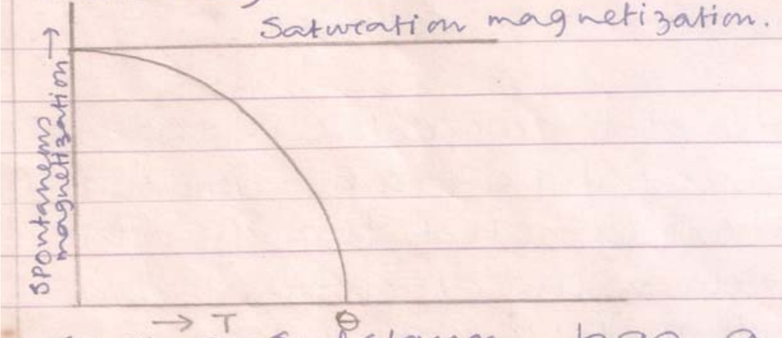
Theory of Ferromagnetism :-

χT = constant → Curie law (For paramagne-

$\chi = \frac{C}{T-\theta}$ → Curie-weiss law . C = Curie cons

θ = Curie temp.

A Substance which posses a spontaneous magnetisation or magnetic moment is called Ferromagnetic.

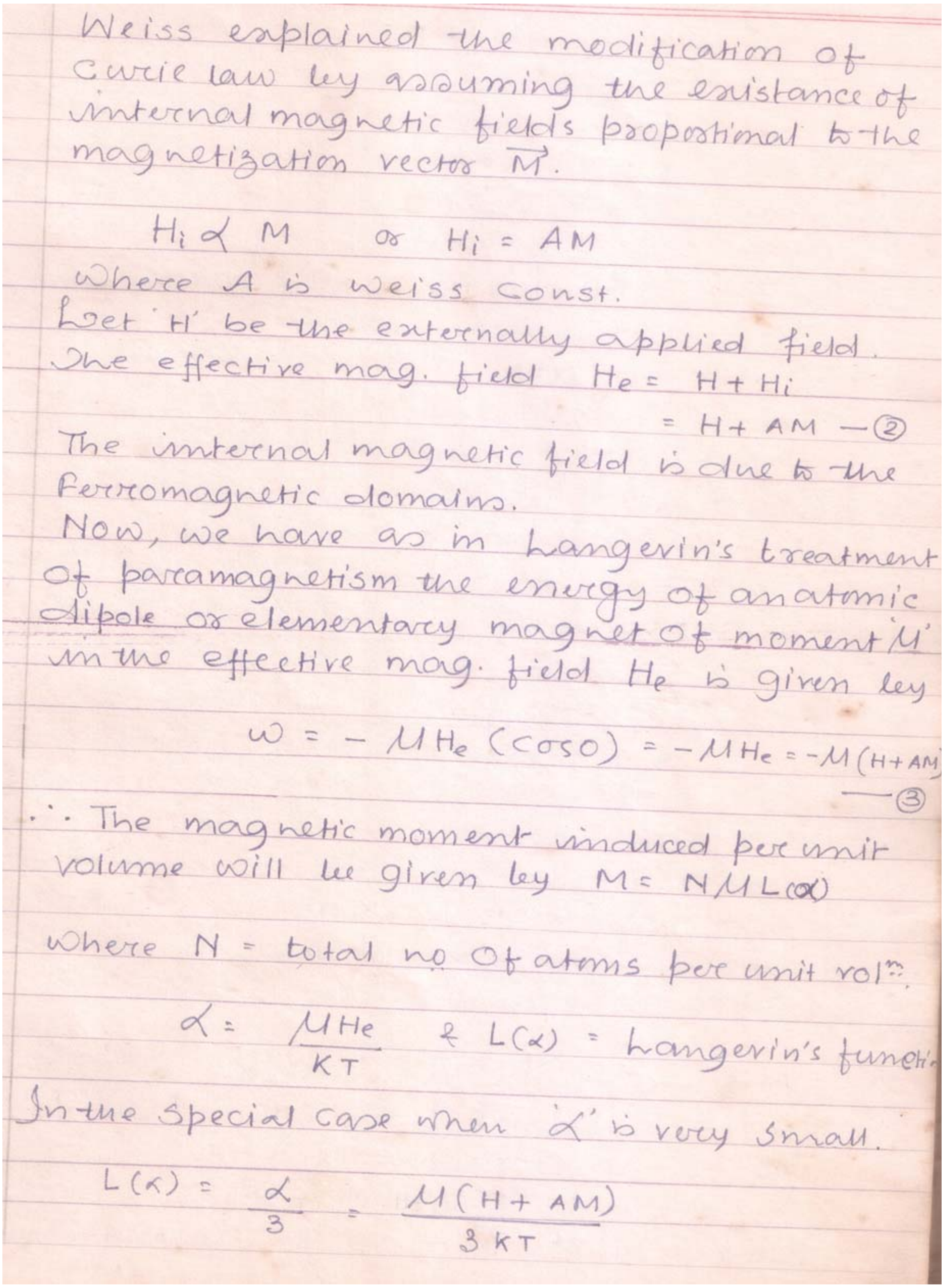


Such a Substance has a magnetic mome even in the absence of an external mag. fie The paramagnetic Curie temp. 'θ' is the tem above which spontaneous magnetisation vanish and the material becomes paramagnetic.

Weiss observed on the basis of the experimental result that only a few magnetic substances obey strictly the Curie law i.e $\chi = \frac{C}{T}$. The susceptibility fitted well in the modified formula

$$\chi = \frac{C}{T-\theta} \quad —— ①$$

