CHAPTER NO. 16 'COMPOSITES'

What are the four main types of materials.
(i) Metals
(ii) Ceramics
(iii) Compositles
(iv) Polymers.

Define Ceramics and give examples.

Ceramics are compounds composed of metallic and non-metallic elements bonded together through ionic and covalent bonds.

Example:- Alumina, SiC, porcelain etc.

Define Composites and give examples.

Composites are materials made from two distinct constituent materials with different physical or chemical properties.

Example.
(i) Wood (Cellulose fibre in ligin matrix)
(ii) Bone (collagen & calcium)
(iii) Safety helmets and bullet proof vests.
(iv) Fiber glass tanks (fiber glass, re-enforced plastic)
(v) plywood
(vi) Mud & straw plaster/Bricks.
(vii) Reinforced Cement concrete
(viii) Boats, sports equipement

Why do we use composites in comparison to other materials.

Metals Polymers Ceramics

Metals do have intermediate strength, moduli and good ductility but they are heavy

Polymers are light weight, low cost but have low strength and low moduli and large strains

strong stiff but brittle

* Furthermore engineering applications often require combinational properties ∴ composites are used.

Example:-

Aerospace industries would require strong stiff, light weight and abrasion resistant materials.

=> available strong materials like metals/ ceramics may be too heavy/dense.

=> While light weight polymers are not good abrasion resistant and lack strength.

Therefore we use composites like 'PMCs, CMCs and MMCs'.

other examples in;
automobile,
transportation, sports industry etc.

Question:- Describe and enlist the components of composites.

Following are the components of a composite.

(i) Matrix

Continuous phase that holds the composite together, provides cohension, shape and support. example; may be; metal, polymer or ceramic.

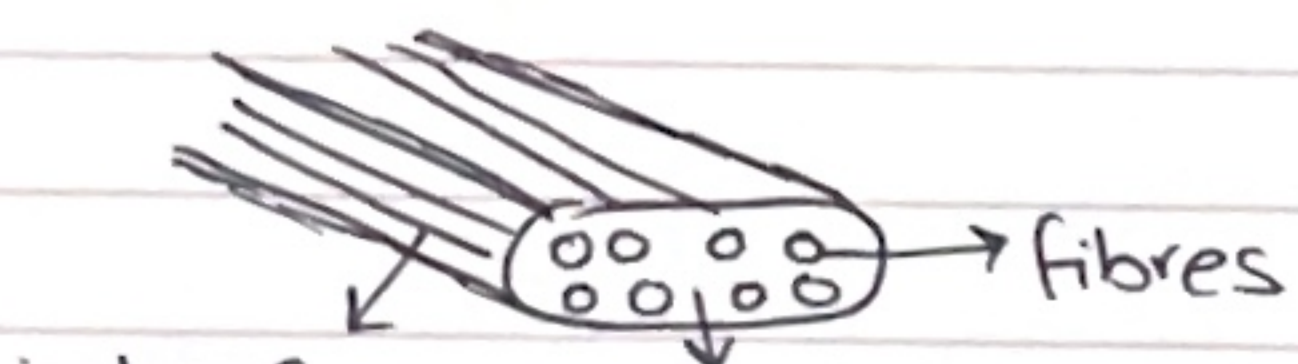
(ii) Re-enforced materials:-

discontinuous phase that is dispered in the matrix; provides strength, stiffness, and specific properties.

They are materials like glass, carbon, aramid or natural fibers.

(iii) interface:-

Region where the matrix interacts with the re-enforcing material.
Crucial for stress transfer and load distribution.



