin\alpha$

where (k) is constant of proportionality. In SI units, the value of k is unity. Therefore put $K = 1$

$$F = (1)\, ILB \sin\alpha$$

$$\boxed{F = ILB\sin\alpha} \quad \text{——— (5)}$$

If the wire is perpendicular to the field ($\alpha = 90°$), then the force is maximum and

$$F_{max} = ILB \qquad \therefore (I \perp B)$$

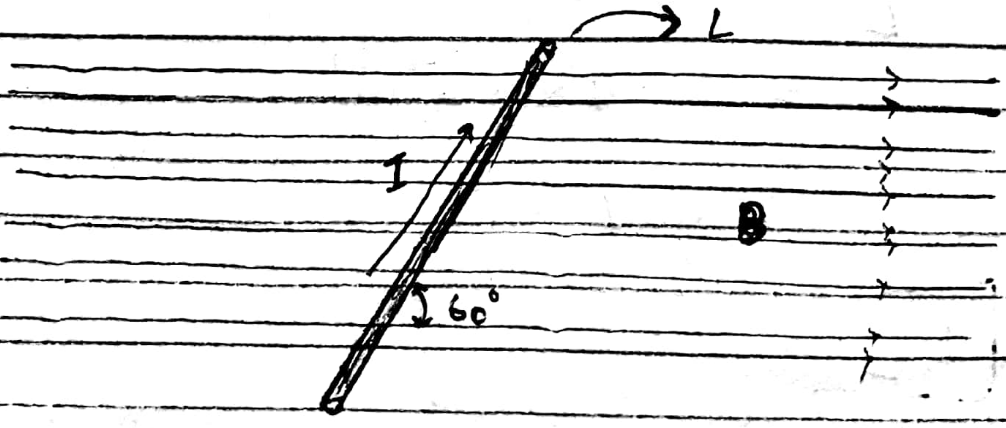
If the wire is parallel to the field ($\alpha = 0°$), then the force is zero.

$$F_{min} = 0 \qquad \therefore (I \parallel B)$$

In vector notations, the above Eq (5) can be written as:

$$\boxed{\vec{F} = I\vec{L} \times \vec{B} = ILB \sin\alpha\, \hat{n}}$$

where $\vec{L}$ is a vector whose magnitude is the length of the wire & whose direction is along the wire (assumed straight) in the direction of the current. The unit vector $\hat{n}$ is along the direction of $\vec{F}$ and is perpendicular the plane defined by $\vec{L}$ and $\vec{B}$.



Q3 (b)

Given data:

Current flowing through the wire, $I = 1.2A$

strength of the magnetic field, $B = 0.75T$

Required data:

Force per meter length, $\frac{F}{L} = ?$

Solution:

We know that

$$F_{max} = ILB$$

so,

The magnitude of the force per unit meter

$$\frac{F}{L} = IB$$

$$\frac{F}{L} = (1.2A) \times (0.75T)$$

$$= 0.9 A N A^{-1} m^{-1}$$

$$= 0.9 N m^{-1}$$

$$F/L = 0.9 \, N/m$$

Q 4
(a) **Electrical classification of solids:**

The fundamental electrical property of a solid is its ability to conduct current. The requirement for electrical for electrical conduction is the presence of free charges within the material. On the basis of electrical properties, solids can be classified as conductors, semiconductors and insulators.

Conductor :-

A substance which offers low resistance to the flow of electric current is called a conductor.

Current can pass easily through conductors. They contain free electrons. Metals such as silver, copper and aluminium are very good conductors. The conductivity of the conductors is of the order of 10^7 mho/m $(\Omega - m)^{-1}$. Their electrical resistivity is of the order of 10^{-7} ohm-meter $(\Omega - m)$.

Example :-

Examples of conductor include metals, aqueous solutions of salts (i.e, ionic compound dissolved in water), graphite and human body.

Insulator:-

A substance which (at a particular voltage) does not allow the flow of electrons (current) through them is called an insulator.

They are very poor conductors of electricity. charges are bound; no free electrons in insulators. Dry wood, diamond, glass, and polythene and most of the non-metals are good insulators. The conductivity of the insulators is very low, ranging between $10^{-10} (\Omega-m)$ to $10^{-20} (\Omega-m)^{-1}$. Their electrical resistivity is of the order of $10^{10} (\Omega-m)$ to $10^{20} (\Omega-m)$.