'θ' depends on nature of the material.



Weiss explained the modification of Curie law by assuming the existance of internal magnetic fields proportional to the magnetization vector $\vec{M}$.

$$H_i \propto M \quad \text{or} \quad H_i = AM$$

Where A is Weiss const.

Let 'H' be the externally applied field.

The effective mag. field $H_e = H + H_i$

$= H + AM$ — ②

The internal magnetic field is due to the Ferromagnetic domains.

Now, we have as in Langevin's treatment of paramagnetism the energy of an atomic dipole or elementary magnet of moment 'μ' in the effective mag. field H_e is given by

$$w = -\mu H_e (\cos 0) = -\mu H_e = -\mu(H + AM)$$

— ③

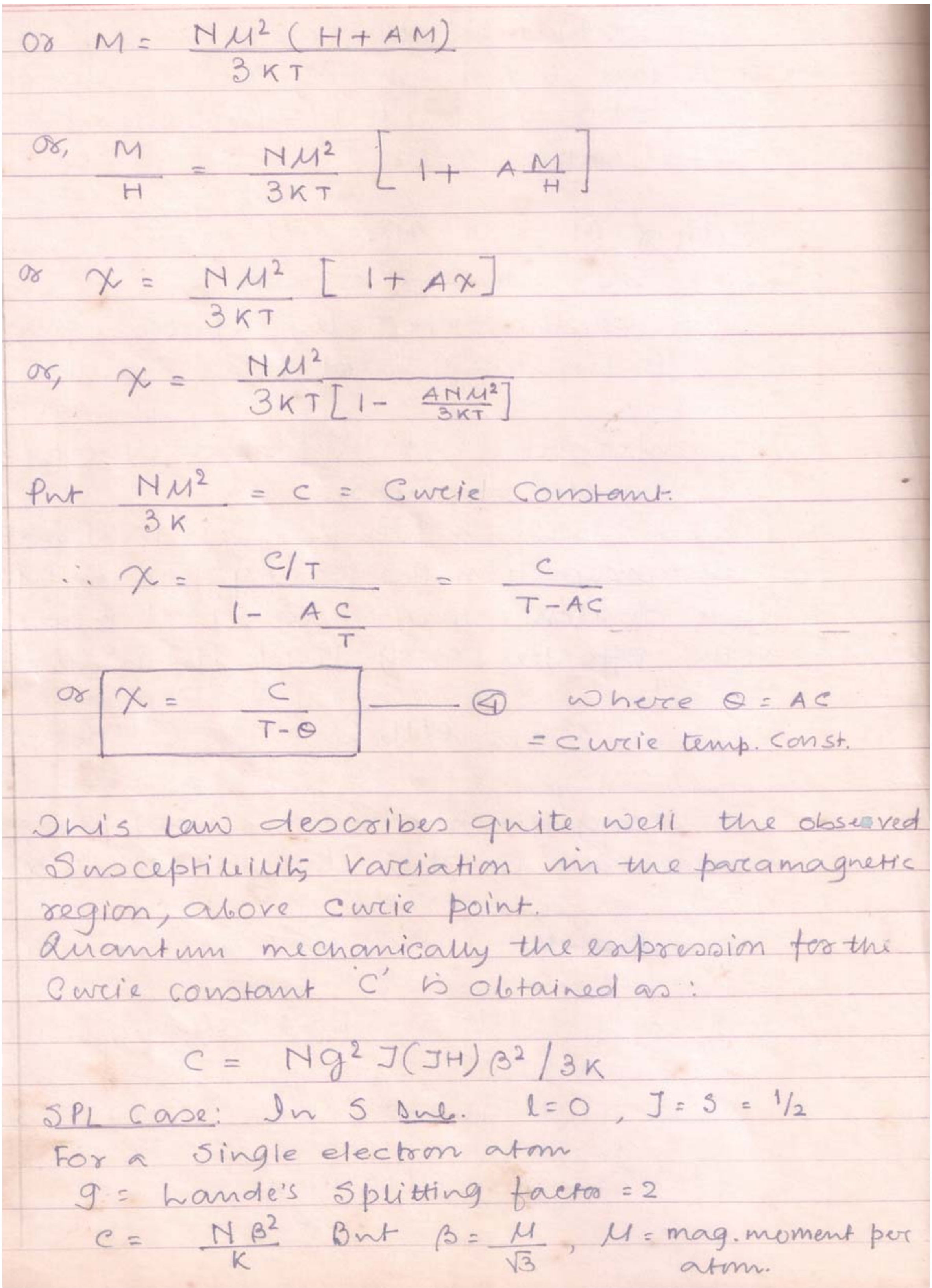
∴ The magnetic moment induced per unit volume will be given by $M = N\mu L(\alpha)$

