ElCoM
ELECTRICAL COMPUTER MECHATRONICS

تقدم لجنة

ملخص لمادة:

مختبر مقاومة مواد

جزيل الشكر للطالب:

حمزة اسماعيل

* Strength of Material Lab :-

* Tensile and Compression test :-

* stress and strain :-

$$\sigma = \frac{P}{A} = \frac{F}{A}$$

σ :- Normal stress.
→ (Tensile, compression)

$$\varepsilon = \frac{\delta}{L} = \frac{\Delta L}{L} = \frac{L_f - L_o}{L_o}$$

δ → deformation.

* Modulus of Elasticity :-

$\sigma = E\,\varepsilon$ ⟶ linear

$$E = \frac{\sigma}{\varepsilon} = \text{slope}$$

Modulus of resilience :-

Area under elastic region = $\frac{1}{2}\sigma_y \varepsilon_y$

σ_y → yield stress ε_y → yield strain.

Area under elastic region = Moduls of resilience

Modulus of resilince = $\frac{1}{2}\sigma_y \varepsilon_y$
in elastic region.

* Poisson ratio (V) :-

$$V = \frac{-\varepsilon_{Lat}}{\varepsilon_{long}} = \frac{-\varepsilon_y}{\varepsilon_x}$$

ε_{Lat} → lateral strain.

ε_{long} → alongation strain.

$$\varepsilon_{Lat} = \frac{d_2 - d_1}{d_1} \qquad \varepsilon_{Long} = \frac{L_2 - L_1}{L_1}$$

* Bulk modulus (K) :-

$$K = \frac{E}{3(1-2V)}$$

E → modulus of elasticity
V → Poisson ratio.

* Tensile and Compression test :-

* shear modulus (G) :-

$$G = \frac{E}{2(1+V)}$$

E → Modulus of elasticity
V → Poisson ratio.

in Elastic region

$$A_1 L_1 = A_2 L_2$$

* Percent elongation and extension :-

$$\%\,\text{elongation} = \frac{L_f - L_o}{L_o} * 100\%$$

↳ for tensile. (إستطالة)

$$\%\,\text{shortening} = \frac{L_o - L_f}{L_o} * 100\%$$

↳ for compression (تقاصر)

⇒ Tension → decresiong in Area.
↳ incresing in hieght.

⇒ Compression → incresiong in Area.
↳ decresing in hieght.

* Modulus of Toughness (Rupture).

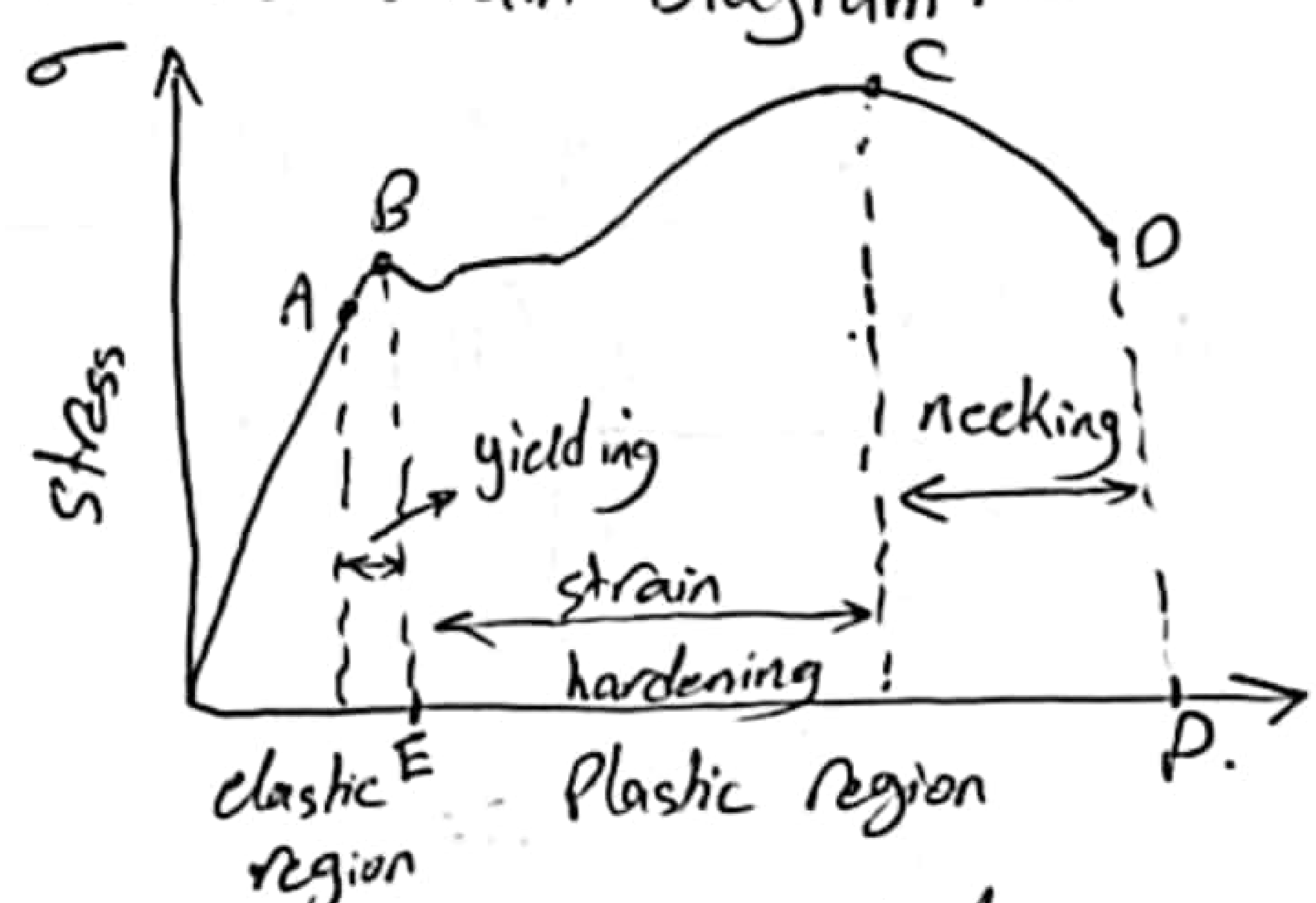
$$\text{Toughness} = \frac{2}{3}\sigma_u \varepsilon_F$$