Example:

Examples of insulators include plastic, styrofoam, paper, rubber, glass and dry air

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Semi-conductors:-

The materials which have their conductivity in b/w those of conductors and insulators are called semiconductors. Elements of Group IV in the periodic table are semiconductors. for example, germanium and silicon are important semiconductors. Their conductivity lies b/w insulator & conductors. They have conductivity in the range of $10^{-4} (\Omega-m)^{-1}$ ~~to~~ $10^{-6} (\Omega-m)^{-1}$.

Q4 (b)

Basis of Difference	Intrinsic Semiconductor	Extrinsic Semiconductor
Doping of impurity	Doping or adding of impurity does not take place in intrinstic Semiconductor	A small amount of impurity is dopped in a pure semiconductor for preparing extrinsictic
Density of electrons and holes	The number of free electrons in the conduction band is equal to the number of holes in the valence band	The number of Free electrons & holes are not equal.
Electrical conductivity	Electrical conductivity is low.	Electrical conductivity is high.
Dependency of electrical conductivity	Electrical conductivity is a function of temperature alone.	Electrical conductivity depends on temperature as well as on the amount impurity doping in the pure semiconductor
Example.	Crystalline form of pure Silicon and Germanium	Impurity like As, Sb, P, In, Bi, Al etc. are dopped with Germainium and Silicon atom.

Intrinsic semiconductor:-

The semiconductor in extremely pure form without any impurity is known as intrinsic semiconductor.

when a covalent bond is broken, an electron-hole pair is generated. The holes and electrons are mobile charges and can take part in electrical condition. The condition due to charges produced by pair generation in pure semi-conducting crystals is known as intrinsic conduction. The intrinsic current level is too low and so sensitive to small changes in temperature to be used for practical devices. pure elemental silicon & germanium are intrinsic semi-conductors.

Extrinsic semiconductors:

Those substances to which some impurities are added to obtain the desired conduction properties are called extrinsic semiconductors.

The dopest semi-conducting materials are called extrinsic semi-conductors.

In order to obtain desired conduction properties, a small amount of impurity is introduced into the pure semiconductor lattice. In practice, pure Ge and Si crystals are doped with minute amount of selected impurities. The doped semiconductors are called extrinsic semiconductors.

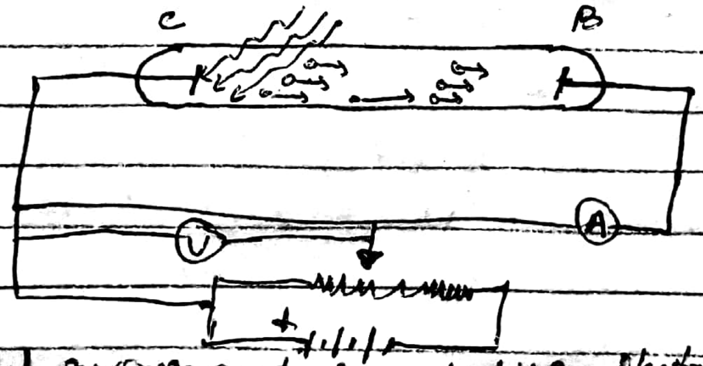
Q5 Photo Electric Effect :-

The phenomenon in which electrons are emitted from a metal surface (photo sensitive plate) when it is illuminated with a high frequency of electromagnetic radiations is called photoelectric effect and the process is called photoelectric emission. The electrons emitted in this process are called photoelectrons and the current produced due to these photo electrons is called photoelectric current.

Modern applications of the photoelectric effects are automatic door openers, burglar alarms, television cameras, exposure meters and many other photo-electronic devices.

Explanation:

The photoelectric effect was first observed by Hertz in 1887. A typical arragement for the study of photoelectric effect is show in figure.



Experimental arrangement for studing photoelectric effect

Light from a source shines on a photosensitive cathode plate C, which emits electrons. Another plate B at a positive potential with respect to the cathode acts as a collector of photoelectron ejected from the cathode. The two plates are sealed in an evacuated tube and are connected externally to a variable voltage source and a sensitive galvanometers or an ammeter. These photo electrons move across the tube to the positive collector and carry current (photoelectric current) through the tube. When the switched off then the current through the circuit will be stop.

photoelectric current is found to depend on two factors:

① The intensity of the incident light (note first it depends on intensity and then frequency).