Where N = total no. of atoms per unit vol^{m}.

$\alpha = \frac{\mu H_e}{KT}$ & $L(\alpha)$ = Langevin's functi

In the special case when 'α' is very small.

$$L(\alpha) = \frac{\alpha}{3} = \frac{\mu(H + AM)}{3KT}$$



or $M = \frac{N\mu^2 (H + AM)}{3KT}$

or, $\frac{M}{H} = \frac{N\mu^2}{3KT}\left[1 + A\frac{M}{H}\right]$

or $\chi = \frac{N\mu^2}{3KT}[1 + A\chi]$

or, $\chi = \frac{N\mu^2}{3KT\left[1 - \frac{AN\mu^2}{3KT}\right]}$

Put $\frac{N\mu^2}{3K} = C =$ Curie Constant.

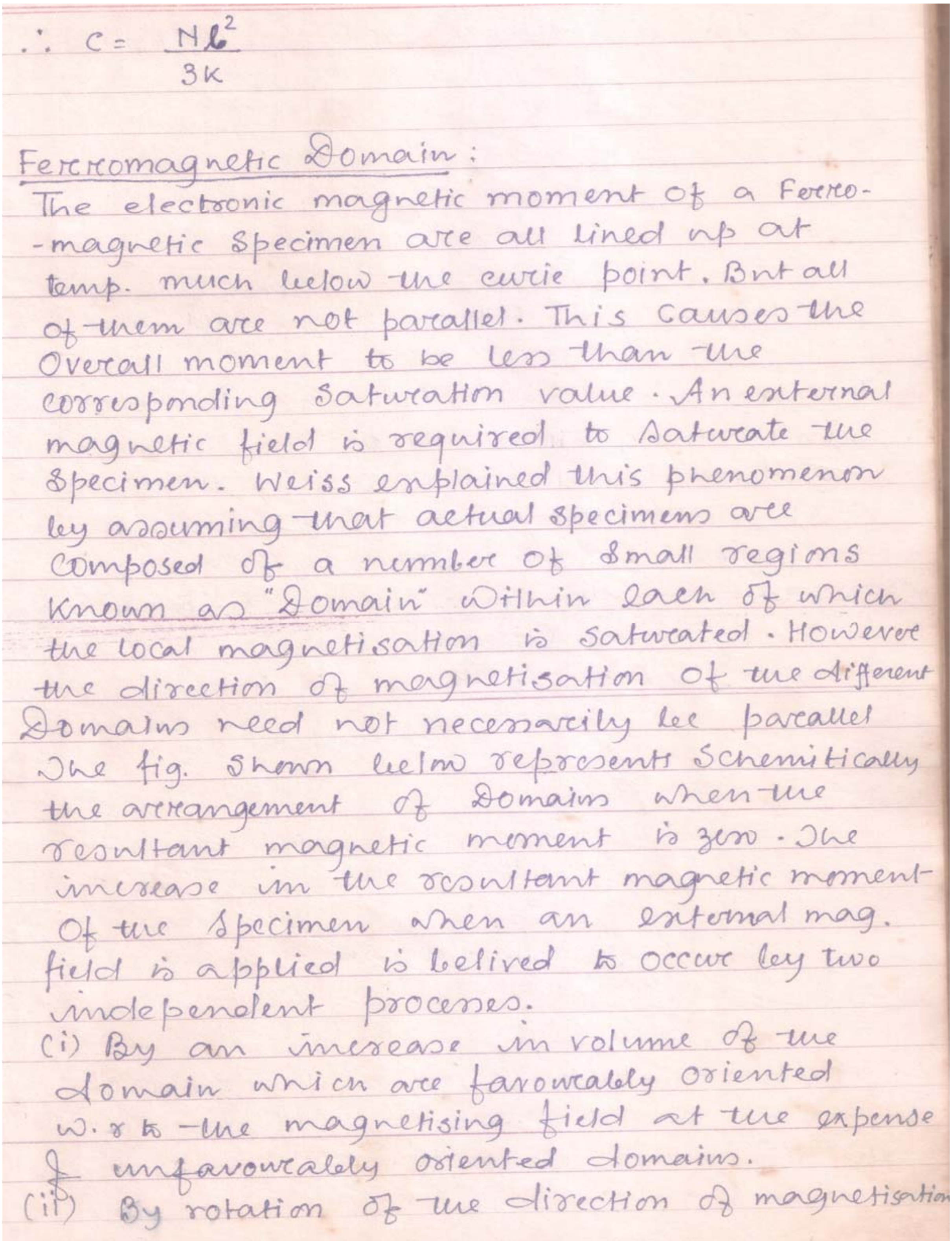
$\therefore \chi = \frac{C/T}{1 - \frac{AC}{T}} = \frac{C}{T - AC}$

