5.(a)(i) What is a central force field? State any two properties of a central force fields

(ii) Show that the equations of motion for a particle in a central force field $f(r)\hat{r}$ is $m(\ddot{r} - r\dot{\theta}^2) = f(r)$ and $m(r\ddot{\theta} + 2\dot{r}\dot{\theta}) = 0$ in polar coordinates given the radial vector $r = r\hat{r}$.
Use $\frac{d\hat{r}}{dt} = \dot{\theta}\hat{\theta}$ and $\frac{d\hat{\theta}}{dt} = -\dot{\theta}\hat{r}$.

(b) Derive the conditions for stable and unstable equilibrium for a conservative scleronomic system

(c)(i) Show that a quantitative relationship between time intervals in different frames of reference is given by

$$\Delta t = \frac{\Delta t_o}{\sqrt{1 - \frac{u^2}{c^2}}}$$

(ii) Discuss the relativisticity of these speeds $6 \times 10^7\ ms^{-1}$ and $6 \times 10^4\ ms^{-1}$

6.(a) Define the term acoustic impedance Z.

(b) Derive the expression for transmission and reflection coefficient of intensity of sound wave at the boundary of two media in terms of the specific acoustic impedance $Z_1$ and $Z_2$

(c) (i) Show that the wave equation for a stretched string of mass per unit length $\rho$ under a constant horizontal tension $T$ is $\frac{\partial^2 y}{\partial x^2} = \frac{\rho}{T}\frac{\partial^2 y}{\partial t^2}$

(ii) Calculate the phase velocity $c_p$ of a wave in a stretched string of mass per unit length $\rho = 0.025 kgm^{-1}$ if a horizontal force $T = 1200N$ is applied.

7. (a) Using energy band theory, distinguish between conductors and Insulators

(b) i. Explain intrinsic and extrinsic conductivity

ii. With a simple energy band diagram distinguish between n-type and p-type semiconductors.

(c) i. Write a short note on p-n junction diode (with respect to diffusion at the interface, the barrier I-V characteristic)

ii. Describe a Zener diode using the I-V characteristic

iii. With the aid of a diagram explain how an AC voltage can be converted into a smoothened DC voltage using two diodes and one other electronic device.

(d) The net current flowing through a diode is 40 mA when a 0.5 volt forward bias is applied at a junction temperature of 30°C. Calculate the saturation current of the diode

8. (a) i. Write an expression to describe Biot-Savart law.

ii. Show that the magnetic field $B_x$ at the center of a circular loop of radius (y) along the axis through the center, carrying current (I) is $B_x = \frac{\mu_o I}{2y}$.

(b) i. Describe a simple experiment to illustrate Faraday law of electromagnetic induction and state the law.

ii. Calculate the peak value of the emf induced in a 5 cm x 2 cm rectangular coil of 1000 turns, rotating at 1800 rpm (rpm – rev per minute) about an axis at right angle to a magnetic field of flux density 0.05 Weber/m$^2$. ($\mu_o = 4\pi \times 10^{-7}$, $\pi = 3.142$).

9.(a) Explain the following terms: (i) PVT systems, (ii) isochoric process, (iii) isobar process, (iv) Adiabatic process, (v) isentropic process.

(b) Show that the internal energy of 1 mole of the Van der Waal's gas is given by

$U = \int C_V dT - \frac{a}{V}$ + Constant, where $C_V$ is the molar heat capacity at constant volume and V is the volume.

(c) Starting from the first law of thermodynamics and the specific heat capacities at constant volume and pressure respectively, show that $C_p - C_v = \left[\left(\frac{\partial u}{\partial T}\right)_v + p\right]V\beta$, where $\beta$ is the volume expansivity at constant pressure.

(d) Derive the first and second Tds equations. 1 mole of a Van der Waal's equation undergoes a reversible isothermal expansion from $V_i$ to $V_f$. By using the first Tds equation, obtain the heat transferred at 27°C from initial volume of 4m$^3$ to final volume of 12m$^3$. R = 8.314J/mol K, b = 0.015m$^3$

(e) An inventor claims to have devised an engine that produces 1200kJ of work while receiving 1000kJ of heat from a single heat reservoir during a complete cycle of the engine. Which law(s) does such an engine violate?

# PHOTOELECTRICITY

When light falls on metal surfaces, electrons are emitted. This is the photo-electric effect. The emitted electrons are known as photo-electrons. i.e when light (e.g ultraviolet rays) fall on zinc plate electrons are librated from zinc plates: This phenomenon is known as photoelectric emission.

— In general, the emission of electrons as a result of electromagnetic wave falling on the matter is reffered to as photoelectric effect.

— Photoelectric emission occurs when electrons are emitted from surface of metal plates when it is illuminated by light of sufficient high frequency.

* The following important observations were made in the study of the photoelectric effect.

i. Electrons are emitted at the instant the surface is illuminated even with light of very weak intensity.

ii. For each metal there is a well defined frequency called the threshold frequency which must be exceeded for electrons emission to occur, no matter how strong the intensity of light may be.

iii. The maximum kinetic energy of the emitted electrons increases with the frequency of the incident light but is independent of the intensity of light.

