3.15 - Problem Set 6 Solutions

Problem 1

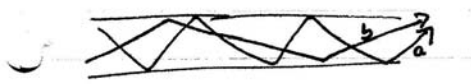
a.

1.55 μm $\rightarrow$ band gap of active region = 0.8 eV.
Choose active: (AlGa)Sb with 10% Al
cladding: (AlGa)Sb with more Al, eg 20 - 40 % to avoid too much mismatch while having higher E_g Mention refractive index too.
Subtrate: GaSb - need a binary.

	active	clad.	substr.
Other Options:	$(In_{75}Al_{25})As$	more Al	InAs
	$(In_{50}Ga_{50})As$	more Ga	InAs or InP
(These are less good - more mismatch)	$In(P_{40}As_{60})$	more P	GaAs or InAs
	$(In_{60}Al_{40})Sb$	more Al	InSb
	$Ga_{70}(As_{50}Sb_{50}$	more As	InP

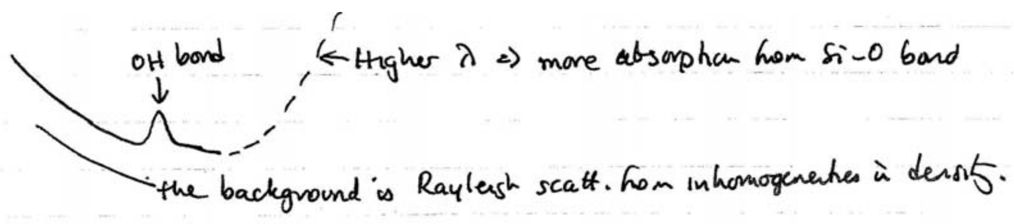
b.

Parabolic profile avoids modal dispersion (in core).



a travels further than b. Make sure a travels faster by having lower refractive index near edge of fiber. Cladding has lower RI to confine light by internal reflection.

c.



d.

$$0.15\text{dB/m} = \frac{10}{L}\log(P_{in}/P_{out}) = \frac{10}{L}\log 1000 = 30/L$$

So:

$$L = 30/0.15 = 200\text{km}.$$

e.

$$\sigma_t = \sigma_\lambda L D_\lambda$$

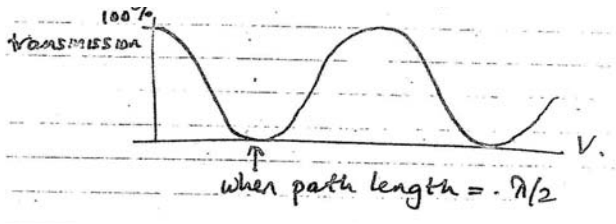
$$D_\lambda = 20\text{ps/km}\cdot\text{nm}, \sigma_\lambda = 2\text{nm}, L = 200\text{km} \Rightarrow \sigma_t = 8\text{ns}$$

Pulses would spread by 8 ns, so max data rate $= \frac{1}{q} \times 10^9/\text{s} = 125\text{MHz}$.

Problem 2

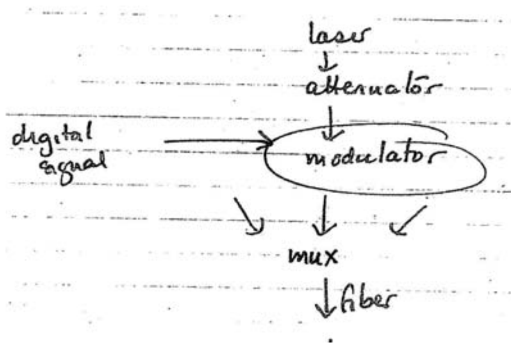
a.

If the refractive index of the material changes (increases), the light will be delayed going through L will be out of phase, so will cancel light from the lower arm.



b.

To modulate a laser signal prior to sending down fiber. Better than turning the laser on & off. That would give temp. drift ⇒ wavelength dring and wouldn't be fast enough.



c.

$$n = n_0 - \frac{1}{2} r n_0^3 \epsilon$$

Here $n_0 = 2, r = 10^{-12}\text{m/V}$,

How much change in n is required? We want to delay the light by a half wavelength as it passes through.

1.5 μm light in vacuum $\rightarrow \frac{1.5}{n} = 0.75\mu$m wavelength in the material.

1 mm length of material contains $\frac{10^{-3}}{\frac{1.5}{n} \cdot 10^{-6}} = 1.33 \cdot 10^3$ wavelengths.

