Makeup Examination September-2023

V-Semester Diploma Examination

Applied Science – 20SC52T

SCHEME & MODEL ANSWERS OF VALUATION

SCHEME OF VALUATION

Course Code : 20SC52T Course: Applied Science

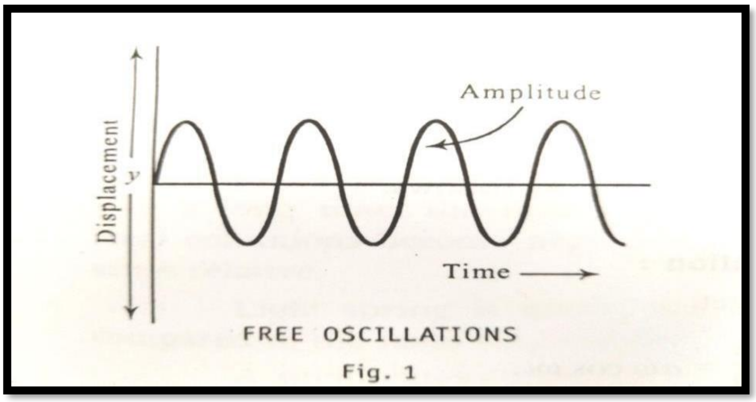
Q.NO	Scheme	MARKS	Q.NO	Scheme	MARKS
SECTION -A					
1(a)	Diagram Hooke's law, + Newton's law Rest	1 1+1 3	2(a)	Diagram Find X_1,X_2,X Rest	2 1+1+1 3
1(b)	Resultant force Rest	3 3	2(b)	Diagram Any four features	2 1X4=4
1(c)	Diagram Construction Working	2 3 3	2(c)	Substitution Finding V Finding Mech Number	2 2 2
SECTION -B					
3(a)	Definition Diagram Any four features	2 2 1X4=4	4(a)	Principle Diagram+ Construction Working	1 2 + 2 3
3(b)	Wein's Law from Plank's law Rayleigh Jeans law from Plank's law	3 3	4(b)	Population Inversion Optical Pumping Meta stable state	2 2 2
3(c)	Explanation Derivation	2 4	4(c)	Diagram Explanation	3 3
SECTION -C					
5(a)	Any three assumption Any three failure	1+1+1 1+1+1	6(a)	Diagram + find V_d using m^* Current Density J + Finding σ	1+2 2
5(b)	Diagram+ Construction Working	2+3 3	6(b)	Diagram Working	3 3
5(c)	Dipole moment / unit volume Internal field Rest	2 2 2	6(c)	Diagram+F_L $J = \rho V d$ & $\rho = B_I / VH\omega$ RH = EH / J B or **RH = 1 / ne**	1+1 2 & 1 1
SECTION -D					
7(a)	Gibb's Energy + ΔG^0 $\Delta G = \Delta G^0 + RTlnK_c$ $E = E^0 - \frac{RT}{nF} ln \frac{1}{[M^{n+}]}$ $E = E^0 + \frac{0.0591}{n} log[M^{n+}]$	1+1 2 2 2	8(a)	Construction Diagram Working	3 2 3
7(b)	Ratio of anodic to cathodic area: Nature of the metal: Nature of the corrosion product Nature of Medium**:**	2 1 1 3	8(b)	Features Oxidation Reaction + Example	4 3
7(c)	Formula + Substitution Calculation	2 3	8(c)	Define Differential aeration. Explain Water line corrosion	2 3
SECTION -E					
9(a)	Definition and each explanation	2+3+3	10(a)	Each source and explanation	(1+3)x2=8
9(b)	Each application	2x3=6	10(b)	Each definition	2x3=6
9(c)	Each impurity	2x3=6	10(c)	Each explanation	3x2=6

I certified that the scheme of valuation is prepared for question paper code 20 SC 52T is correct to the best of my knowledge.

Q.No	Section -A	SCHEME
1a	**Derive the Differential equation for Simple Harmonic Motion.**	

Differential equation of motion of SHM

Consider a body of mass “m” executing SHM.



Consider a body of mass “m” executing SHM.

Let “x” be the displacement of the body under the action of restoring force.

For an oscillating body, from Hooke’s law

$$F = -k\,x \qquad ..... (1)$$

From Newton’s second law of motion, the force experienced by the body under motion is given by

$$F = ma = m\frac{d^2x}{dt^2} \; ....(2)$$

3M

Equating equation (1) and (2),

$$m\frac{d^2x}{dt^2} = -k\,x$$

$$\frac{d^2x}{dt^2} = \frac{-k\,x}{m} \quad …………….. (2)$$

$$\frac{d^2x}{dt^2} + \frac{kx}{m} = 0 \quad \text{OR} \quad \frac{d^2x}{dt^2} + \omega^2 x = 0 \; ...…….(3) \quad \text{where } \omega = \sqrt{\frac{k}{m}} \text{(angular frequency)}$$

This equation is called, equation of motion of SHM

The solution of equation (3) is given by

$$\mathbf{x} = \mathbf{a} \sin \omega t$$

3M

1b	**Derive the Differential equation Damped Oscillations.**	

Consider a body of mass **m** executing damped oscillations in a resistive medium.

The resistive force is proportional to velocity $\frac{dx}{dt}$ of the body and acting in opposite directions.

Therefore, Resistive force = $-\boldsymbol{r}\,\frac{dx}{dt}$ ………………..(1) —

Where, r → damping constant.

From oscillations w.k.t Restoring force = – k x ....(2)

Then,

Resultant force = Resistive force + Restoring forceResultant force

$$F= \; -r\,\frac{dx}{dt} + -kx \quad \ldots\ldots\ldots\ldots(3)$$

2M

From Newton's second law of motion,

$$\text{Resultant force} \quad F = ma = m\frac{d^2x}{dt^2} \quad \ldots\ldots\ldots\ldots\ldots\ (4)$$

Equating (3) and (4)

$$m\frac{d^2x}{dt^2} = -r\,\frac{dx}{dt} + -kx$$

$$m\frac{d^2x}{dt^2} + r\,\frac{dx}{dt} + kx = 0$$

$$\frac{d^2x}{dt^2} + \frac{r}{m}\frac{dx}{dt} + \frac{k}{m}x = 0$$

$$\frac{d^2x}{dt^2} + 2b\,\frac{dx}{dt} + \omega^2 x = 0 \quad \ldots\ldots\ldots..(5)$$

Where $\frac{r}{m} = 2b \;\; and \;\; \omega = \sqrt{\frac{k}{m}}$

This is the equation for damped Oscillation

3M

the solution of equation (5) is given by

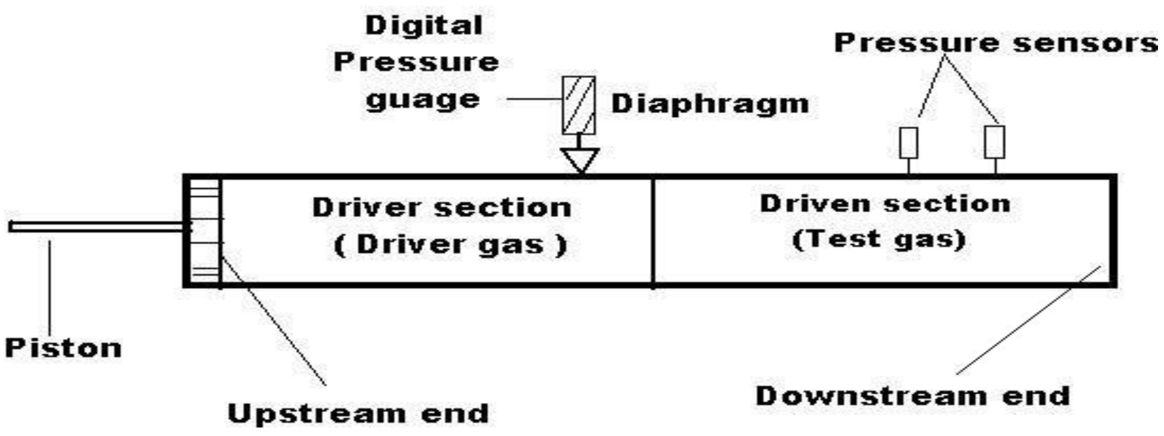
$$\mathbf{x = C}\; e^{\left(-b+\sqrt{b^2-\omega^2}\right)t} + D\, e^{\left(-b-\sqrt{b^2-\omega^2}\right)t}$$

1M

1C **Derive the Differential equation Damped Oscillations.**

Construction and working of Reddy Shock tube.