Total area.

σ_u → Ultimate stress (max stress).

ε_F → Fracture strain (max strain).

* stress strain Diagram :-



A → Proportional Limit. Point.
C → Ultimate stress (σ_u)
D → Fracture stress (σ_B)

* Strength of Materials lab :-

* Torsion Test :-

* Shear stress and strain :-

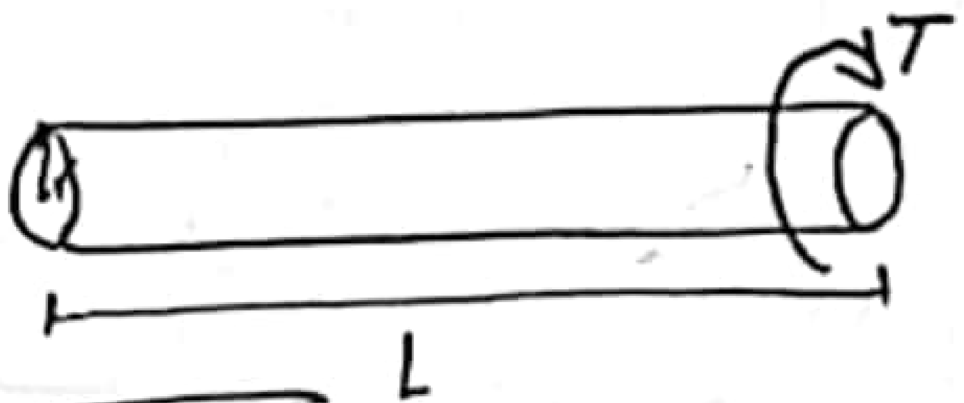
$$\tau = \frac{T\,r}{J}$$

$$J = \frac{\pi}{2} r^4$$

$$J = \frac{\pi}{32} d^4$$

$$J = \frac{\pi}{2}(R^4 - r^4)$$

$\tau \rightarrow$ shear stress.
$T \rightarrow$ Torque.
$J \rightarrow$ moment of inertia
$r \rightarrow$ radius of shaft.



$$\gamma = \frac{r\Phi}{L}\ (\text{rad}) \qquad \Phi = \frac{\gamma L}{r}$$

$\gamma \rightarrow$ shear strain
$r \rightarrow$ radius of shaft.
$\Phi \rightarrow$ twist angle.
$L \rightarrow$ length of shaft.

* Hook's law for shear loading states :-

$$\tau = G\gamma$$

$G \rightarrow$ Modulus of rigidity.

$$\frac{Tr}{J} = G\gamma \Rightarrow T = \left(\frac{GJ}{r}\right)\gamma$$

$$T = \left(\frac{GJ}{r}\right)\left(\frac{r\Phi}{L}\right) \Rightarrow T = \left(\frac{GJ}{L}\right)\Phi$$

* Modulus of Resilience :-

$$\text{Resilience} = \frac{1}{2}\tau_y \gamma_y$$

Area under elastic region.

$\tau_y \rightarrow$ shear stress at yield Point.
$\gamma_y \rightarrow$ shear strain at yield Point.