This follows that, emission of electrons depends on the threshold frequency, but rate of emission of electrons depends on the intensity of the light.

— Threshold Frequency: is the minimum frequency of the illuminating light which will just be sufficient to cause photoelectric emission. The threshold frequency is not the same for all metals. The energy of the emitted electrons varies from zero to a maximum value.

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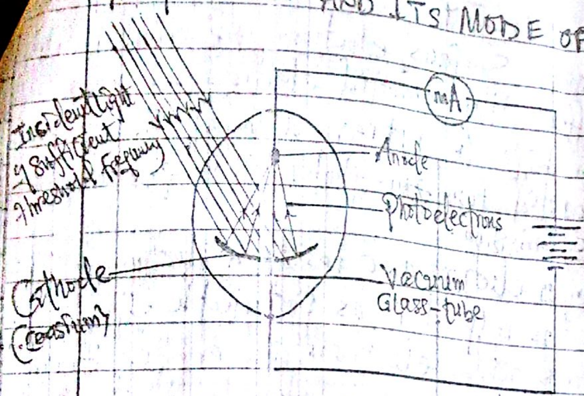
## THE PHOTOCELL AND ITS MODE OF OPERATION




When Light photons incident or fall on the Cathode (i.e caesium metal plate), electrons are emitted which goes to the anode or collector to generate current flow.
When intensity of light varies, the rate of emission of electrons varies. Thus, the flow of current varies.

Explanation of what Happens to energy of Light before Emission of Electrons Begins:
The energy of illuminating Light is absorbed by photo-cell and are used to overcome the force that bind the electron together, but this may not be sufficient to remove the electron until Light with sufficient threshold frequency is attained.
One factor that may affect the number of emitted electron is the Intensity of the Light.

Work Function:
The minimum Energy required to Liberate an electron from the surface of a metal is called the work function of that metal or Binding Energy.
⇒ Work function = $hf_0$, where f is the threshold frequency and h = Planck's Constant.

– Energy of the Illuminating Light $= hf$.
where $f$ = frequency of the light. Part of this energy is used to overcome the work function of the metal (i.e to get the electron free from the atom and away from the metal surface). The remainder of the energy is used to give the liberated electron a kinetic energy, [$E_K = \frac{1}{2}mv^2$] where $v$ is the velocity of the photoelectron of mass, m. The work function, $W = hf_0$.

⇒ Energy of the illuminating Light = Work function + Kinetic Energy of Electrons

⇒ Maximum Kinetic Energy a photoelectron can posses = Energy of the illuminating Light — Work function ——— (i)

⇒ $E_K = hf - hf_0$ [where $E_K = \frac{1}{2}mv^2$]
This is Einstein's Photoelectric Equation.

Note that, the energy of the ejected electron may be found by determining what potential difference (V) must be applied to stop its motion. ——— (ii)
Then, $E_K = \frac{1}{2}mv^2 = eV_s$
The product eV is the electron-Volt.
and $V_s$ is the stopping potential.
– Stopping Potential ($V_s$) is point attain for which no electrons reach the collector (Anode).
⇒ $E_K = eV = hf - hf_0$ ——— (iii)

– Note also that, Number of electrons hitting the anode per second
$= \frac{\text{Current}}{\text{electron Charge}}$.
i.e No of electrons striking the target per sec $= \frac{\text{current}}{\text{electron charge}} = \frac{I}{e}$.

Also, The electric Power Input, $P$ = Current × Voltage $= IV$

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## Examples:

Calculate the frequency of the photon whose energy is required to eject a surface electron with kinetic energy of $1.97 \times 10^{-16} eV$ if the work function of the metal is $1.33 \times 10^{-16} eV$.
$\{1eV = 1.6 \times 10^{-19} J, \; h = 6.6 \times 10^{-34} Js\}$.

Soln

Data: $W = hf_0 = 1.33 \times 10^{-16} eV$
$E_K = 1.97 \times 10^{-16} eV$
$h = 6.6 \times 10^{-34} Js, \; 1eV = 1.6 \times 10^{-19} J$ //

Using $E_K = hf - hf_0$ (Making f the subject of the formula)

$\Rightarrow f = \frac{E_K + hf_0}{h}$ where $E_K = 1.97 \times 10^{-16} eV$
$W = hf_0 = 1.33 \times 10^{-16} eV$
$h = 6.6 \times 10^{-34} Js$.

$\Rightarrow f = \frac{1.97 \times 10^{-16} + 1.33 \times 10^{-16}}{6.6 \times 10^{-34}}$

$= \frac{3.3 \times 10^{-16}}{6.6 \times 10^{-34}} = 5.0 \times 10^{17} eV$ //

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## APPLICATION OF PHOTOELECTRIC EMISSION

- Production of television Camera
- Burglary alarm
- Automatic Switches for putting on Light at dusk
- Industrial Controls and Counting Operations.

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