Reddy tube is a hand operated shock tube capable of producing shock waves by usinghuman energy



2M

Construction:

- Reddy tube consists of a cylindrical stainless-steel tube of about 30mm diameter & of length nearly 1m.
- It is divided into two sections one is **driver section** & the other is **driven section**
  separated by a thick aluminum or Mylar or paper diaphragm of thickness 0.1mm.
- Far end of driver tube is fitted with a piston & the far end of driven tube is closed.
- A digital pressure gauge is mounted in the driver section next to the diaphragm.
- Two piezoelectric sensors S_1 and S_2 are mounted 70mm apart towards the closed end of the shock tube.
- A port is provided at the closed end of the driven section for filling the test gas to the required pressure.

3M

- The driver section is filled with driver gas which is held at a relatively high pressure due to the compressing action of the piston. The gas in the driven section is called driven gas (test gas).

Working:

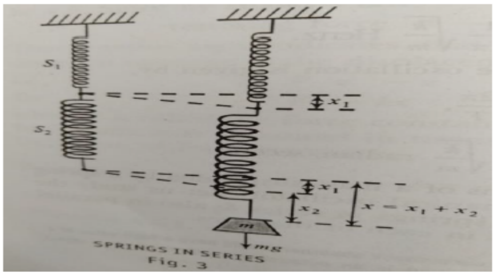
- The driver gas is compressed by pushing the piston hard into the driver tube until the diaphragm ruptures. The driver gas moves to the driven section

3M

- Hence there is sudden increase of pressure, temperature and density of driven sectionnear the downstream end . This generates a moving shock wave that traverses the length of the driven section.
- The propagating primary shock wave is reflected back from the downstream end. After reflection, the test gas further undergoes compression produces the secondary shock waves, which increases the pressure & temperature to still higher values.
- The pressure rise caused by the primary & also the reflected shock wave are sensed as signals by the sensors S_1 and S_2 respectively & are recorded in a digital cathode ray oscilloscope CRO as data
- Using the data so obtained, Mach number, pressure & temperatures can be calculated.

2a **Using Hooke's law arrive at the equations for the effective spring constants of Series**

Expression for force constant (Spring constant) for series combination of springs:



SPRINGS IN SERIES
Fig. 3

2M

Consider the spring **S1** with force constant **k1** suspended by mass **m** and displaced through ***x1***

from Hooke's law, $F = -k_1x_1$

$$x_1 = \frac{-F}{k_1} \qquad \ldots\ldots\ (1)$$

1M

Similarly for the spring s2

$$x_2 = \frac{-F}{k_2} \qquad \ldots\ldots(2)$$

1M

When the springs are connected in series, $\boldsymbol{k_s}$ is the force constant and displaced through $\boldsymbol{x}$ suspended by a same mass **m**.

From Hooke's law,

$$x = \frac{-F}{k_S} \qquad \ldots\ldots\ldots\ldots\ldots(3)$$

The displacement for series combination is $\boldsymbol{x = x_1+x_2}$ $\quad\ldots\ldots\ldots\ldots(4)$

1M

Substituting eqn (1), (2) and (3) in equation (4)

$$\frac{-F}{k_s} = \frac{-F}{k_1} + \frac{-F}{k_2}$$

$$\frac{1}{k_s} = \frac{1}{k_1} + \frac{1}{k_2}$$

$$\frac{1}{k_s} = \frac{k_1+k_2}{k_1k_2}$$

2M

This is an expression for spring constant of two springs connected in series combination.

If "n" number of springs connected in series, then

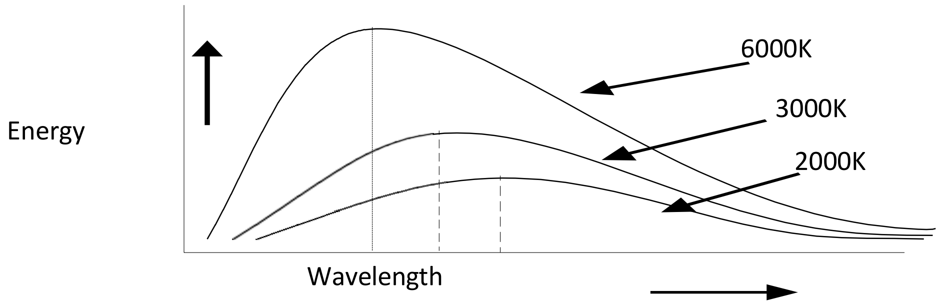
$$\frac{\mathbf{1}}{\boldsymbol{k_s}} = \frac{\mathbf{1}}{\boldsymbol{k_1}} + \frac{\mathbf{1}}{\boldsymbol{k_2}} + \frac{\mathbf{1}}{\boldsymbol{k_3}} + \ldots\ldots\ldots\ldots\ldots + \frac{\mathbf{1}}{\boldsymbol{k_n}}$$

1M

2b **Discuss the spectral distribution energy in the blackbody radiation spectrum**

Blackbody Radiation spectrum

A graph plotted energy radiated (Intensity) versus wavelength of emitted radiation is as called black body radiation spectrum and is shown below.



2M

Salient features of the spectrum are

1. There are different curves for different temperatures of the black body.
2. At a given temperature the distribution of energy is not uniform over all the wave length.
3. At a given temperature intensity of radiation increases with increase in wavelength andreaches a maximum for a particular temperature, beyond which the intensity decreases.
4. With increase in temperature of the body the maximum intensity increases and thewavelength corresponding to maximum intensity λ_m shifts towards lower wavelength side.
5. The area under the curve gives the energy emitted per unit area of cross section of the blackbody.

4M

2C The distance between the two pressure sensors in a shock tube is 150 mm. The time taken by the shock wave to travel this distance is 0.3 ms. If the velocity of sound under the same condition is 340 m/s. Find the Mech Number of the Shock wave.

Data: Distance between the two pressure sensors, $d = 150 \times 10^{-3}$ m

Time taken to travel this distance, t = 0. s

Velocity of sound, $a = 340\ ms^{-1}$

To find: Mach number, M =?

2M

Solution: Shock speed, $v = d/t$

$=150\times10^{-3} / 0.3 \times 10^{-3}$

$=500$ m/s

2M

$\therefore\ \boldsymbol{M=v/a}$

$=500/340=\mathbf{1.47}$

Mach no. of the shock wave is **1.47.**

2M

Section -B

3a **What is perfect Blackbody? Explain Blackbody radiation spectrum**

Blackbody:

A Blackbody is one which absorbs the entire radiation incident on it and emits all the absorbed radiation when it is heated to a suitable high temperature. A true blackbody does not exist practically.