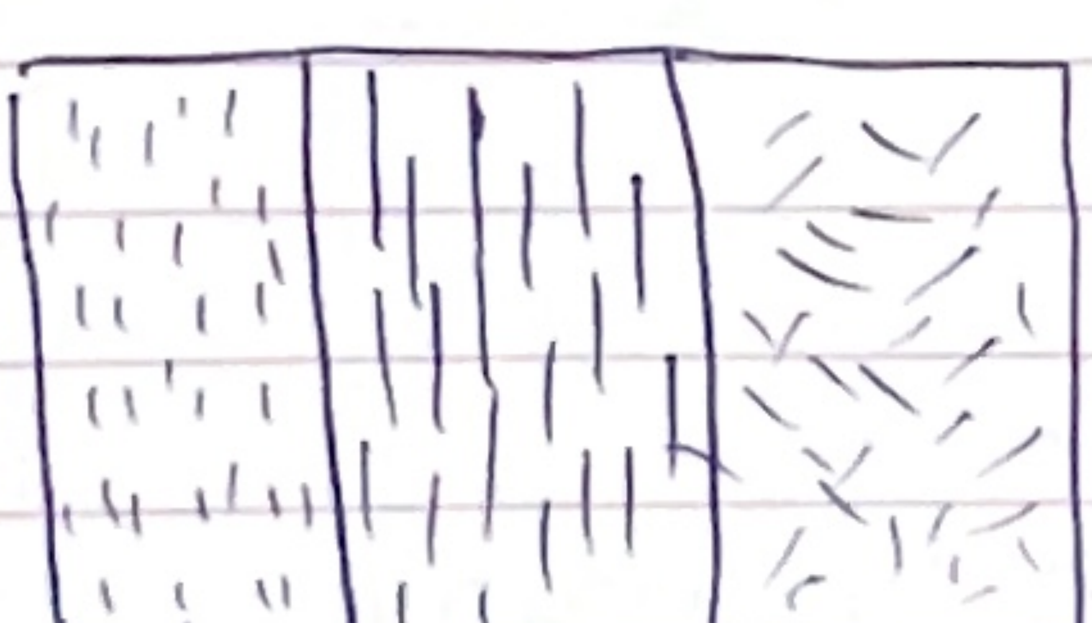
Question:-
How can ~~the~~ composites b classified ?