or $\boxed{\chi = \frac{C}{T - \Theta}}$ —— ④ where $\Theta = AC$ = Curie temp. const.

This law describes quite well the observed susceptibility variation in the paramagnetic region, above curie point.
Quantum mechanically the expression for the Curie constant 'C' is obtained as:

$$C = Ng^2 J(J+1)\beta^2/3K$$

SPL case: In S Sub. $l = 0$, $J = S = 1/2$
For a single electron atom
g = Lande's splitting factor $= 2$
$C = \frac{N\beta^2}{K}$ But $\beta = \frac{\mu}{\sqrt{3}}$, μ = mag. moment per atom.



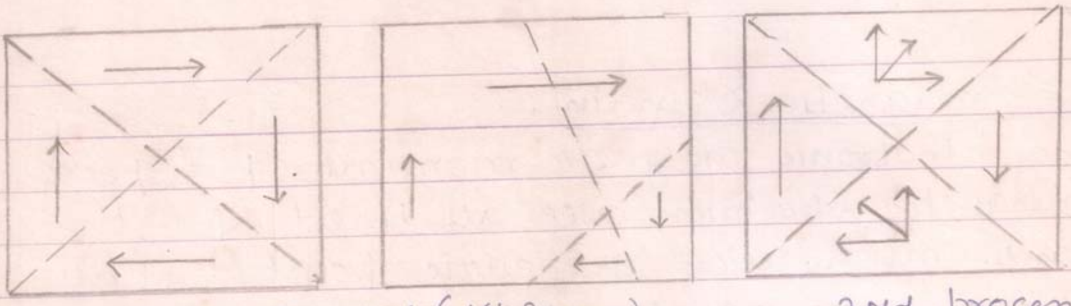
$$\therefore C = \frac{Nb^2}{3K}$$

Ferromagnetic Domain :