* Modulus of Toughness (Rupture) :-

$$\text{Toughness} = \frac{2}{3}\tau_u \gamma_f$$

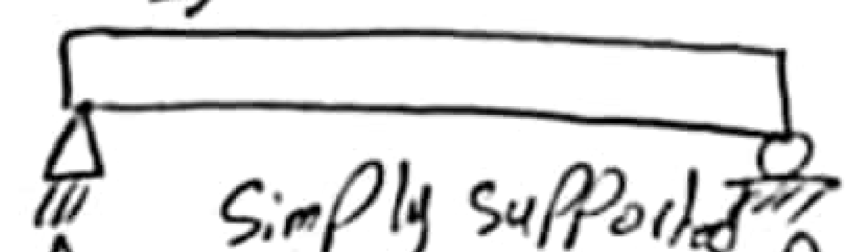
$\tau_u \rightarrow$ ultimate stress.
$\gamma_f \rightarrow$ Fracture strain.

$\Phi_{\text{Ductile}} \gg \Phi_{\text{Brittle}}$. *

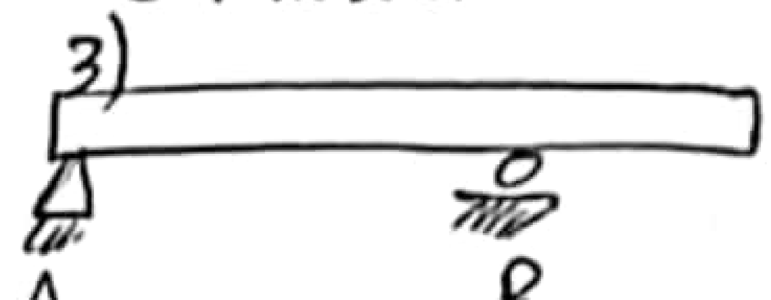
* Deflection of beams :-

* Types of Beams :-

Cantilever.



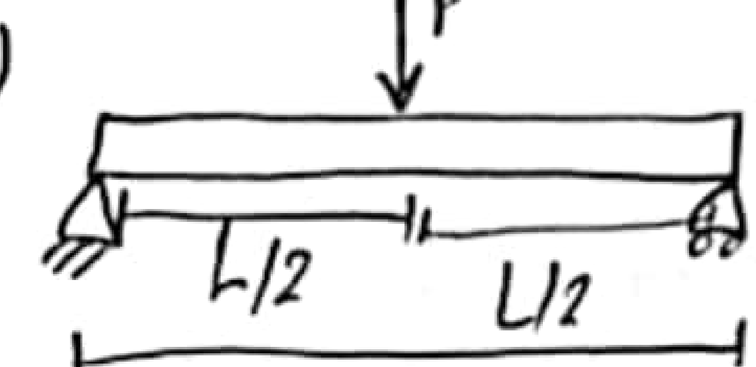
Simply supported



over hanging beams.

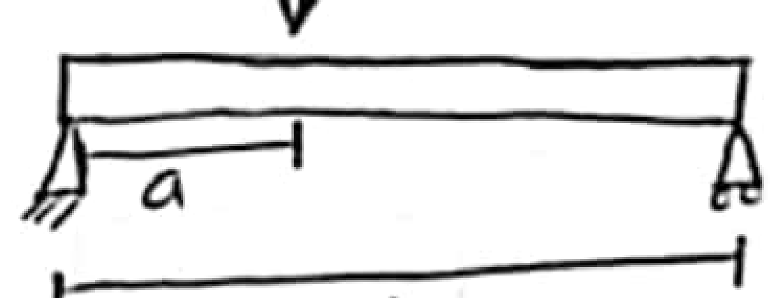
* Deflection of simple supported beams :-

1)



$$\delta = \frac{PL^3}{48EI}$$ → موقع القوة.

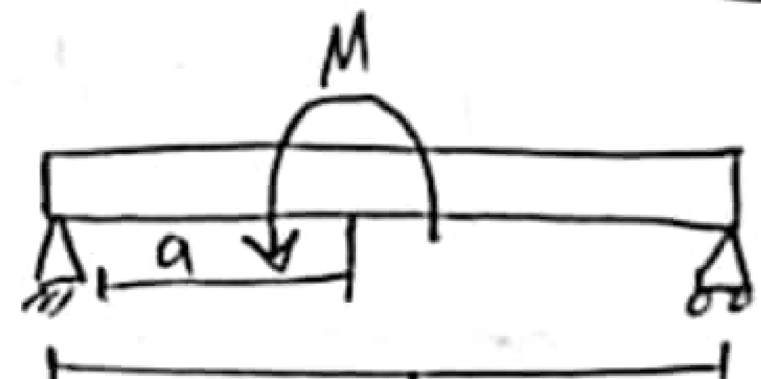
2)



$$\delta = \begin{cases} \dfrac{\sqrt{3}\,Pa(L^2-a^2)^{\frac{3}{2}}}{27EIL} & a \le \frac{L}{2} \\[2ex] \dfrac{\sqrt{3}\,Pb(L^2-b^2)^{\frac{3}{2}}}{27EIL} & a > \frac{L}{2} \end{cases}$$