If we want $(1.33 \cdot 10^3) + \frac{1}{2}$ wavelengths, wew need to change n so that $\frac{10^{-3} n}{1.5 \cdot 10^{-6}} = \frac{1}{2} + \frac{2 \cdot 10^{-3}}{1.5 \cdot 10^{-6}}$

or $\frac{10^3}{1.5} n = \frac{1}{2} + \frac{4}{3} \cdot 10^3$

$$n = 2.00075$$

So we need $n - n_0 = 0.00075$.

$$\frac{1}{2} r n_0^3 \epsilon = 0.00075$$

$$\epsilon = \frac{0.00075}{10^{-10}} \times 2/8 = 0.188 \text{MV/m}$$

Over a distance of 10 μm, $V = 1.88$ volts.

d.

Materials lacking a center of symmetry (& transparent!)

$LiNbO_3$	trigonal 3 m
$NH_4H_2PO_4$	tetragonal 42 m
KH_2PO_4	

e.

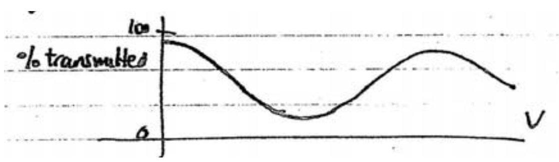
10 dB/cm $\Rightarrow$ the light is attenuated by 1 dB since it is 1 mm long.

$$\text{attenuation} = 10 \frac{\text{dB}}{\text{cm}} = \frac{10}{L} \log \left(\frac{P_{in}}{P_{out}} \right)$$

$$10 \log(P_{in}/P_{out}) = 1$$

$$P_{in}/P_{out} = 1.25$$

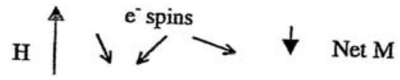
So 25% of the light power is absorbed. This will degrade the performance. Even when the light is out of phase, some will get through since there will be incomplete cancellation.



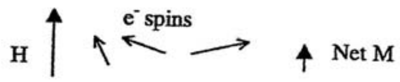
Problem 3

a.

Diamagnet - μ_r is slightly less than one. Magnetization of the material weakly opposes the applied field.



Paramagnet - μ_r is slightly greater than one. Magnetization is weakly aligned with applied field.



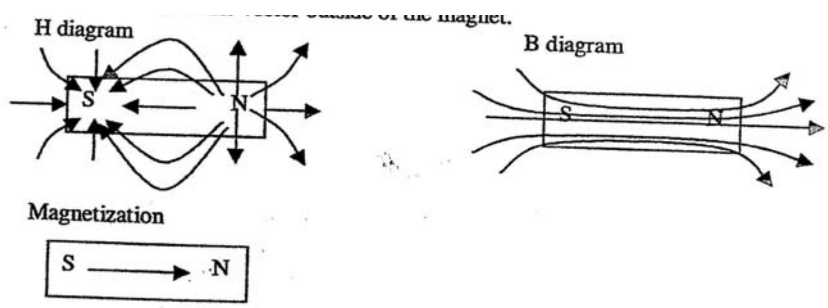
Ferromagnet - spins are aligned by the exchange interaction. μ_r is very large, on the order of 100-1000's and non-linear. Material experiences spontaneous magnetization.

Antiferromagnet - spins are antiparallel. No net magnetization occurs. Occurs if there is separation between magnetic atoms so exchange energy does not dominate.

Ferrimagnet - similar to antiferromagnet but opposing spins do not cancel in the sublattice so there is a net magnetization.

b.

B and H are the same vector outside the magnet.



c.

$$\text{Joule } = F \cdot d = \frac{\text{kg} \cdot \text{m}^2}{\text{s}^2}$$

d.

B-H loop is the same as the M-H loop except for a factor of μ_0 and the $\mu_0 H$ term which is linear. The B-H loop has a slope and shows the magnetic flux density vs. H while the M-H shows the material magnetization vs. H.

Coercivity is the applied field required to return a material to a state of zero net magnetization. Remanance is the remaining magnetization when the applied field is removed from a saturated magnet. Permeability characterizes the material response to an applied magnetic field, $\mu_r = 1 + \frac{M}{H}$.

Hysteresis loss is energy used in cycling the B-H loop due to irreversible processes such as domain wall motion.

Eddy current loss refers to the resistive losses due to the induced eddy currents.