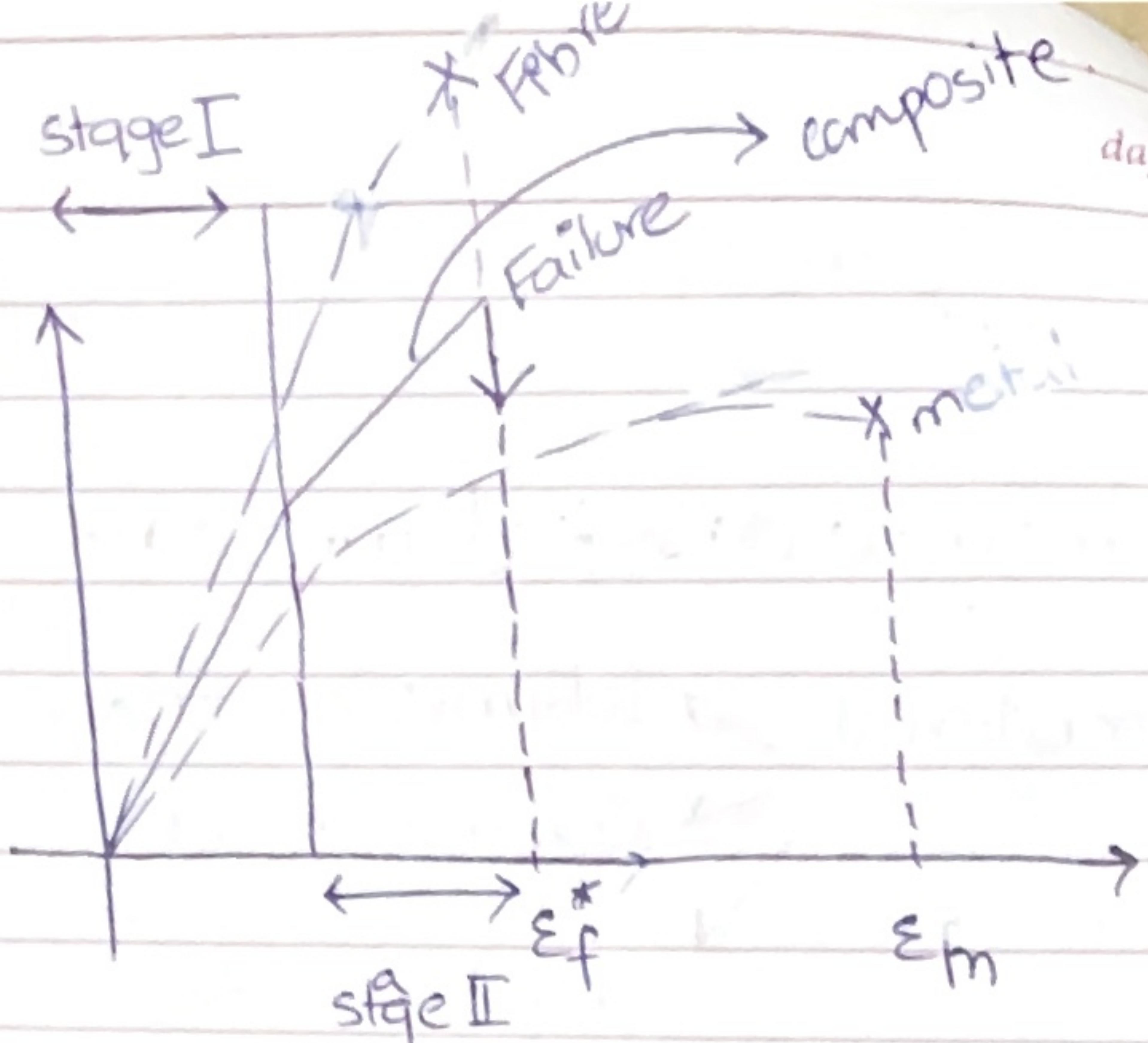
Composites may be classified w.r.t to:-

(i) Matrix material → Polymer matrix
→ Ceramic matrix
→ Metal matrix

(ii) Re-enforcement material.
&
(iii) Re-inforcement morphology/phase → conce
→ size
→ shape
→ distribution
→ orientation.

Composites
- Plastic reenforced
  - large particles
  - Dipersion strengthened
- Fiber reinforced
  - continuous (aligned)
  - discontinuous (short)
    - aligned
    - Random orientation
- Structural
  - Laminate
  - Sandwich panals.
- Nano





Why composite failure / fracture is not catastrophic?

=> Not all fibers break at the same time; there are considerable variations of the fracture strength in the brittle fiber material. Similarly the matrix is not fracture even after ε_f^* ∴ some fibers in the matrix may still be intact.

Q. Describe the equation $l_c = \frac{\sigma_f^* d}{2\tau_c}$

The length of the fibre in fibre-re-inforced composites is necessary to take in account as some critical fibre length 'l_c' is necessary for the composite strengthening.

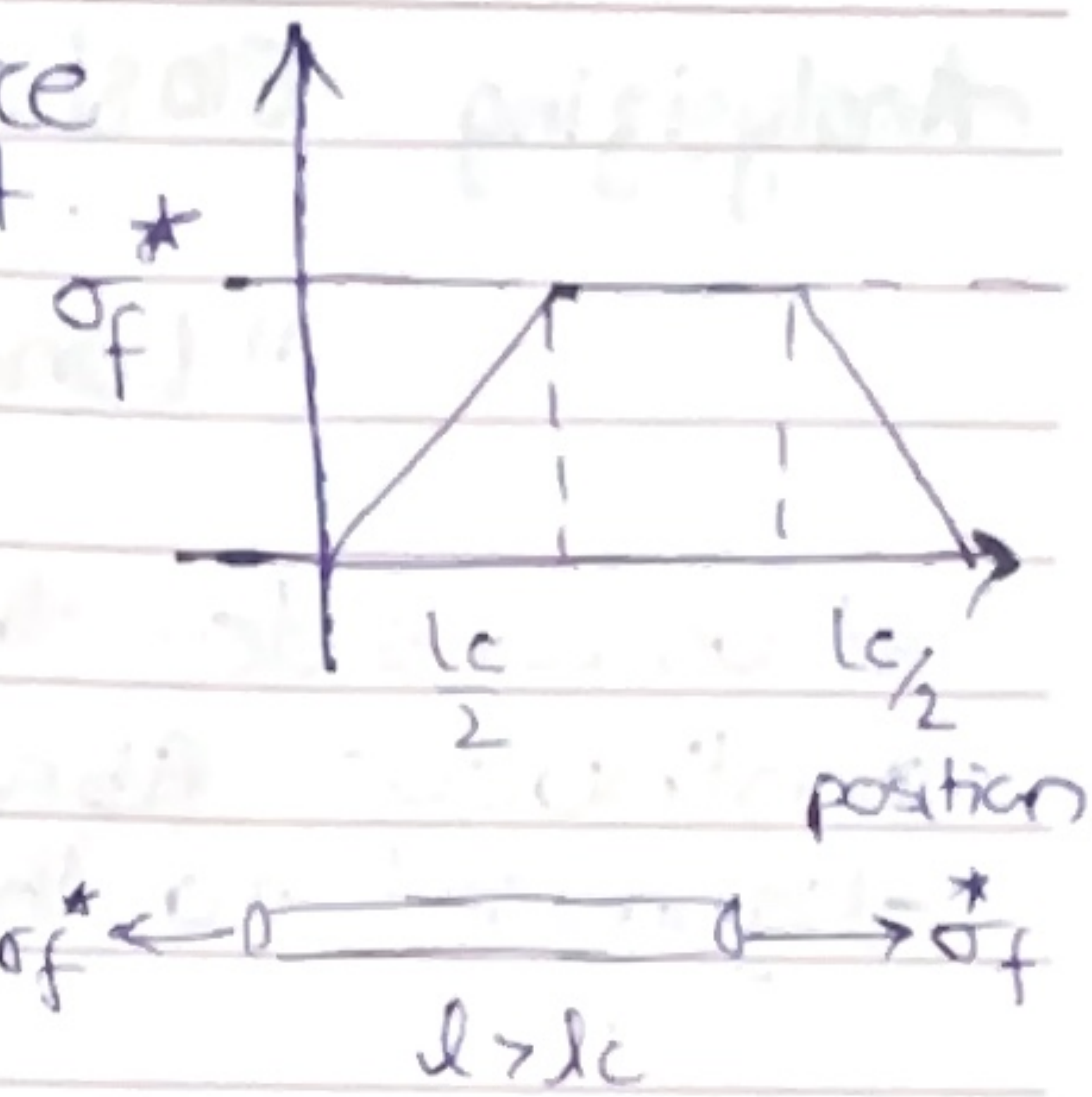
σ_f^* => fracture / limit stress of fibre.

