PHYSICS IAT-2 SCHEME FOR ECE

1A

CLAUSIUS – MOSOTTI RELATION:

This expression relates dielectric constant of an insulator (ε) to the polarization of individual atoms(α) comprising it.

$$\frac{\varepsilon_r - 1}{\varepsilon_r + 2} = \frac{N\alpha}{3\varepsilon_0}$$

where N is the number of atoms per unit volume

α is the polrisability of the atom

ε_r is the relative permittivity of the medium

ε_o is the permittivity of free space.

Proof:

If there are N atoms per unit volume,the electric dipole moment per unit volume –known as polarization is given by

$$P = N\alpha E_i$$

$$E_i = \frac{P}{N\alpha}$$

By the definition of polarization P, it can be shown that

$$P = \varepsilon_0 E_a (\varepsilon_r - 1)$$

$$E_a = \frac{P}{\varepsilon_o(\varepsilon_r - 1)}$$ ....(1) (3 marks)

The internal field at an atom in a cubic structure (γ =1/3) is of the form

$$E_i = E_a + \frac{\gamma p}{\varepsilon_0}$$

$$\frac{P}{N\alpha} = \frac{P}{\varepsilon_o(\varepsilon_r - 1)} + \frac{P}{3\varepsilon_o}$$

$$\frac{1}{N\alpha} = \frac{1}{\varepsilon_o(\varepsilon_r - 1)} + \frac{1}{3\varepsilon_o}$$

$$\frac{1}{N\alpha} = \frac{3 + \varepsilon_r - 1}{3\varepsilon_o(\varepsilon_r - 1)}$$

$$\frac{N\alpha}{3\varepsilon_o} = \frac{1}{\left[\frac{\varepsilon_r + 2}{\varepsilon_r - 1}\right]} = \frac{\varepsilon_r - 1}{\varepsilon_r + 2}$$

Simplify to get (3 marks)

$$\left[\frac{\varepsilon_r - 1}{\varepsilon_r + 2}\right] = \frac{N\alpha}{3\varepsilon_0}$$

1B

Electronic polarization: (2 marks)

These are generally seen in the case of covalent compounds.

When a covalent compound is placed in electric field, displacement of electron cloud takes place relative to the nucleus. This displacement creates a dipole which develops dipole moment.

Electronic polarisability $\alpha_e = \dfrac{\varepsilon_o(\varepsilon_r - 1)}{N}$

N is number of dipoles per unit volume

It is independent of temperature.

Ionic polarization: (2 marks)

This is exhibited by ionic compounds.

When ionic compounds are kept in an electric field, displacement of positive and negative ions occurs developing a dipole moment.

Ionic polarisability $\alpha_i = \dfrac{\varepsilon_o(\varepsilon_r - 1)}{N_i} \approx 0.1\alpha_e$

2A

Fermi probability factor: It represents the probability of occupation of an energy level. (1 mark)

$$f(E) = \frac{1}{e^{\left(\frac{E-E_F}{kT}\right)} + 1}$$ (1 mark)

To show that energy levels below Fermi energy are completely occupied:

For E < E_F, at T = 0,

$$f(E) = \frac{1}{e^{\left(\frac{E-E_F}{kT}\right)} + 1} = 1$$

Variation of Fermi Probability factor with temperature and Energy

For E > E_F, at T=0

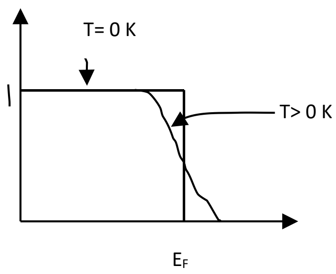
$$f(E) = \frac{1}{e^{\left(\frac{E-E_F}{kT}\right)} + 1} = 0$$

At ordinary temperatures, for E = E_F,

f(E) = $\frac{1}{2}$ (3 marks)

Fermi energy for T > 0k, $E_f = E_{f0}\left[1-\frac{\Pi^2}{12}\left(\frac{kT}{E_F}\right)^2\right]$

Graph: (1 mark)



2B Formula 1 mark, Substitution 1 mark, Answers- 2marks

$$f(E)=\frac{1}{e^{\frac{E-E_F}{kT}}+1}$$

$$e^{\frac{E-E_F}{kT}}=\frac{1}{f(E)}-1$$

$$f(E)=0.01$$

$$\frac{E-E_F}{kT}=\ln\left[\frac{1}{f(E)}-1\right]$$

$$E=E_F+kT.\ln\left[\frac{1}{f(E)}-1\right]$$

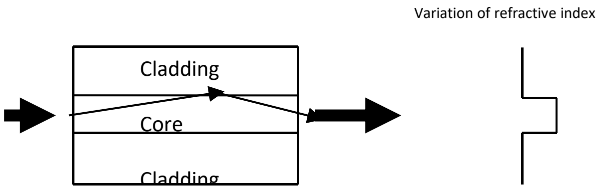
$$E=9x10^{-19}J=5.6eV$$

3A

Types:

1. Single mode fiber: (2 marks)

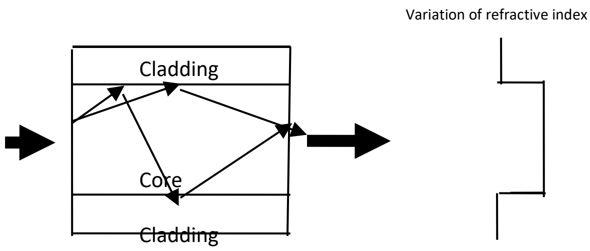
Core diameter is around 5-10 μm. The core is narrow and hence it can guide just a single mode.



- No modal dispersion
- Difference between n_1& n_2 is less.Critical angle is high. Low numerical aperture.
- Low Attenuation -0.35db/km
- Bandwidth -100GHz
- Preferred for short range

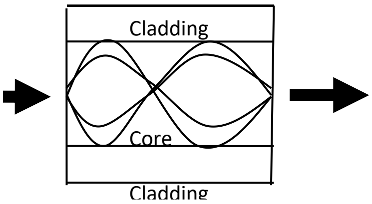
Step index multimode fibre :(2 marks)

- Here the diameter of core is larger so that large number of rays can propagate. Core diameter is around 50. µm.
- High modal dispersion
- Difference between n_1& n_2 is high. Low Critical angle. Large numerical aperture.
- Losses high
- Bandwidth -500MHz
- Allows several modes to propagate
- Preferred for Long range

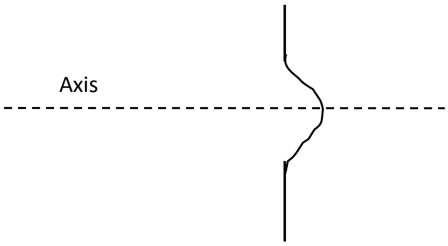


Graded index multimode fiber:(2 marks)

In this type, the refractive index decreases in the radially outward direction from the axis and becomes equal to that of the cladding at the interface. Modes travelling close to the axis move slower where as the modes close to the cladding move faster.As a result the delay between the modes is reduced. This reduces modal dispersion.



Variation of refractive index



- Low modal dispersion
- High data carrying capacity.
- High cost
- Many modes propagate
- Bandwidth -10GHz

3B

Formula 1 mark, Substitution 1 mark, Answers- 2marks

$$NA = \frac{\sqrt{n_1^2 - n_2^2}}{n_0}$$

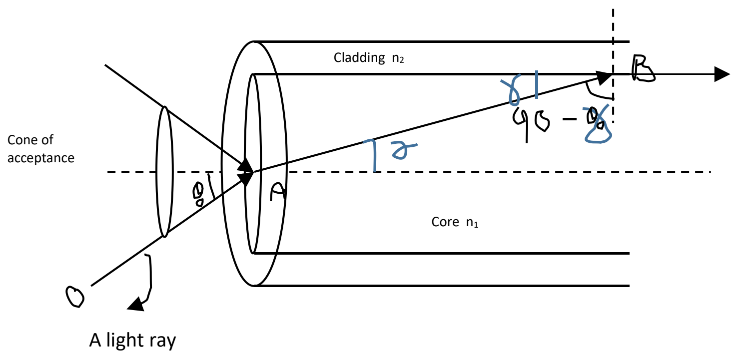
$$n_1 = 1.56$$

$$\Delta = \frac{n_1 - n_2}{n_1}$$

$$\Delta = 0.019$$

$$\theta_A = \sin^{-1}(0.3) = 17.45^0$$

4A



Expression for condition for propagation :(2 marks)

Consider a light ray falling in to the optical fibre at an angle of incidence θ_o equal to acceptance angle. Let n_0 be the refractive index of the surrounding medium .

Let n_1 be the refractive index of the core.

Let n_2 be the refractive index of the cladding.

From Snell's Law:

For the ray OA $\quad n_0 \sin\theta_0 = n_1 \sin r = n_1\left(\sqrt{1-\cos^2 r}\right)$............ (1)

For the ray AB

$$n_1 \sin(90 - r) = n_2 \sin 90$$

$$n_1 \cos r = n_2$$

$$\cos r = \frac{n_2}{n_1}$$

[here the angle of incidence is (90 - θ_1) for which angle of refraction is 90^0].

