Problem 1

a.

1.55 µm → 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.
Substrate: GaSb - need a binary.

<table>
<thead>
<tr>
<th>Other Options:</th>
<th>active</th>
<th>clad.</th>
<th>subr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(These are less good - more mismatch)</td>
<td>(In$<em>{25}$Al$</em>{75}$)As</td>
<td>more Al</td>
<td>InAs</td>
</tr>
<tr>
<td></td>
<td>(In$<em>{50}$Ga$</em>{50}$)As</td>
<td>more Ga</td>
<td>InAs or InP</td>
</tr>
<tr>
<td></td>
<td>In(P$<em>{40}$As$</em>{60}$)</td>
<td>more P</td>
<td>GaAs or InAs</td>
</tr>
<tr>
<td></td>
<td>(In$<em>{40}$Al$</em>{60}$)Sb</td>
<td>more Al</td>
<td>InSb</td>
</tr>
<tr>
<td></td>
<td>Ga$<em>{70}$(As$</em>{80}$Sb$_{30}$)</td>
<td>more As</td>
<td>InP</td>
</tr>
</tbody>
</table>

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. 

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

So:

\[ L = \frac{30}{0.15} = 200 \text{km}. \]

e. 

\[ \sigma_t = \sigma_\lambda LD_\lambda \]

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

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

![Graph showing transmission vs. voltage](image)

When path length = $\lambda/2$.

b.

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

![Diagram showing laser, attenuator, modulator, digital signal, mux, fiber](image)

c.

\[ n = n_0 - \frac{1}{2}rn_0^3\epsilon \]

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

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

If we want $(1.33 \cdot 10^3) + \frac{1}{2}$ wavelengths, we 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 $\mu$m, $V = 1.88$ volts.

d.

Materials lacking a center of symmetry (& transparent!)

- LiNbO$_3$ trigonal 3 m
- NH$_4$H$_2$PO$_4$ tetragonal 42 m
- KH$_2$PO$_4$

e.

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

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

$10 \log \left( \frac{P_{in}}{P_{out}} \right) = 1$

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

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 - $\mu_r$ is slightly less than one. Magnetization of the material weakly opposes the applied field.

![Diagram of diamagnetism](image)

Paramagnet - $\mu_r$ is slightly greater than one. Magnetization is weakly aligned with applied field.

![Diagram of paramagnetism](image)

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

![Diagram of ferromagnetism](image)
Antiferromagnet - spins are antiparallel. No net magnetization occurs. Occurs if there is separation between magnetic atoms so exchange energy does not dominate.

![Antiferromagnet Diagram](image)

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

![Ferrimagnet Diagram](image)

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 \(\mu_0\) 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.