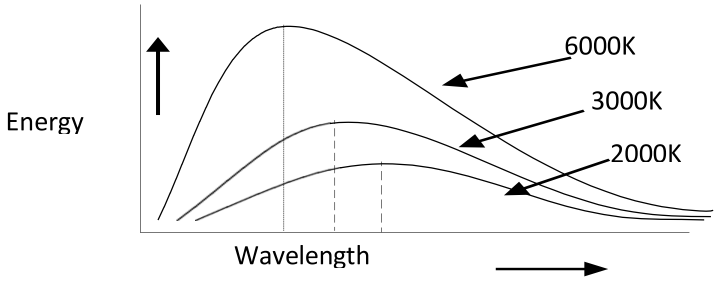
Ex: Lamp black body can be considered to be nearest natural black body
Ferry's Black body can be considered to be nearest man made black body

2M

Blackbody Radiation spectrum

Since a perfect black body does not exist in nature, in 1895, Lumer and Preingshiem designed a special type of black body which has features very close to the black body. They studied the spectrum of black body.

A graph plotted energy radiated (Intensity) versus wavelength of emitted radiation is as called black body radiation spectrum and is shown below.



2M

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4M

3b	**Deduce Wein's Displacement Law and Rayleigh Jeans law from Plank's law of radiation**	

Wein's Displacement Law from Plank's law of radiation :

According to Plank's law of radiation

$$E_{\gamma}\, d\lambda = \frac{8\pi hC\gamma^{-5}}{e^{\frac{hC}{\gamma kT}}-1}\, d\lambda \;\ldots\ldots\ldots\ldots(1)$$

For shorter wavelengths, $\upsilon = c/\lambda$ is large.

When υ is large, $e^{h\upsilon/kT}$ is very large.

$\therefore e^{h\upsilon/kT} >> 1$

$\therefore (e^{h\upsilon/kT}-1) \approx e^{h\upsilon/kT} = e^{hc/\lambda kT}$

Substituting in eqn 1

$$E_{\gamma}\, d\lambda = \frac{8\pi hC}{\lambda^{5}}\left[\frac{1}{e^{hC/\lambda kT}}\right] d\lambda$$

$$E_{\gamma}\, d\lambda = \mathbf{C_1}\, \lambda^{-5}\left[e^{\frac{C2}{\lambda T}}\right] d\lambda$$

Whare $C_1 = 8\pi hC$ and $C_2 = hC/k$

This is wein's law.

3M

Reduction of Planck's law to Rayleigh Jeans law:

For longer wavelengths $\upsilon = c/\lambda$ is small.

When υ is small $h\upsilon/kT$ is

very small.Expanding

$e^{h\upsilon/kT}$ as power series

$$e^{h\upsilon/kT} = 1 + h\upsilon/kT + (h\upsilon/kT)^2 + \ldots$$

$$\approx 1 + h\upsilon/kT$$

∵ If $h\upsilon/kT$ is small, its higher powers are neglected.

$$e^{h\upsilon/kT} - 1 = 1 + h\upsilon/kT - 1 = hc/\lambda kT$$

Substituting in eqn 1

$$E_\gamma\, d\lambda = \frac{8\pi hC\lambda^{-5}}{hC\backslash\lambda kT}\, d\lambda$$

$$E_\gamma\, d\lambda = 8\boldsymbol{\pi} kT/\lambda^4 \quad d\lambda$$

This is Rayleigh Jeans Law of Radiation.

3M

3c **Explain De- Broglie Hypothesis and deduce an expression De-Broglie wave length**

On the basis dual nature of light, in 1923, Louis de Broglie gave a hypothesis known as de Broglie hypothesis

“Since nature loves symmetry, if the radiation behaves as particles under certain conditions and as waves under certain conditions, then one can expect that, the entities which ordinarily behavesas particles (ex. Like electrons, protons, neutrons) must also exhibit properties attributable to waves under appropriate circumstances” This is known as **de Broglie hypothesis.**

2M

De broglie’s Wavelength:

A particle of mass ‘m’ moving with velocity ‘c’ possess energy given

by$E = mc^2$ → (Einstein’s Equation) (1)

According to Planck’s quantum theory the energy of quantum of frequency ‘υ’ is

$$E = h\upsilon \rightarrow (2)$$

From (1) & (2)

$$mc^2 = h\upsilon = hc/\lambda$$

since

$$\upsilon = c/\lambda$$

$$\lambda = hc/mc^2 = h/mc$$

$\lambda = h/mv$ since $v \approx c$

since momentum $P=mv$

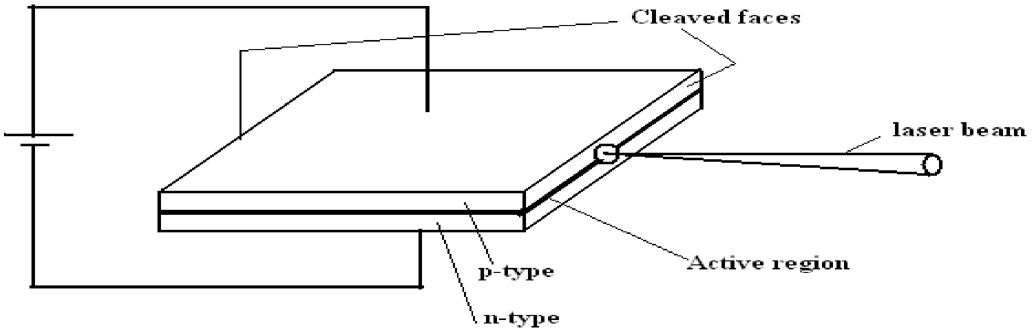
$$\lambda = h/P$$

4M

4a **Discuss principle, construction and working of semiconductor LASER with neat labelled diagram**

Semiconductor diode laser

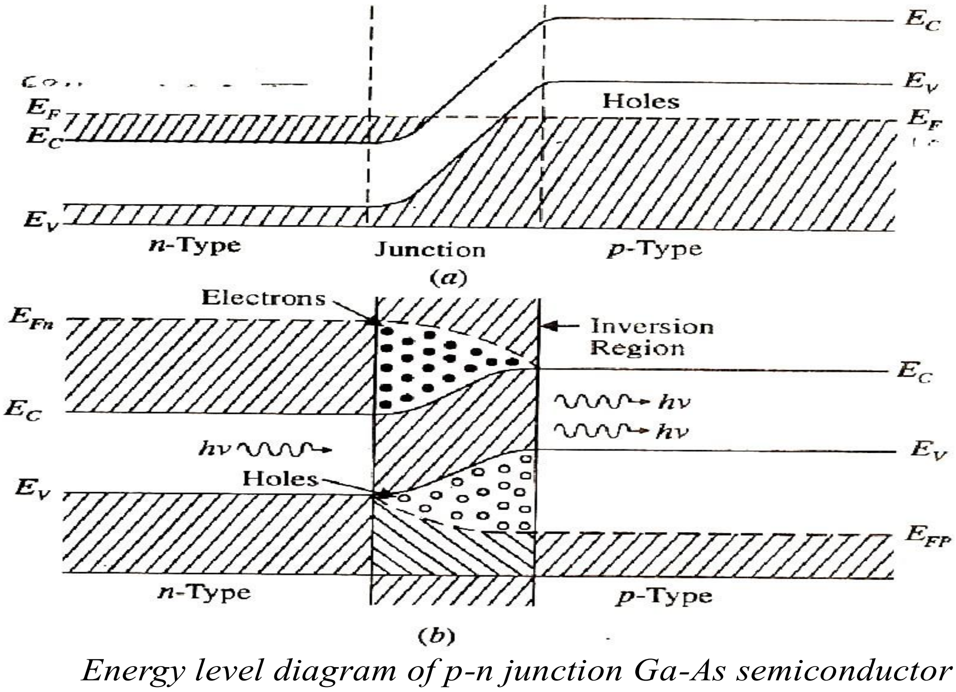
A Semiconductor diode laser is one in which the active medium is formulated by semiconducting materials



4M

Construction: Gallium-Arsenide Laser is a single crystal of GaAs consists of heavily doped n-type and p-type. The diode is very small size with sides of the order of 1mm.The width of the junction varies from 1-100□ m. The top and bottom surfaces are metalized and Ohmic contacts are provided for external connection. The front and rear faces are polished. The polished faces functions as the resonant cavity. The other two faces are roughened to prevent lasing action in that direction.

