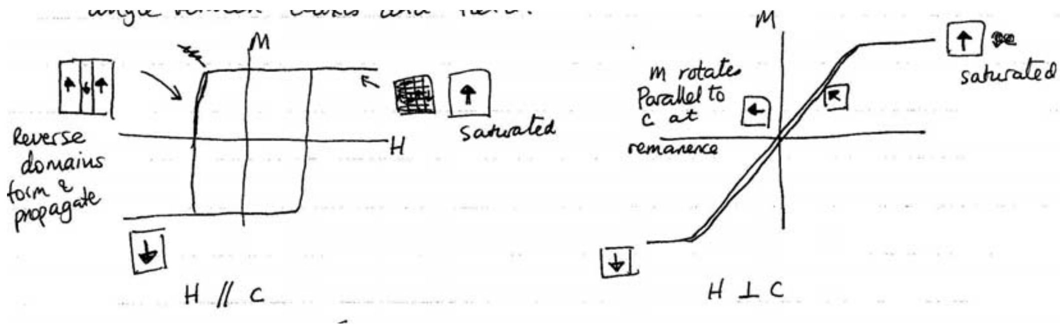
Sample Final - Solutions

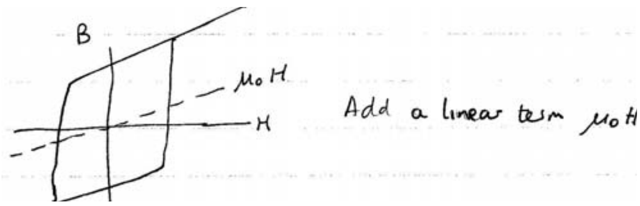
Problem 1

a.

Material is multidomain.
Domains in Co line up with c-axis. Hoop shape will depend on angle between co-axis and field.



b.



Add a linear term $mu_0 H$.

c.

Assume thermal instability when kT ≈ energy needed to reverse particle.

$$kT = 1.38 \cdot 10^{-23} \times 300\text{J} \approx \frac{1}{25} K_u \cdot \frac{4}{3}\pi r^3$$

$$r = 25 \cdot \frac{3}{4\pi}\left(\frac{1.38 \cdot 10^{-23} \times 300}{5 \cdot 105}\right)^{\frac{1}{3}} \text{m} = 3.7\text{nm if} kV = kT$$

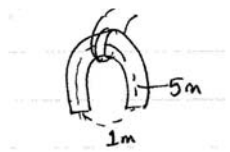
For $r < r_c$ since it's thermall unstable, $H_c = 0$ and time-averaged $M_r = 0$.

d.

Alnico: Small elongated single domain NiCo particles in AlNi nonmagn matrix have high H_c because they cannot support a domain wall.
$SmCo_5$: has v. high $K_u \to h$
a-FeSiB: very soft because $K_i \approx 0$, no pinning sites for DWs.

Problem 2

a.



Ampere's Law says:

$$\int H dl = ni$$

$$5H_{core} + H_{gap} = 10^4$$

Force we need to exert is $2 \cdot 10^4$ N.
Max. magnetization of car = $B_s = 1$T. $B = \mu_0(H + M)$.
So:

$$M_s = \frac{1}{\mu_0} B_s = \frac{1}{4\pi 10^{-7}} \text{A/m} = 0.08 \cdot 10^7 \text{A/m or} 800\text{kA/m}$$

Force on car is: $\mu_0 H_{gap} M_s V = 2 \cdot 10^4 N$ so we need $H_{gap} = \frac{2 \cdot 10^4}{\mu_0 M_s V}$.
Volume of steel is: $\frac{500\text{kg}}{2.5\text{g/cm}^3} = \frac{500}{25000} m^3 = 0.2m^3$.
$H_{gap} = \frac{2 \cdot 10^4}{0.2} = 10^5$ A/m or 100 kA/m.