The electronic magnetic moment of a Ferro-magnetic specimen are all lined up at temp. much below the curie point. But all of them are not parallel. This causes the overall moment to be less than the corresponding saturation value. An external magnetic field is required to saturate the specimen. Weiss explained this phenomenon by assuming that actual specimens are composed of a number of small regions known as "Domain" within each of which the local magnetisation is saturated. However the direction of magnetisation of the different Domains need not necessarily be parallel. The fig. shown below represents schemitically the arrangement of Domains when the resultant magnetic moment is zero. The increase in the resultant magnetic moment of the specimen when an external mag. field is applied is belived to occur by two independent processes.

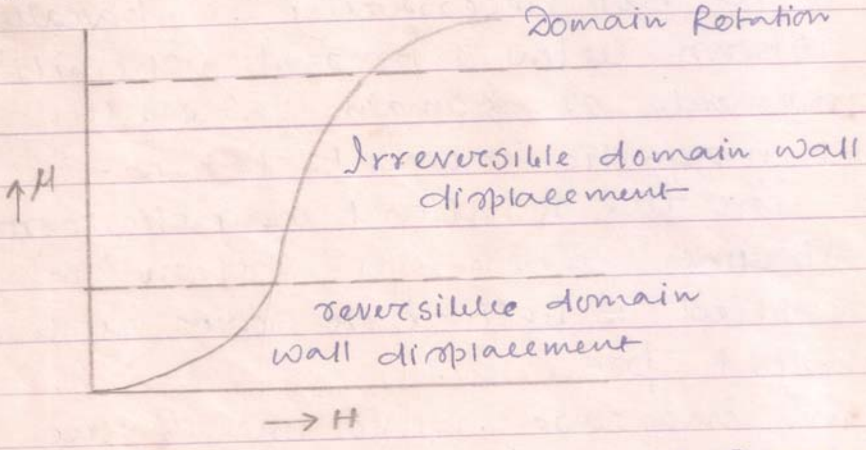
(i) By an increase in volume of the domain which are favourably oriented w.r.t the magnetising field at the expense of unfavourablely oriented domains.

(ii) By rotation of the direction of magnetisation towards the direction of magnetising field.

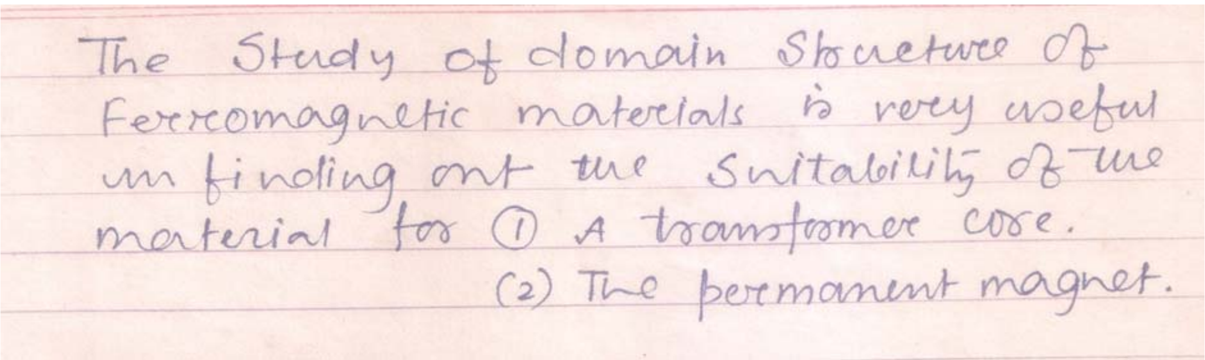


Single Crystal (1st Process)   2nd process.

The fig. above show how a single crystal can be magnetised by the two process. It has been found experimentally that in weak fields, the magnetization changes by the process of domain wall displacements i.e change in domain size. In a strong mag. field the magnetisation changes by rotation of the direction of magnetisation.



A typical magnetization curve of ferromagnetic specimen is shown in the diagram with the regions in which the two process are dominant.



The Study of domain Structure of Ferromagnetic materials is very useful in finding out the suitability of the material for ① A transformer core.

(2) The permanent magnet.