② The frequency f of the light.

Major features of photoelectric effect:

(i) Threshold Frequency:

No matter how intense the light may be, no photoelectron are emitted, if the frequency of the light is less than a certain minimum frequency f_0. The value of the threshold frequency depends on the nature of the photosensitive cathode. For most metals f_0 is in the blue or UV region of the electromagnetic spectrum.

(ii) Instantaneous Effect :-

Photoelectric effect is an instantaneous process. No matter how weak the beam of light is, if its frequency $f > f_0$, electrons are emitted at the instant the light strikes the cathode; the photoelectric effect occurs at once with no time delay.

(iii) Dependence on light Intensity:

With $f > f_0$, the number of photo electrons from the cathode is directly proportional to the intensity of the light beam. The number of photoelectrons ejected depends upon the intensity of incident light. The maximum kinetic energies of the photo electrons do not depend on the intensity of the light. It depends on the frequency of the incident light.

(iv) Maximum kinetic Energy:

The maximum kinetic energy of the ejected electrons is determined by reversing the battery in the circuit and making the cathode C negative with respect to the collector B. As C is made more and more negative the current rapidly decreases and stops at some define retarding potential V_0 which is called the stopping potential (stopping voltage) detected by the voltmeter.

The maximum kinetic energy lost by an electron of charge (e) in moving up the ~~m~~ retarding potential (V_0) is given by.

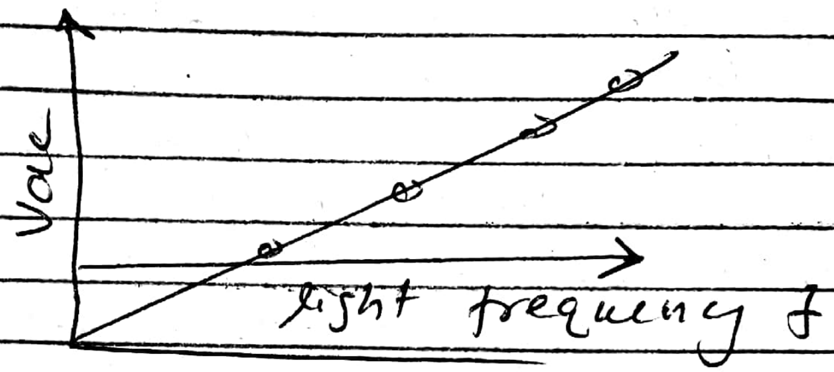
$$(K.E)_{max} = \frac{1}{2} m v^2_{max} = eV_0 \quad \text{—} (A)$$

(v) The maximum kinetic energy is measured for light of different frequencies. The graph of $K.E_{max}$ against the frequency of the light is found to be a straight line as shown in figure

the equation of the line is

$$KE_{max} = eV_0 = hf - hf_0$$
$$= h(f - f_0) \quad \text{—} (B)$$

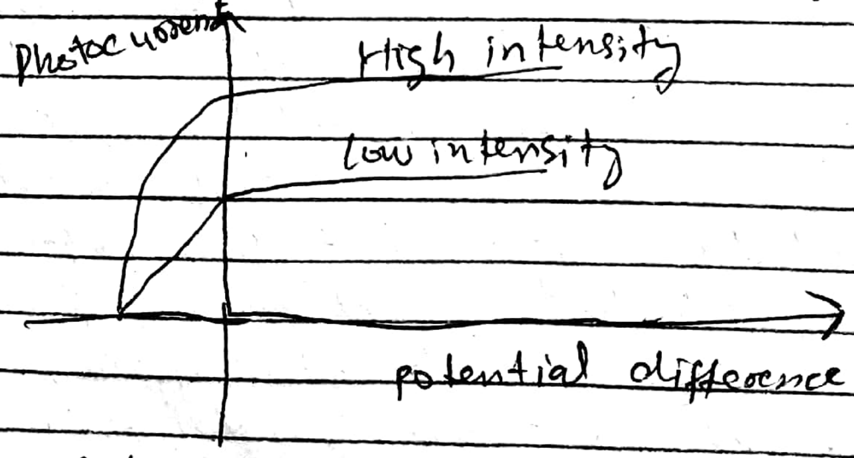
where, h is the slope of the line and f_0 is the threshold frequency.