Substituting for cosr in equation (1)

$$n_0 \sin\theta_0 = n_1 \sqrt{1 - \frac{n_2^2}{n_1^2}}$$

$$\sin\theta_0 = Sin\theta \frac{\sqrt{n_1^2 - n_2^2}}{n_0}$$

If the medium surrounding the fiber is air then $n_0 = 1$,(3 marks)

Numerical aperture = $\sin\theta_0 = \sqrt{n_1^2 - n_2^2}$

The total internal reflection will take place only if the angle of incidence $\theta_i < \theta_0$

$$\therefore \sin\theta_i < \sin\theta_0$$

$\sin\theta_i <$ $\sqrt{n_1^2 - n_2^2}$

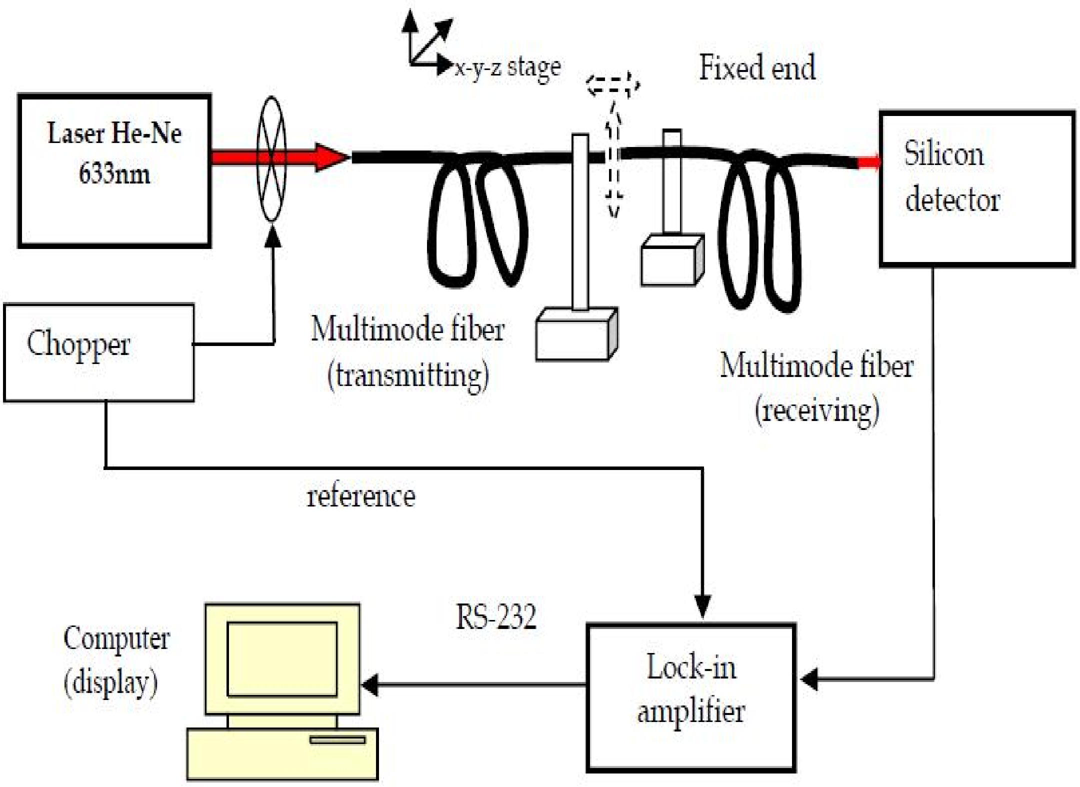
This is the condition for propagation.(1 mark)

4B Fig- 1mark, Description- 3marks

FIBER OPTICS SENSOR FOR DISPLACEMENT MEASUREMENT

This technique is one of the simplest techniques for the displacement measurement, which is based on comparing the transmitted light intensity against incident intensity to provide information on the displacement between the probe and the target. A silicon photo-diode is used to measure the transmitted and reflected light intensity.

Apparatus consists of two set of fiber, one set is connected to a light source and is termed as the transmitting fiber, and the other set is connected to a silicon detector and is known as the receiving fiber. In the experiment, the transmitting fiber located opposite to the receiving fiber is moved laterally and axially. The light is scattered after travelling out from the transmitting fiber and the receiving fiber collect a portion of the scattered light to transmit into the silicon detector where its intensity is measured. The intensity of the collected light is a function of axial and lateral displacement of the fiber. The light source is a He-Ne laser with a peak wavelength of 633 nm.