d => diametre of fiber.

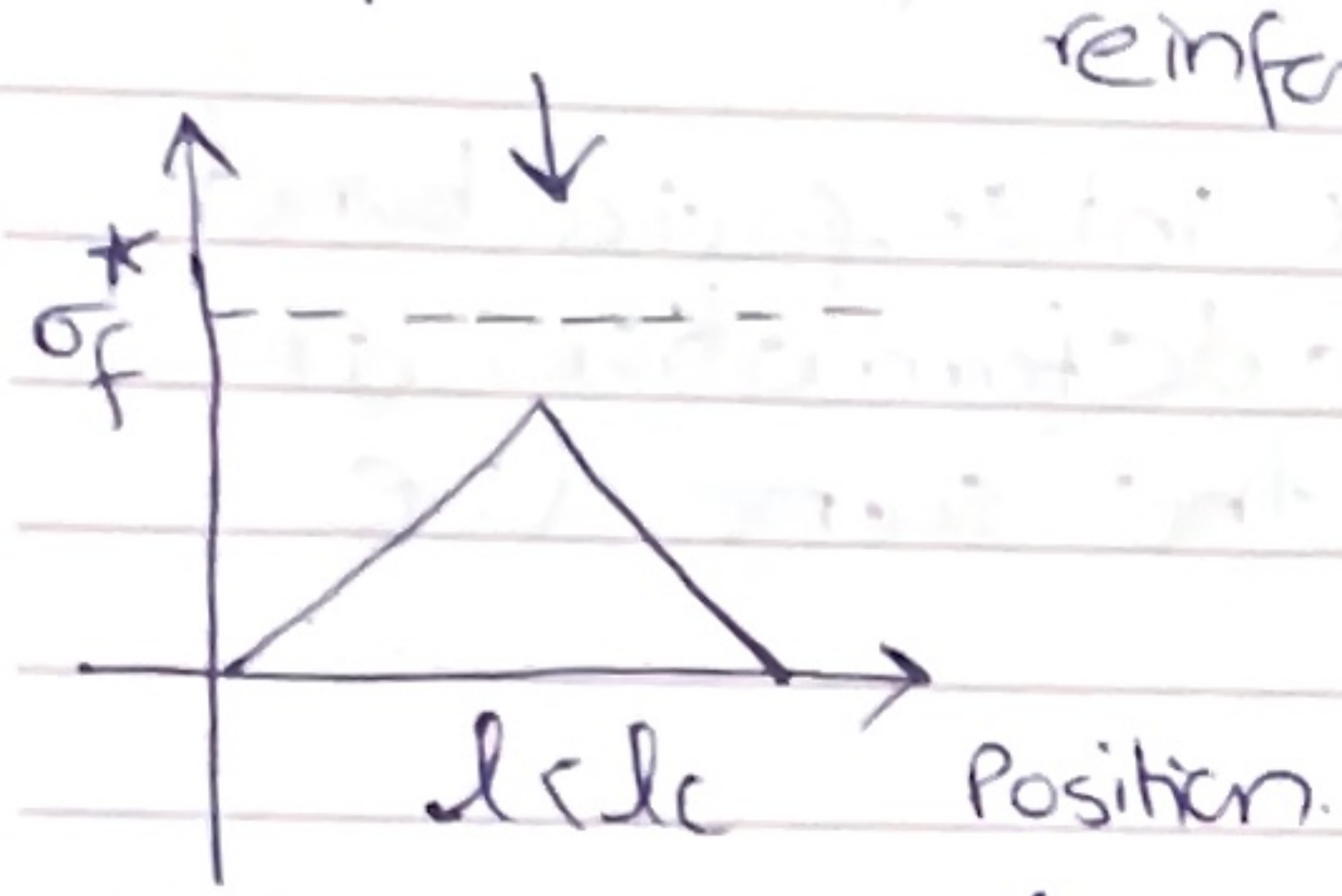
τ_c => fibre matrix bond strength
(or shear yield strength of the matrix which ever is smaller.)