Working



Energy level diagram of p-n junction Ga-As semiconductor diode ***laser***

4M

(a)Before biasing (b) After biasing

1. The energy band diagram of heavily doped p-n junction is as shown. At thermal equilibrium the Fermi level is uniform.
2. Because of very high doping on **n- side**, the Fermi level is pushed into the conduction band and electrons occupy the portions of the conduction band that lies below the Fermi level and on **p-side**, the

Fermi level lies within the valence band and holes occupy the portions of the valence band that lies above the Fermi level.

3. A suitable forward bias is applied to overcome the potential barrier. As a result electrons from n-region and holes from p-region injected into the junction.
4. The current begins to flow following which there will be a region in junction in which the population inversion can be achieved.
5. Initially concentration of electrons in the energy levels at the bottom of the conduction band will be less than that of energy levels at top of valence band so that the recombination of electrons and holes results only in spontaneous emission, then junction works as LED.
6. When the current exceeds the threshold value, population inversion is achieved in the active region which is formulated in the junction.
7. At this stage the photons emitted by spontaneous emission triggers stimulated emission, over a large number of recombination leading to build up laser.
8. Since the energy gap of GaAs is 1.4eV, the wavelength of emitted light is 8400A^{o}.

4b **Explain the following necessary condition for LASER action**
(i) Population Inversion (ii) Optical Pumping (iii) Meta stable state

Condition for laser action:

1. Population Inversion:

It is the state of the system at which the population of a higher energy level is greater than that of the lower energy level.

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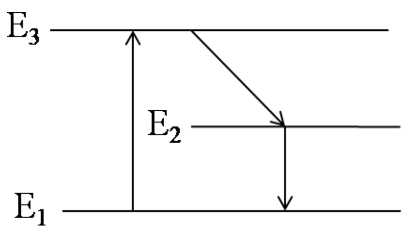


Let E1, E2, E3be the energy levels of the system E3>E2>E1. E2is the metastable state of the system. Atoms get excited from the state E1to E3by means of external source and stay there for short time. These atoms undergo spontaneous transitions to E2 and E1. The atoms at the state E2 stay for longer time. A stage is reached in which the number of atoms at state E2 is more than the number of atoms at E1 which is known as population inversion.

2. The pumping process:

2M

It is the process of supplying energy to the medium in order to transfer it to the state of population inversion is known as pumping process
Optical Pumping: It is the process of exciting atoms from lower energy level to higher energy level by using high intensity light or by operating flash tube as an external source called optical pumping.

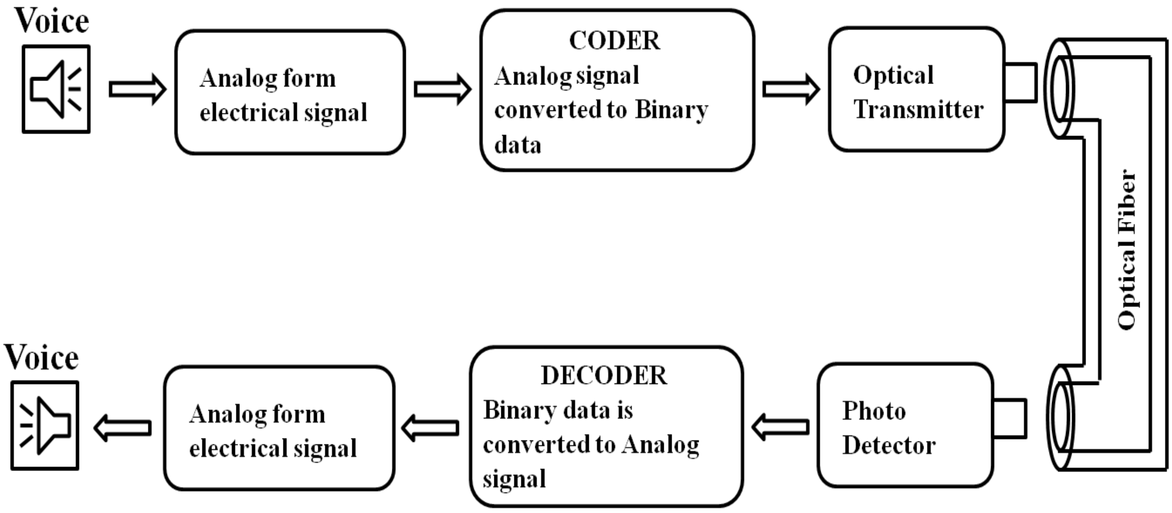
3. Meta Stable State:

2M

It is the special type of excited state where in the lifetime of atom is more than the normal excited state.
This state plays an important role in lasing action. In metastable state, atoms stay of the order of $10^{-3}$to 10^{-2}second. In normal excited state other than metastable atom stay of order of 10^{-8}to10^{-9}seconds. It is possible to achieve population inversion condition in certain system which possesses a metastable state.

4c **Discuss the block diagram of point to point communication**

Point to point optical fiber communication System



3M

- In point to point communication analog information such as voice of a telephone coming out of the transmitter section of the telephone are fed to the coder.
- The coder converts analog information into binary data which comes out as electrical pulses.
- The electrical pulses from the coder are fed to optical transmitter which converts signals into pulses of optical power.
- These optical pulses are fed into the fiber. The incident light which is funneled into the core within the acceptance angle propagate within the fiber by means of total internal reflection.
- The photo detector converts optical signals into electrical pulses in binary form and the decoder converts the binary data into analogue signal which will bethe same information such as voice.

3M

Section -C

5a **Discuss any three assumption and failure of classical free-electron theory**

Assumptions of classical free electron theory:

1. The metal consists of free electrons; the current flowing through a metal is due drift velocity of electrons.
2. The electric potential due to the ionic cores is assumed to be constant throughout the metal
3. The attraction between the lattice ions and electrons, the repulsion between the electrons are neglected.

1+1+1 M

Failures of classical free electron theory:

1. **Specific heat:** according to the classical theory the specific heat is independent of temperature whereas experimentally specific heat is proportional to temperature.
2. **Temperature dependence of electrical conductivity:** Experimentally, electrical conductivity σ is inversely proportional to the temperature T. But According to the assumptions of classical free electron theory σ is directly proportional to square root temperature T.
3. **Dependence of electrical conductivity on electron concentration:** According to classical free electron the theory electrical conductivity is directly proportional to electron concentration but experimentally electrical conductivity is independent of electron concentration.