This is quite a small field so should be possible to achieve.
From Ampere: if $H_{gap} = 10^5$ A/m, $10^4 = 5H_{core} + 10^5$.
Max value of $H_{core} = \frac{1}{\mu_0} B_{core}$, choose *soft, high* B_s core like Fe-Si.

$$B_{core} = 2.1\text{T}$$

$$H_{core} = \frac{2.1}{4\pi 10^{-7}} \text{A/m} = \frac{1}{6} 10^7 \text{A/m} = 1.67 \cdot 10^6 \text{A/m}$$

$$10^4 = 10^5 + 5 \times \frac{2.1}{4\pi 10^{-7}} = 10^5 + \frac{10}{12} \cdot 5 \times 10^7 \approx 8.5 \cdot 10^6 \text{A}$$

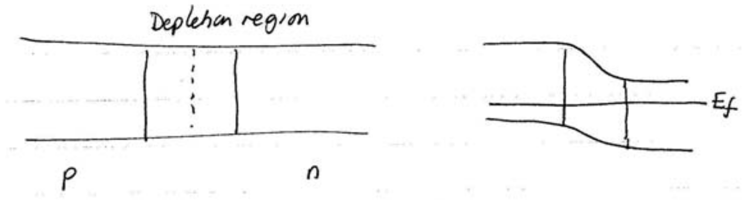
So need current of 850A.

A lot of current needed, because the magnet is large and $\oint H dl$ is big $\Rightarrow$ get hot.

Problem 3

a.

(i)



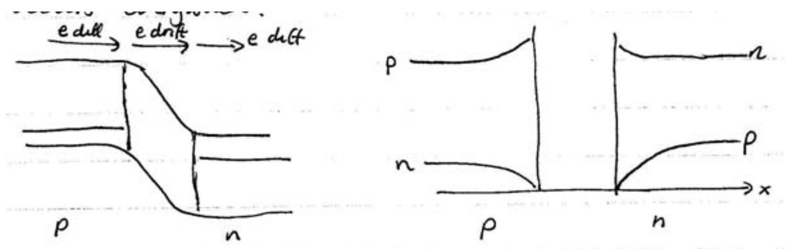
Only in depl. region:

→ hole diffusion, e⁻ drift
←ediffusion, h drift

Therma R & G occurs everywhere.

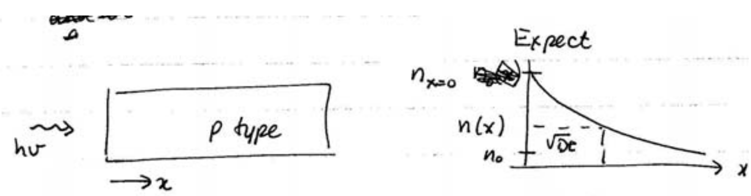
(ii)

Reverse Bias:



→ hole diffusion is very small - neglect
holes diffuse away from depl. region ←←← (hole drift) holes diffuse to edge of depl region

b.



$$\frac{dn}{dt} = \frac{dn}{dt}_{drift} + \frac{dn}{dt}_{diff} + \frac{dn}{dt}_{thermalRG} + \frac{dn}{dt}_{otherRG} = 0 \text{ at steady state}$$

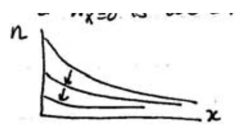
$$\frac{dn}{dt}_{drift} = 0 \text{ no } \epsilon, \frac{dn}{dt}_{otherRG} = 0 \text{ inside Si. Recombination.}$$

$$\frac{dn}{dt}_{drift} + \left(\frac{n - n_0}{\tau}\right) = 0$$

$$D_n \frac{d^2 n}{dx^2} + \frac{n - n_0}{\tau} = 0 \text{ has solutions } (n - n_0) = (n_{x=0} - n_0 \exp\left(\frac{-x}{\sqrt{Dt}}\right.$$

where n_0 = equilibrium corner density and $n_{x=0}$ determined by light intensity.

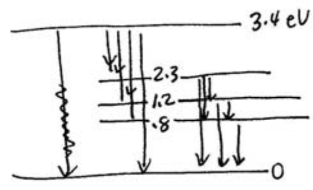
c.



It decays so that $n_{x=0}(t) = n_{x=0}(t = 0) \exp -t/\tau$.

Problem 4

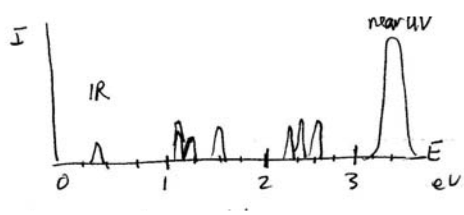
a.