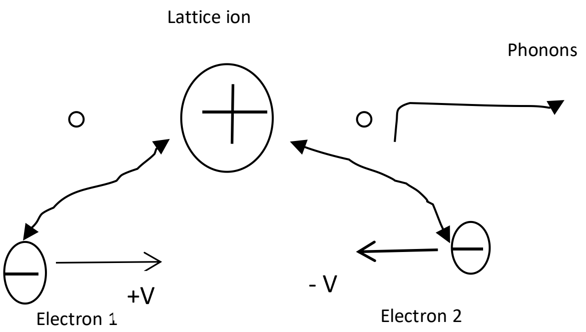


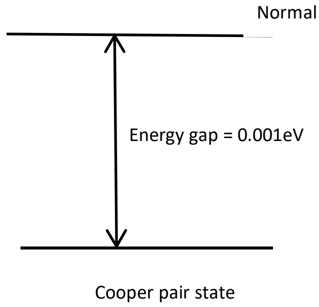
5A

BCS Theory :[Bardeen , Cooper, Schrieffer]

1. When the temperature of the material is reduced below critical temperature, electrons attain lower energy state than the normal energy creating an energy gap of few milli electron volt.
2. Positively charged lattice ion attracts a pair of electrons with equal and opposite spin and momentum through a feeble attractive interaction known as electron-lattice-electron interaction constituting cooper pairs.(2 marks)
3. Cooper pairs interact through exchanging Phonons.
4. All the cooper pairs are in same energy state and possess common wavefunction and Energy.

5. When a potential differnce applied, the current is constituted by flow of cooper pairs and are not scattered as the energy required to break it up is large enough. This reduces the resistance. (2 marks)





6. When the temperature / magnetic field is increased beyond critical limit, cooper pairs breakup and normal state is restored.(2 marks)

5B Formula 1 mark, Substitution 1 mark, Answers- 2marks

$$H_c = H_o(1-\left(\frac{T}{T_c}\right)^2)$$

$$2.7x10^4 = H_0\left(1-\frac{9^2}{T_c^{\ 2}}\right) \text{........(1)}$$

$$5.3x10^4 = H_0\left(1-\frac{6^2}{T_c^{\ 2}}\right) \text{.......(2)}$$

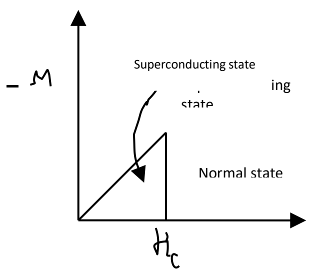
From (1) and (2)

Tc = 11.3 K

H_o = 7.3x10^4A/m

6A

Type 1 Superconductors: (3 marks)



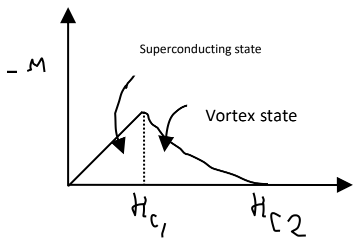
These are pure superconductors.

When kept in magnetic field, initially they continue to exhibit superconductivity and the negative magnetic moment increases. At critical magnetic field there is a sharp transition to normal state due to the penetration of magnetic flux lines. The transition is sharp.

These possess low critical magnetic fields. Their critical temperatures also low.They are generally pure metals.

Ex: Al, Pb

Type 2 superconductor: (3 marks)



These are generally alloys.

When kept in magnetic field, initially they continue to exhibit superconductivity and the negative magnetic moment increases. At lower critical magnetic field H_{C1}, the flux lines start penetrating .As the magnetic field is increased, the super conductivity coexists with magnetic field and this phase is known as mixed state(vortex state). At higher critical magnetic field H_{C2}, the penetration is complete and the material transforms to normal state. They possess higher critical magnetic fields. Their critical temperatures are high.

Ex: Nb_3Ge, $YBa_2Cu_3O_7$

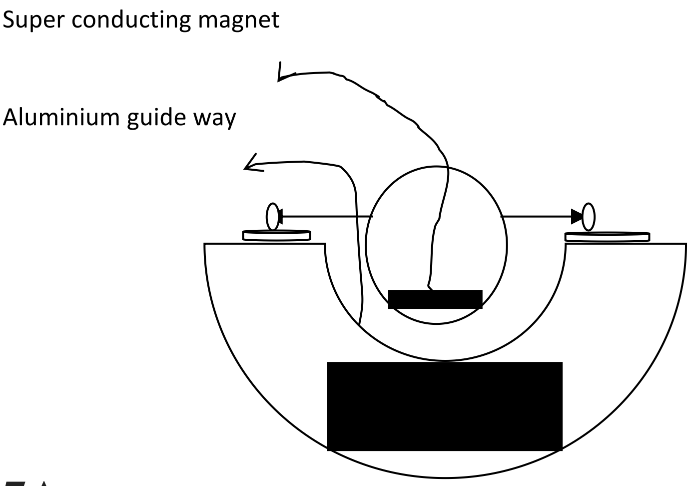
TYPE I	TYPE II
Pb $40x10^3$A/m	Pb – Bi $100x10^3$A/m