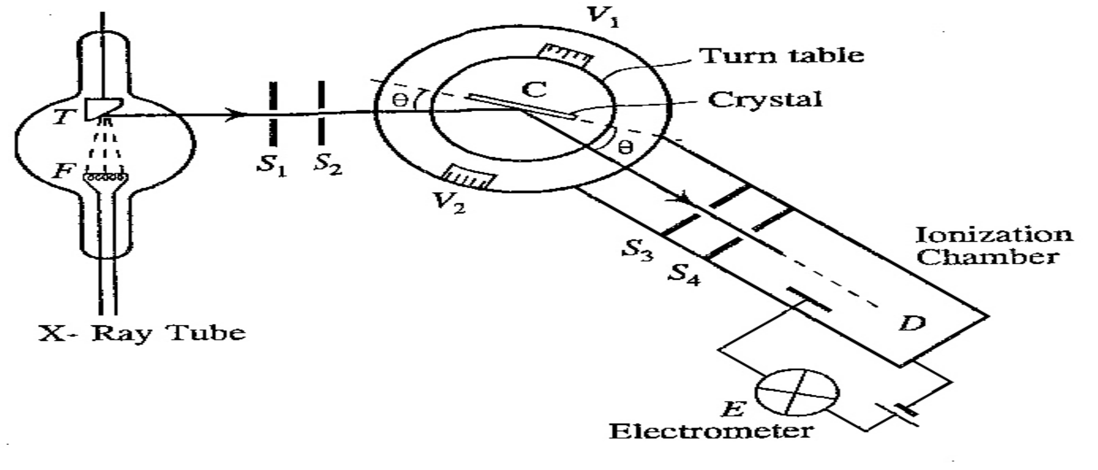
1+1+1 M

5b **Explain the construction and working of X-ray diffactrometer**

Construction and working of X-ray Diffractometer

The schematic diagram of Bragg's x-ray spectrometer is shown in figure. It has 1) x-ray source 2) A Crystal fixed on a circular table provided with scale and Vernier. 3) Ionization chamber.

1M



BRAGG'S X-RAY SPECTROMETER

3M

Working

1. X-rays from the X-ray tube are allowed to pass through the slits S_1 and S_2, then it is made to fall on a crystal C mounted at the center of rotating turn table provided with a graduated scale V_1 to measure the angular displacement of crystal.

4M

2. X-ray after reflection enters into ionization chamber fixed to the turn table and the position can be noted on the scale V_2.
3. The X- ray enters into ionization chamber ionizes the gas and produces ionization current which is measured by electrometer connected to it.
4. For every rotation of turn table by an angle 'θ' on the crystal, the ionization chamber must rotate by an angle 2θ to satisfy Brags law.
5. While the experiment is carrying out by rotating the turn table at different reflected rays the sudden rise in current is observed.
6. A plot of ionization current for different incident angles to study the x-ray diffraction spectrum is shown in fig.
7. Let Peaks are observed at angles θ_1, θ_2, θ_3 etc. for n=1,2,3, etc. for a set of parallel planes in the crystal, when the x-ray beams satisfy Braggs law of diffraction
8. By knowing, wavelength of X-ray, interplanar spacing (d) and order of diffraction (n), the diffraction angle θ can be calculated using Braggs Law **$2d\sin\theta = n\lambda$.**

5c **Derive an expression of Clausius -Mossotti equation**

Clausius – Mossotti Equation:

Consider a solid dielectric material with dielectric constant Er. If 'n' is the number of atoms/unit volume and 'μ' is the dipole moment of the atoms in the material.

Therefore, the dipole moment / unit volume = N μ ………(1)

The field experienced by the atom is an internal field Ei. αe is the electronicpolarizability of the atoms.

Then dipole moment / unit volume $= N\alpha_e E_i$

2M

The dipole moment $\mu = \alpha_e E$

Dipole moment / unit volume is nothing but polarization (P)

$P = N\alpha_e E_i$

$$E_i = \frac{P}{N\alpha_e} \qquad \text{……….(3)}$$

we have $P = \epsilon_0(\epsilon_r - 1)E$

$$E = \frac{P}{\epsilon_0(\epsilon_{r-1})} \qquad \text{………(4)}$$

The expression for internal field for 3D material is given by

2M

$E_i = E + \frac{P}{3\ \epsilon_0}$

Substituting (3) and (4) in the above equation

$$\frac{\boldsymbol{P}}{\boldsymbol{N\alpha_e}} = \frac{P}{\epsilon_0\,(\epsilon_{r-1})} + \frac{P}{3\epsilon_0}$$

$$\frac{1}{\boldsymbol{N\alpha_e}} = \frac{1}{\epsilon_0\,(\epsilon_{r-1})} + \frac{1}{3\epsilon_0} = 1 \notin_0 \left(1 \notin_{r-1} - \frac{1}{3}\right)$$

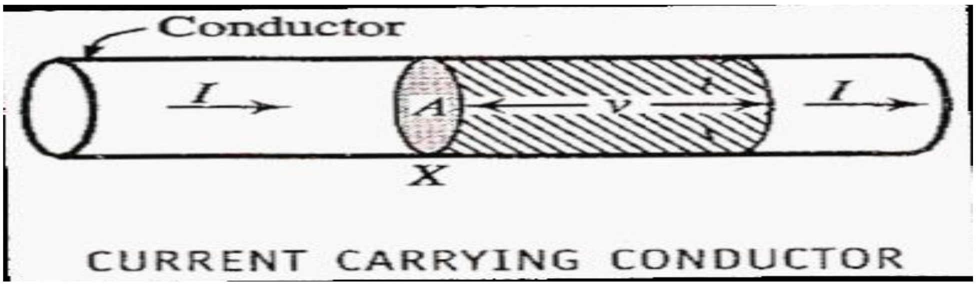
$$\boldsymbol{\frac{\epsilon_r\ -1}{\epsilon_r\ +2} = \frac{N\alpha\, e}{3\epsilon_0}}$$

2M

This is called Clausius Mossotti equation.

6a **Deduce the Expression for electrical conductivity for conductor according to quantum free electron theory of metals**

Consider the motion of an electron in a metal in an influence of an electric field E. let e is the charge; m is the mass of an electron and A is the area of cross section. Let v_d (drift velocity) is the distance travelled in unit time



2M

According to de Broglie hypothesis, $\lambda = h\ /P$

$P = \frac{h}{\lambda} = \frac{hk}{2\pi}$ …………(1) $[k = \frac{2\pi}{\lambda}]$

Since $P = mv = mv_d$

Substituting the value of P in equation (1)

$mv_d = \frac{hk}{2\pi}$

$v_d = \frac{hk}{2\pi m*}$ ………………..(2)

2M

where m* = m = effective mass of electrons.

Integrating eqn (1) w.r.t “t”

$\frac{dp}{dt} = \frac{h}{2\pi}\frac{dk}{dt}$ …………………..(3)

By applying electric field E, the force experience by the electrons is eE and isequal to rate of change of momentum of the electrons.

$$F = eE = dp/dt$$

Substitute dp/dt in equation (3)

$$eE = \frac{h}{2\pi}\frac{dk}{dt}$$

$$\square\square = \frac{2\pi}{h}\, eE\, dt$$

Integrating on both sides

$$\int dk = \frac{2\pi}{h}\, eE \int dt$$

$k = \frac{2\pi}{h}\, eE\tau$ ------- (4) (since t = τ mean collision time)

Substituting eqn (4) in eqn (2) we have

$$v_d = \frac{h}{2\pi m*}\frac{2\pi}{h}\, eE\tau$$

$v_d = \frac{eE\tau}{m*}$ -------------- (5)

2M

Current density is J = neVd

Substituting eqn (5) in the above equation

$$J = ne\frac{eE\tau}{m*}$$

As we know, J= σE ,

$$\sigma = \frac{J}{E}$$

$$\sigma = \frac{ne^2\tau}{m*}$$

According to quantum free electron theory mean collision time $\tau = \frac{\lambda}{Vf}$