LED makes 3.4 eV, 2.6, 2.2, 1.1 eV
2.3,1.5, 1.1 eV
1.2, 0.4
0.8

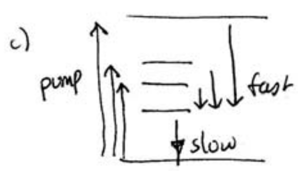
10 possible colors through some overlap. Intensity depends on transition probability and number of carriers in the level' which depends on how manny states are present in gap. Since $E_r = 1\%$, the brightest line would be 3.4 eV and broadest. Width is less for the others since energy levels sharper.

b.



The peaks would be broader because there is a distribution of energy levels.

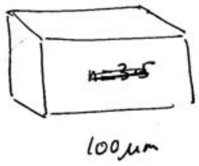
c.



Pump with $\geq$ 3.4 eV (though $\geq$ 2.3 eV would also work, it would give fewer carriers).

Color:

$$0.8\text{eV} \Rightarrow \lambda = \frac{1.24}{0.8}\mu\text{m} = 1.55\mu\text{m}$$



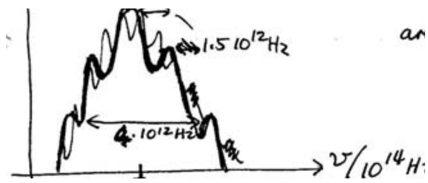
Frequency:

$$c = v\lambda; v = \frac{3\cdot 10^8 \times 0.8}{1.24\times 10^6} = 1.93\cdot 10^{14}\text{Hz}$$

Cavity modes have frequency:

$$v = \frac{dN}{2d}, textrmNisaninteger.$$

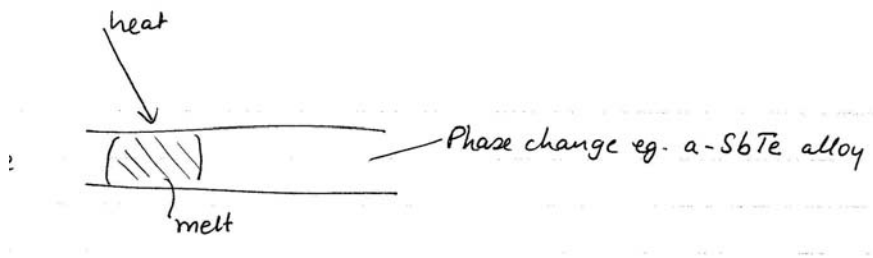
Spacing of cavity modes is $c/2d = \frac{3\times 10^8}{2\times 100\cdot 10^{-6}} = 1.5\cdot 10^{12}$ Hz.



So the center frequency is $1.93\cdot 10^{14}$ Hz and modes are spaced at $0.015\cdot 10^{14}$ Hz. If spectral width is 2% of center frequency, we will see just 3 modes.

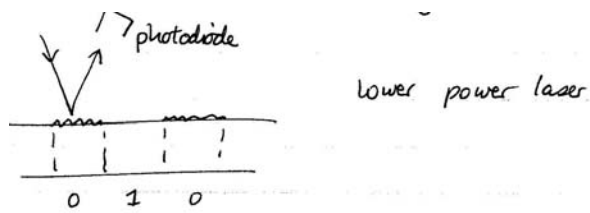
Problem 5

a.



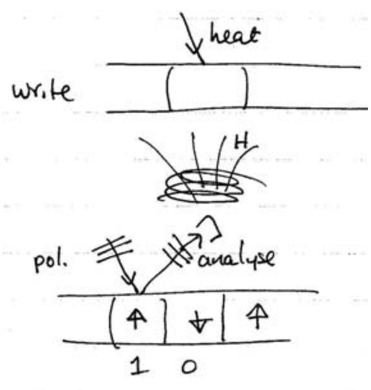
As material resolidifies - a fast quench ⇒ shiny amorph. surface = 1, slow ⇒ rough crystalline surface = 0.

Read:

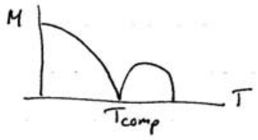


Lower power laser.

b.



MO material = ferrimagnetic a-RE-TM alloy. Antiferromag at T_{comp} RT but still high keff coeff.
Write: heat above compensation temp, allow to cool in field from coil.
Read: measure K_{err} rotation, need polarizer/analyzer and photodetector.



c.
Limited by diffraction size of laser spot or by heat transport (whichever is larger).

d.
MO media more complex - needs external field as well as laser. Also readback is smaller signal since Kerr rotation is $< 1°$ whereas reflectivity change in phase change media is larger effect.