day / date:

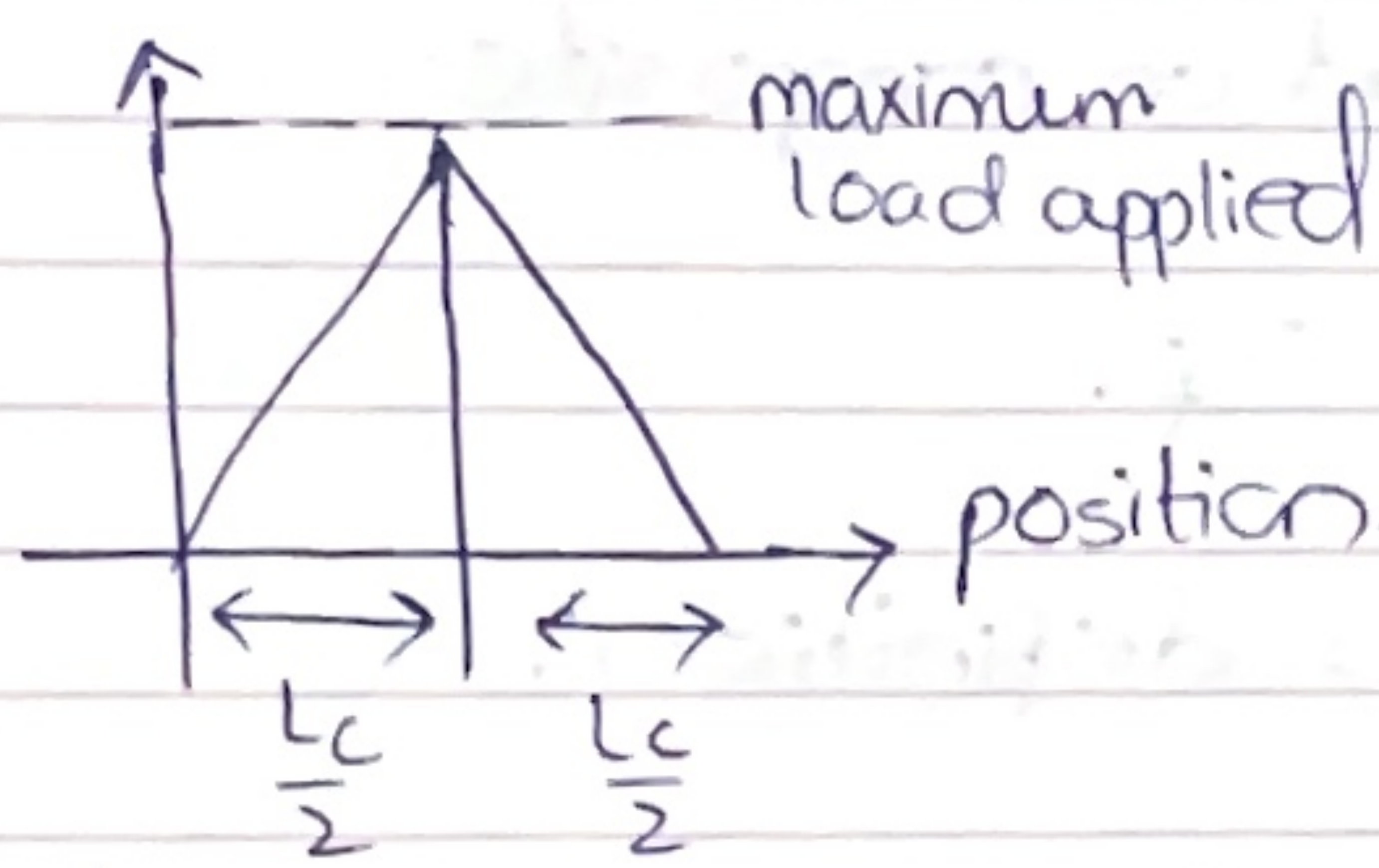
$l > l_c \Rightarrow$ more effective reenforcement