Where Vf is the Fermi velocity

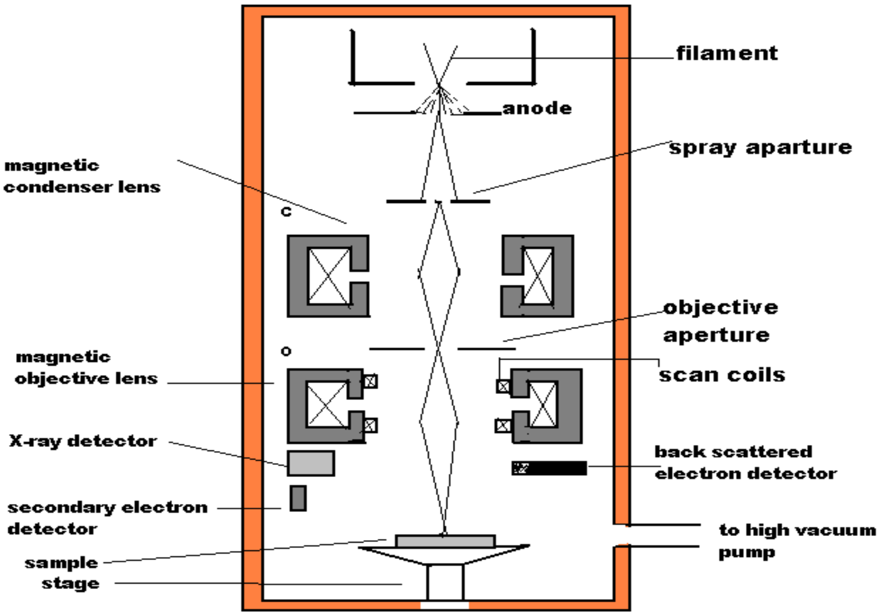
The expression for conductivity becomes

$\sigma = \frac{ne^2\lambda}{m*Vf}$ Where m* is the effective mass of electrons

2M

6b **Explain the working of Scanning Electron Microscope with the help of neat Diagram**

Working of Scanning electron microscope (SEM)



3M

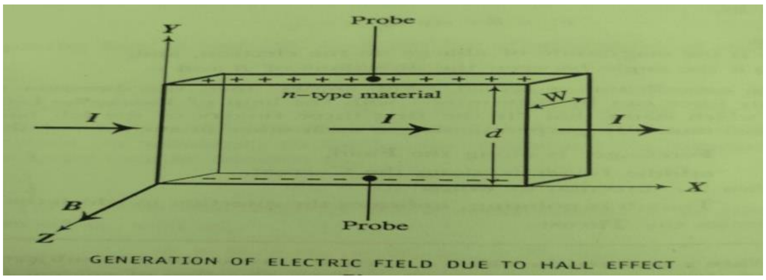
Working

- The sample to be investigated is placed on the specimen stage after which, inside of the chamber is evacuated by connecting it to a high vacuum pump.
- Electrons are emitted by the filament by thermionic emission. A suitable positive potential is applied to the anode with respect to the filament.
- The accelerated electrons from the electron gun pass through the spray aperture from where the electron beam emerges.
- The condensing lens C converges the beam & eliminates some high angle electrons.
- The beam then passes through the objective aperture where the size of the beam can be controlled. A thinner beam then enters into the field of objective lens O. the objective lens focuses the beam onto the desired part of the specimen.
- A set of coils called scan coils placed along with the objective lens enable the beam to scan the specimen in the particular way called raster. The scan coils are connected to the raster scan generator which directs the beam onto the spot on the specimen & dwells on it momentarily.
- The electrons incident on the sample are called primary electrons. Upon incidence some of the electrons are knocked out from the atoms in the specimen due to the impact of the beam which are called secondary electrons. Some of them will be scattered by the specimen called back scattered electrons. X- Rays are emitted when electrons from a higher shell in the atom transit to a vacant position created in its lower shell from where an electron has been knocked off.
- Back scattered electrons, secondary electrons & the X-rays emitted are detected by the respective detectors & a corresponding signal is produced. This signal is converted into a micro spot of corresponding brightness on a screen. The beam focus is then shifted to the next adjacent spot in order, where it again dwells momentarily. This way the image is built on the screen point by point.
- Image produced on the screen will be in grey scale. For aesthetic purposes, these are colorized by using feature-detection software.

3M

6c **Obtain the expression for the Hall coefficient**

Expression for Hall coefficient :



GENERATION OF ELECTRIC FIELD DUE TO HALL EFFECT

1M

Consider a rectangular n –type semiconductor material in which current is flowing in +ve x -direction.

Let the magnetic field (B) applied along z-direction.

Therefore, the electrons experience the Lorentz force (F_L) along –ve y-direction given by,

$$F_L = -Bev \quad ……(1)$$

1M

Therefore, the electrons density increases in lower surface and in the upper surface become positively charged due to deficiency of electrons. Hence the potential developed between two surfaces called Hall voltage, which producesan electric field E_H called Hall field (E_H).

The electrons exerts an upward force FH due to the Hall field and is given by,

1M

$F_H = -eE_H$..................... (2)

Equating equations (1) and (2)

$-eE_H = -BeV_d$

$E_H = BV_d$ ……(3) $V_d \rightarrow$ drift velocity.

If “d” is the distance between upper and lower surface then $E_H = V_H/d$

$V_H = E_H d$ (from3)

$V_H = BV_d d$………(4) 1M

The current density $J = I/A = neVd = \rho V_d$ ……(5)

Therefore, $\rho = ne$

For the given semiconductor, $J = I/A = I/\omega d$ …….(6)

$\omega \rightarrow$thickness of the material . therefore ($A = \omega d$)

equating (5) & (6)

$\rho V_d = I/\omega d$

$V_d = I/\rho\,\omega\,d$ ………..(7)

Substituting eqn (7) in (4)

$V_H = B I/\rho\,\omega$

$$\rho = \frac{B\,I}{V_H\,\omega}$$

Expression for Hall coefficient:

Since, $E_H \propto J B$

$E_H = R_H J B$

($R_H \rightarrow$ Hall coefficient)

$R_H = E_H / J B$

[From eqn (3) and (5)]

$R_H = BV_d / \rho V_d B = 1/\rho = 1/ne$

$R_H = 1/ne$ 2M

The above expression represents **Hall coefficient**

Section -D

7a **Derive Nernst Equation for single electrode.**

Nernst derived an equation to establish relationship between electrode potential and concentration of metal ion at a particular temperature.

Due to the power output from an electrochemical cell, the free energy decreases i.e.

$$G = -nFE$$

n = No. of electrons **1M**
F = Faraday's constant
E = Electrode potential

Under standard conditions the free energy ΔG is given by the equation **1M**

$$\Delta G^0 = -nFE^0 ------(1)$$

E° is a constant called standard reduction potential.