6B

Maglev vehicles:

These are the vehicles which are set afloat above the track reducing the friction. With such an arrangement, great speeds could be achieved with low energy consumption.(1mark)

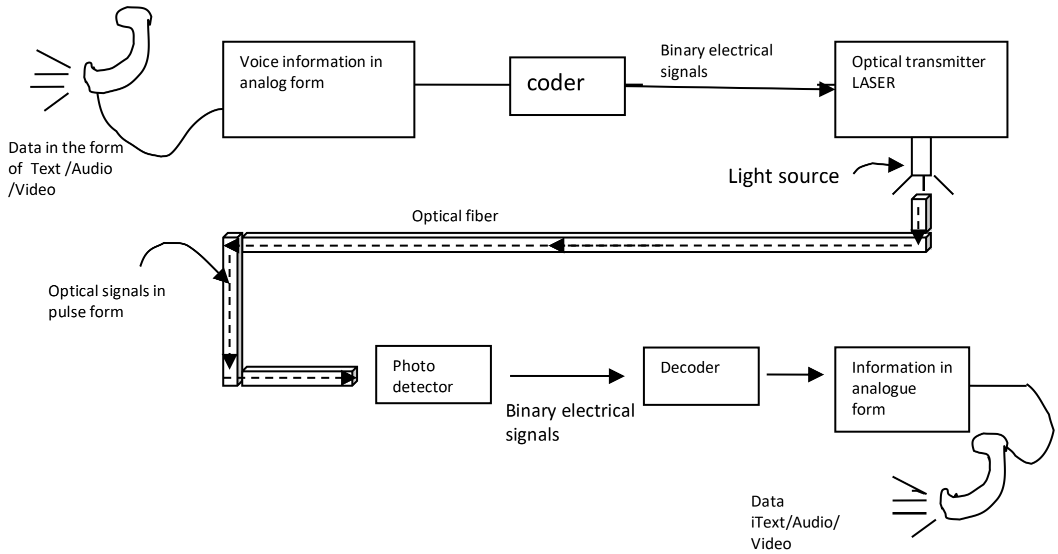
The vehicle consists of superconducting magnets built at the base. Large currents are passed through aluminum guide way. Due to the interaction between the magnetic fields produced by the superconducting magnet and the aluminum guide way, the vehicle is set afloat. These magnetic fields also propel the vehicle. (3 marks)



7A Block diagram: 1 mark

Point to point communication system using optical fibers

This system is represented through a block diagram as follows.



The information in the form of voice/ picture/text is converted to electrical signals through the transducers such as microphone/video camera. The analog signal is converted in to binary data with the help of coder. The binary data in the form of electrical pulses are converted in to pulses of optical power using Semiconductor Laser. This optical power is fed to the optical fiber. Only those modes within the angle of acceptance cone will be sustained for propagation by means of total internal reflection. At the receiving end of the fiber, the optical signal is fed in to a photo detector where the signal is converted to pulses of current by a photo diode. Decoder converts the sequence of binary data stream in to an analog signal . Loudspeaker/CRT screen provide information such as voice/ picture.(3 marks)

Merits and Demerits of optical fiber communication

Merits –(2 marks)

Large bandwidth (1000GHz)
Data security
No Electrical Interference (No cross talk)
Low loss (0.01dB/km)
Portable
Cheaper

Demerits

Repair costs high
Light emitting sources are limited to low power
The distance between the transmitter and receiver should keep short or repeaters are needed to boost the signal.

7B Formula 1 mark, Substitution 1 mark, Answers- 2marks

$$\alpha = \frac{10}{L}\log\left(\frac{P_{IN}}{P_{OUT}}\right)$$

$$\log\frac{P_{IN}}{P_{OUT}} = \frac{\alpha L}{10}$$

$$\frac{P_{in}}{P_{out}} = 10^{\frac{\alpha L}{10}} = 1.05$$

$$P_{out} = \frac{P_{in}}{1.05} = 0.95 P_{in}$$