② $l < l_c$;
the matrix deforms around the fibre and there is no stress tranferrence $\Rightarrow$ low reinforcement



③ $l = l_c$



Q. Rule of mixtures:-

It is used to estimate the properties of composites by volume fractions of matrix and re-enforcements.

$$E_c = E_m V_m + E_f V_f$$

OR

$$E_c = \frac{E_m E_f}{E_f V_m + E_m V_f}$$

Note:- This formula is used when σ is $\perp$ to the direction of fiber alignment.

f - fibres / particulate
E = elastic Modulus.
V = volume ; m = matrix.

Analysizing Elastic behaviour of composites at "Longitudinal Loading".

let us consider the elastic behavious of continuous fibrous composite with load in alignment to the direction of fiber.

Assume that fibre-matrix inter facial bond is very good, such that the deformation of both matrix and fibres is the same (i.e iso strain condition).

$\therefore$ Total load on composite;

$$F_c = F_m + F_f.$$

also by stress's definition.

$$\sigma_c A_c = \sigma_m A_m + \sigma_f A_f.$$

$$\sigma_c = \sigma_m \frac{A_m}{A_c} + \sigma_f \frac{A_f}{A_c}$$

where A_m/A_c & A_f/A_c are the area fractions of the matrix and fibre phases.

if composite, matrix & fibre phase lengths are equal.

$$\Rightarrow \sigma_c = \sigma_m V_m + \sigma_f V_f \quad -(a)$$

Now the isostrain assumption means.

$$\varepsilon_c = \varepsilon_m = \varepsilon_f$$

∴ dividing (a) with strain of each respective material's component.

$$\frac{\sigma_c}{\varepsilon_c} = \frac{\sigma_m}{\varepsilon_m} V_m + \frac{\sigma_f}{\varepsilon_f} V_f \quad \text{— (b)}$$

Also if the composite, matrix & fibre deformations are all elastic then.

$$\frac{\sigma_c}{\varepsilon_c} = E_c \;,\quad \frac{\sigma_m}{\varepsilon_m} = E_m \;,\quad \frac{\sigma_f}{\varepsilon_f} = E_f \quad \text{— (c)}$$

Using (c)'s equations in (b).

$$E_c = E_m V_m + E_f V_f$$

or

$$E_c = E_m(1 - V_f) + E_f V_f$$

Note:- This formula is used when σ longitudinal to the fibre alignment.

because $V_m + V_f = 1$.

↓

equal to the volume fraction weighted average of the moduli of Elasticity of fibre and matrix phases.

also note;

$$\boxed{\frac{F_f}{F_m} = \frac{E_f V_f}{E_m V_m}}$$

$V\% = 30\% + 10\% = 40\%$ } glass
$E = 69\ GPa$

$V\% = 60\%$ } resin
$E = 3.4\ GPa$

(a) $E_c = ?$

$E_c = (V_m)(E_m) + (V_f)(E_f)$
$= 3.4\ GPa\ (0.6) + (69\ GPa)(0.4)$
$\Rightarrow 30\ GPa.$

(b) $A = 250\ mm^2$
$\sigma = 20 + 30 = 50\ MPa$
$F_f = ?$ & $F_m = ?$

$$\frac{F_f}{F_m} \Rightarrow \frac{E_f V_{fr}}{E_m V_m} \Rightarrow \frac{(69\ GPa)(0.4)}{(3.4\ GPa)(0.3)} = 13.5$$

$F_f = 13.5 F_m.$

$F_c = \sigma A_c \Rightarrow (250)(50) \Rightarrow 12500\ N.$

$F_c = F_f + F_m$

$12500 \Rightarrow 13.5 F_m + F_m$

$F_m = 860\ N.$

$F_f = F_c - F_m$
$= 12500 - 860$
$= 11640\ N$