Consider an equilibrium redox reaction:

$$M^{n+} + ne^- \rightarrow M ----(2)$$ **1M**

For spontaneous reaction, the change in the free energy depends on the concentration of reac species.

$$\Delta G = \Delta G^0 + RTlnK_c ----- (3)$$

$Where\ K_c = \frac{[Products]}{[Reactants]}$, From equation 2, $K_c = \frac{[M]}{[M^{n+}]}$ **2M**

Substituting the value of Kc in equation (3), we get

$$\Delta G = \Delta G^0 + RTln\frac{[M]}{[M^{n+}]} ----(4)$$

Substitute for ΔG and ΔG° in equation (4)

$$-nFE = -nFE^0 + RTln\frac{[M]}{[M^{n+}]} ----- (5)$$

Under standard conditions [M] = 1

Dividing equation (5) by – n F, we get

$$E = E^0 - \frac{RT}{nF}ln\frac{1}{[M^{n+}]} ----- (6)$$ **1M**

Converting ln to log we get

$$E = E^0 - \frac{2.303RT}{nF}log\frac{1}{[M^{n+}]} ----- (7)$$

Substituting for R = 8.314, T = 298K and F = 96500 in equation (7) we get

$$E = E^0 - \frac{0.0591}{n}log\frac{1}{[M^{n+}]} \quad OR \quad E = E^0 + \frac{0.0591}{n}log[M^{n+}] ----(8)$$ **2M**

Equation (8) is called Nernst equation for single electrode potential

7b	**Discuss the factors effecting on the rate of corrosion**	
	Factors affecting the rate of corrosion **Ratio of anodic to cathodic area:** 1) The rate of corrosion (x) is directly proportional to the ratio of area of anode to the area of cathode. i.e., x = area of anode/ area of cathode 2) Higher the value of x, greater is the rate of corrosion. 3) When anode is small and cathode is large, all the electrons liberated at anode and are consumed at the cathode. This further intensifies the anodic reaction leading to increase in overall rate of corrosion. **Nature of the metal:** 1) Metals with higher electrode potentials do not corrode easily. They are noble metals like, gold, platinum, silver. Whereas metals with lower electrode potentials, readily undergo corrosion.e.g. metals like, zinc, magnesium, aluminium. When two metals are in contact with each other, higher the difference in electrode potentials greater is the corrosion. 2)Position of the metal/alloy in the galvanic series also decides the rate of corrosion. 3)The metal top in the series is more anodic and undergoes corrosion faster than the metal below it. **Nature of the corrosion product:** 1) In a moist atmosphere almost all metals get covered with a thin surface film of metal oxide as the corrosion product. 2) The corrosion product formed like metal oxide may act as protective film, if it is stable, insoluble and non porous. If it acts as protective film it prevents further corrosion by acting as barrier between metal surface and corrosion medium. 3) On the other hand if corrosion product is unstable, porous and soluble, it further enhances corrosion. **Nature of Medium:** **pH of the medium:** 1) The rate of corrosion increases with decrease in pH of the medium. 2) Acidic media are generally more corrosive than alkaline/neutral media. This is due to evolution of hydrogen at cathode. 3) When the pH < 4, the rate of corrosion increases due to higher concentration of H^+ ions. When pH > 10, the rate of corrosion decrease due to formation of insoluble metal hydroxides on the surface of metal. **Conductivity:** 1) The rate of corrosion increases with increase in the conductance of the medium. 2) As the conductance of the medium increases, ions can move easily trough the medium. 3) This decreases the polarization potential and due to this rate of corrosion increases. **Temperature:** 1) Generally rate of corrosion increases with increase in temperature. 2) As the temperature increases conductance of the ions in the medium increases which reduces the polarization. Therefore the rate of corrosion increases. 3) A passive metal become active at high temperature and increases the rate of corrosion.	**2M** **1M** **1M** **3M**
7c	**Calculate the single electrode potential of Cu electrode at 27^{o}C when the standard potential of Cu is 0.34V and [Cu2+] 0.1M**	
	$E_{red} = E°_{red} + \frac{0.0591}{n}\log_{10}[cu^{2+}]$ putting the value of $E°_{red}$ =0.34v,n=2 and $[cu^{2+}]=0.1M$	**2M**

E red =0.34+(0.0591/2) $\log_{10}$[0.1]
=0.34+0.02955 x (-1)
=0.34—0.02955
= 0.31045volt.

3M

8a **Explain the construction and working of Calomel Electrode**

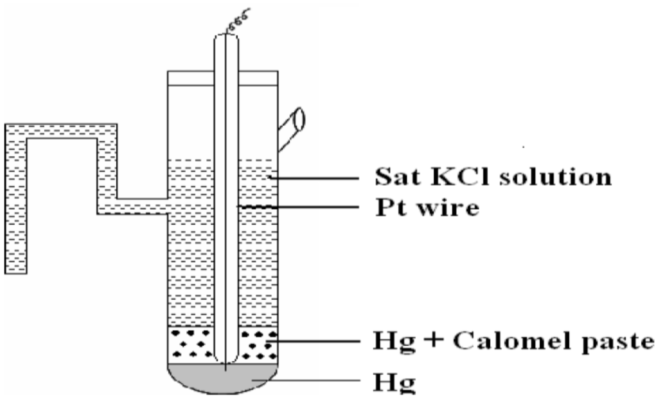
Calomel Electrode:
Construction:
1. Calomel electrode consists of long glass tube with two side tubes.

2. One at the top to fill saturated KCl solution and the other side tube is connected to the salt bridge. Mercury is placed at the bottom which is covered with a layer of Hg and Hg_2Cl_2 (calomel) paste.

3M

3. The remaining portion is filled with saturated KCl solution.

4. A platinum wire is dipped into the mercury and is used to provide external electrical contact.



2M

5. The calomel electrode is represented as, Hg /Hg_2Cl_2/ Cl^-

Working:

3M

Calomel electrode behaves as anode or cathode depending upon the nature of electrode. The half-cell reaction when it acts as an anode is

$$2Hg + 2Cl^- \rightarrow Hg_2Cl_2 + 2e^-$$

The half-cell reaction when it acts as a cathode is

$$Hg_2Cl_2 + 2e^- \rightarrow 2Hg + 2Cl^-$$

The electrode reaction is,

$$Hg_2Cl_2 + 2e^- \leftrightarrow 2Hg + 2Cl^-$$

Applying Nernst equation,

$$E = E^0 + \frac{0.0591}{n} log \frac{[Reactants]}{[Products]}$$

$$E = E^0 + \frac{0.0591}{n} log \frac{[Hg_2Cl_2]}{[Hg]^2[Cl]^{2-}}$$

Since [Hg_2Cl_2] = [Hg]^2 = 1, the above equation becomes

$$E = E^0 + \frac{0.0591}{2} \log \frac{1}{[Cl]^{2-}}$$

8b **Explain Electrochemical theory of corrosion**

Electrochemical theory of corrosion:

According to this theory,

1. When a metal is in contact with moist air or when dissimilar metals are contact with each other in a solution, large numbers of galvanic cells are formed with the existence of anodic and cathodic area on the metal.
2. In this corrosion, oxidation of the metal and reduction of species present in solution takes place.
3. The anodic part of the metal undergo oxidation and suffers from corrosion, cathodic part undergo reduction and protected from corrosion.
4. The electrons are transferred through the metal from anode to cathode.
5. During corrosion the following reactions takes place.

3M

At anode (oxidation reaction) : $M \rightarrow M^{n+} + ne^-$

The reaction at cathode (reduction reaction) depends on the nature of the environment:

If the medium is acidic,

In the presence of dissolved oxygen : $2H^+ + \frac{1}{2}O_2 + 2e^- \longrightarrow H_2O$

In the absence of dissolved oxygen : $2H^+ + 2e^- \longrightarrow H_2\uparrow$

If the medium is alkaline/neutral,

In the presence of dissolved oxygen : $H_2O + \frac{1}{2} O_2 + 2e^- \longrightarrow 2OH^-$

In the absence of dissolved oxygen : $2H_2O + 2e^- \longrightarrow 2OH^- + H_2\uparrow$

Example: Rusting of an Iron in the presence of moist air

Anodic reaction : $Fe \rightarrow Fe^{2+} + 2e^-$

Cathodic reaction : $H_2O + \frac{1}{2} O_2 + 2e^- \rightarrow 2\,OH^-$

Products of anode & cathode : $Fe^{2+} + 2\,OH^- \rightarrow Fe(OH)_2$

In the presence of oxygen : $2\,Fe(OH)_2 + \frac{1}{2} O_2 \rightarrow \underset{\text{(Rust)}}{Fe_2O_3.2H_2O}$

4M

8c **Define Differential aeration corrosion. Explain Water line corrosion**

Differential aeration corrosion

1) When a metal is exposed to different concentration of air (O_2), part of the metal exposed to lower concentration of O_2 becomes anodic and undergoes corrosion.