(VI) The absence of lag time :-

when radiation strikes the target material in the electrode, electrons are emitted almost instantaneously, even at very low intensities of incident radiation. This absence of lag time contradicts our understanding based on classical physics. classical physics predicts that for low-energy radiation, it would take significant time before irradiated electrons could gain sufficient energy to leave the electrode surface; however, such an energy buildup is not observed.

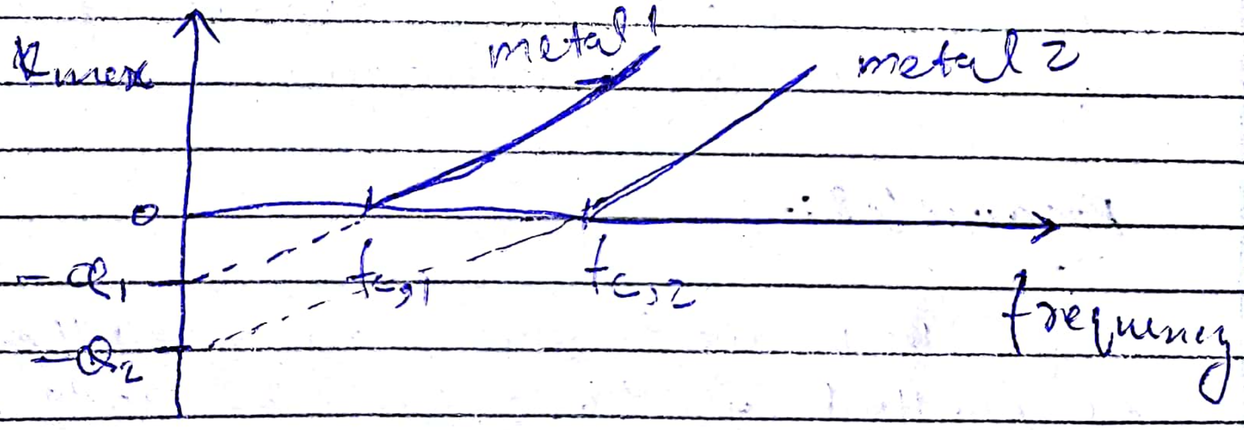
(vii) The intensity of incident radiation and the kinetic energy of photoelectrons:
Typical experimental curves are shown in figure, in which the photocurrent is plotted versus the applied potential difference between the electrodes. For the positive potential difference, the current steadily grows until it reaches a plateau. Furthermore the potential increase beyond this point does not increase the photocurrent at all. A higher intensity of radiation produces a higher value of photocurrent. For the negative potential difference, as the absolute value of the potential difference increases, the value of the photocurrent decreases and become zero at the stopping potential. For any intensity of incident radiation, whether the intensity is high or low, the value of the stopping potential always stays at one value.



The detected photocurrent plotted versus the applied potential difference shows that for any intensity of incident radiation, whether the intensity is high or low, the value of the stopping potential is always the same

(viii) The presence of a cut-off frequency:-

For any metal surface, there is a minimum frequency of incident radiation below which photo~~electric~~ current does not occur. The value of this cut-off frequency for the photoelectric effect is a physical property of the metal. Different materials have different values of cut-off frequency. Experimental data show a typical linear trend (Figure). The kinetic energy of photoelectrons at the surface grows linearly with the increasing frequency of incident radiation. Measurements of all metal surfaces give linear plots with one slope.



Characteristics of photoelectric effect

① The threshold frequency varies with material, it is different for different materials.

② The photoelectric current is directly proportional to the light intensity.

③ The kinetic energy of the photoelectrons is directly proportional to the light frequency

④ The stopping potential is directly proportional to the frequency & the process is instantaneous.

Examples:-

When light shines on a cathode plate, the emitted electrons from the plate hit the anode and create a current. A solar panel is created from linking these together. Also, there was a case where respberry pis, which are very small computers often used by hobbyists, would shout down when someone took a picture of it. It turns out that the camera flashes were causing a photoelectric effect on one of the chips, causing the computer to malfunction.