2) Other part of the metal exposed to higher concentration of O_2 becomes cathodic and protected from the corrosion.

3) The difference in O_2 concentration produces a potential difference and causes corrosion. This type of corrosion is called differential aeration corrosion.

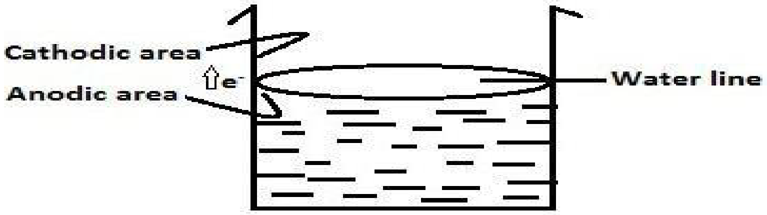
2M

Water line corrosion

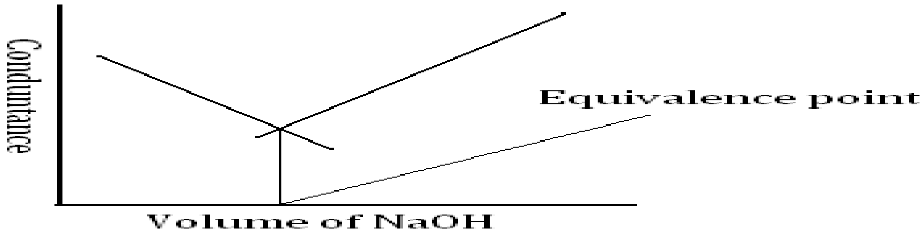
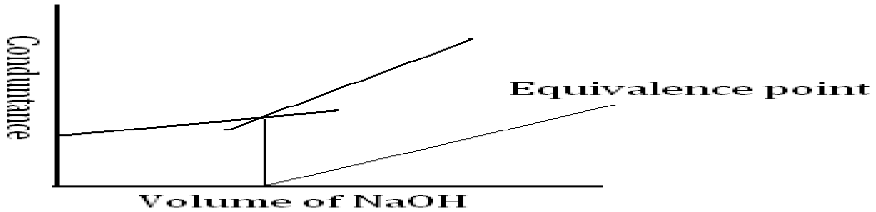
1) It is observed in steel or iron water tank partially filled with water. Part of the tank just below water level is exposed to lower concentration of O_2 becomes anodic and undergoes corrosion.

2) Part of the tank above the water line which is exposed to higher concentration of O_2 becomes cathodic and protected from the corrosion.

3) More corrosion is observed just below the water line; hence this type is called water line corrosion.



	Reactions: $At\ anode: - Fe \rightarrow Fe^{2+} + 2e^-$ $At\ cathode: - H_2O + \frac{1}{2} O_2 + 2e^- \rightarrow 2OH^-$ $Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$ $2Fe(OH)_2 + \frac{1}{2} O_2 \rightarrow Fe_2O_3 . 2H_2O$	3M
	Section -E	
9a	**What is hardness of water? Explain Temporary hardness and permanent hardness**	
	Hardness of water is caused by divalent metal ions such as Ca^{2+} and Mg^{2+}. The hardness of water can be classified into 2 types. i.e. 1) Temporary hardness and 2) Permanent hardness. 1) **Temporary hardness**: It is also called Carbonate hardness. It is caused due to the presence of bicarbonates of Ca and Mg i.e. calcium bicarbonate [$Ca (HCO_3)_2$] and magnesium bicarbonate [$Mg (HCO_3)_2$]. Temporary hardness can be removed by physical treatment like boiling. $CaCO_3 + H_2O + CO_2 \longrightarrow Ca (HCO_3)_2$ $MgCO_3 + H_2O + CO_2 \longrightarrow Mg (HCO_3)_2$ 2) **Permanent hardness**: It is also called non-carbonate hardness. It is caused due to the presence of chloride, sulphates of Ca and Mg i.e. calcium chloride, calcium sulphate and magnesium chloride, magnesium sulphate. Permanent hardness can be removed by chemical treatment. $CaCl_2 + 2Na\text{-}st \longrightarrow Ca\text{-}st + 2NaCl$ $MgCl_2 + 2Na\text{-}st \longrightarrow Mg\text{-}st + 2NaCl$ $MgSO_4 + 2Na\text{-}st \longrightarrow Mg\text{-}st + Na_2SO_4$	2M 3M 3M
9b	**Discuss any three applications of colorimetry**	
	1. Analysis of blood, 2.water, soil nutrients and foodstuffs, 3.determination of solution concentration, 4.determination of reaction levels, and 5.determination of bacterial crop growth.	ANY THREE 2+2+2
9c	**Mention any three major categories of impurities present in water**	
	Impurities in water: The major categories of impurities found in the water may be broadly classified into four categories. 1. Dissolved impurities 2. Suspended impurities 3. Dissolved gases 4. Organic matter	6
10a	**List and explain the sources of water**	
	1. Surface water: It is available on the surface of the earth either still form or in flowing from. Example: rain water, river water, lake water and sea water. 2. Underground water: It is developed by any type of well or spring from beneath the surface of the ground whether the water flows from the well or spring by natural force or is withdrawn by pumping, other mechanical device, or artificial process. Example: Springs, well and tube wells.	8
10b	**Define the following term molality, ppm and normality**	
	Molality (m) “Molality of any solution is represented as the number of moles of solute present per kg of solvent per litre of solution”. Unit is mol/kg. **Parts per million** (ppm) “It is defined as the parts of a component per million parts of the solution. It is widely used when a solute is present in trace quantities”. It can also be expressed as milligrams per litre (mg/L).	2M 2M

	Normality (N) “is the number of gram equivalent weight of solute per litre of solution”. Unit is gram equivalent/ L.	2M
10c	**Estimate the percentage of acids and bases in the following cases by conductometric tritration:** 1) Strong acid v/s strong base 2) weak acid v/s strong base	
	Strong acid v/s strong base  HCl v/s NaOH If the strong acid like HCl is titrated against a strong base such As NaOH, the conductance first decreases due to replacement of fast moving H^+ ions by slow moving Na^+ ions HCl + NaOH NaCl + H_2O After the neutralization point, conductivity rapidly rises with further addition of NaOH because of continuous addition of fast moving OH- ions. A plot of conductance against the volume of base added is shown in the figure. The point of intersection of two curves gives the neutralization point. **Weak acid v/s Strong base** Consider the titration of acetic acid against NaOH.  The conductance of the acid will be initially low since acetic acid is a weak electrolyte. When NaOH is added to the acid, the salt formed is highly ionized and the conductance increases. On complete neutralization of the acid, further addition of base leads to an increases in the number of mobile OH^- ions. Hence the conductance increases sharply. CH_3COOH+ NaOH CH_3COONa + H2O A plot of conductance against the volume of base added is shown in the figure. The point of intersection of two curves gives the neutralization point.	3M 3M

NOTE: Give equal weight age to any alternative answers.

I certified that the scheme of valuation is prepared for question paper code 20 SC52T-Applied Science is correct to the best of my knowledge.