$b = L - a$

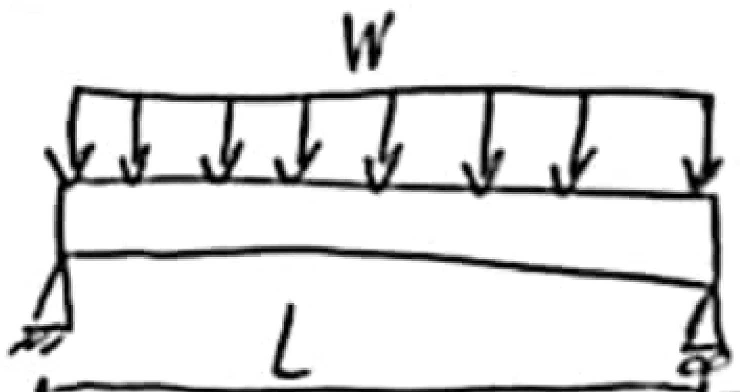
3)



$$\delta = \begin{cases} \dfrac{-\sqrt{3}\,M(L^2-a^2)^{\frac{3}{2}}}{27EIL} & a \le \frac{L}{2} \\[2ex] \dfrac{\sqrt{3}\,M(L^2-b^2)^{\frac{3}{2}}}{27EIL} & a > \frac{L}{2} \end{cases}$$

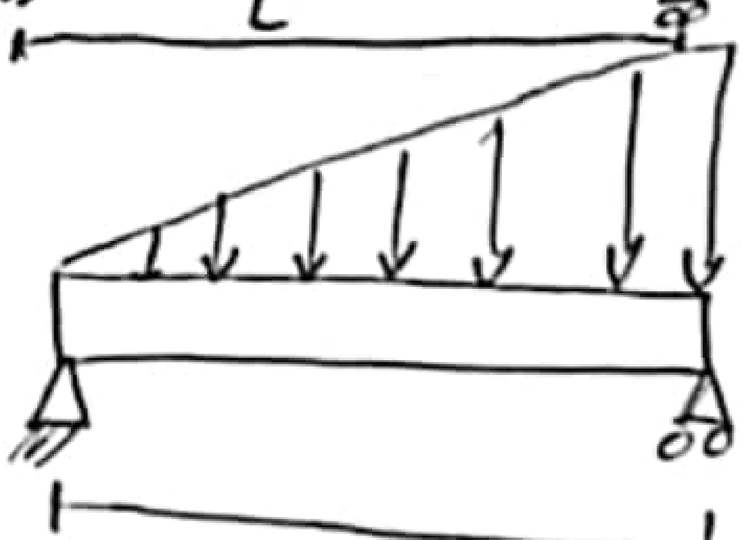
$b = L - a$

4)



$$\delta = \frac{5wL^4}{3375EI}$$

5)



$$\delta = \frac{Cw_1 L^4}{3375EI}$$

$C = 22.012$

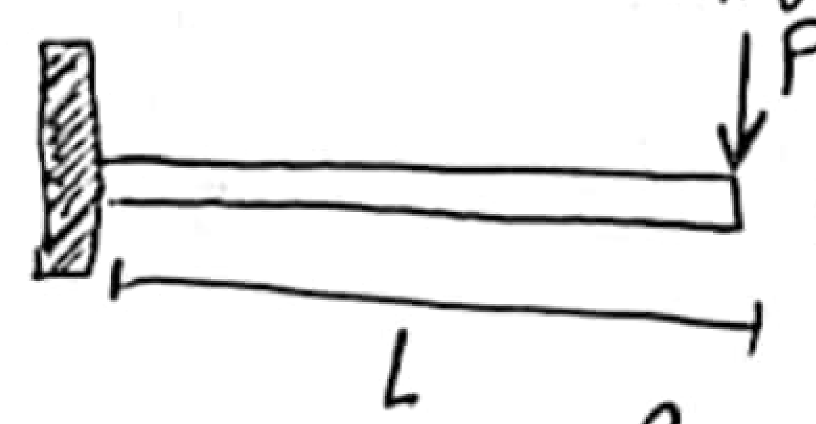
$P \rightarrow$ single force
$W \rightarrow$ Compound force
$M \rightarrow$ moment. $L \rightarrow$ Length.
$I \rightarrow$ moment of inertia. $I = \frac{1}{12} b h^3$
$E \rightarrow$ moduls of Elasticity.

عرض ← b ، ارتفاع ← h (الرقم الأكبر) ..

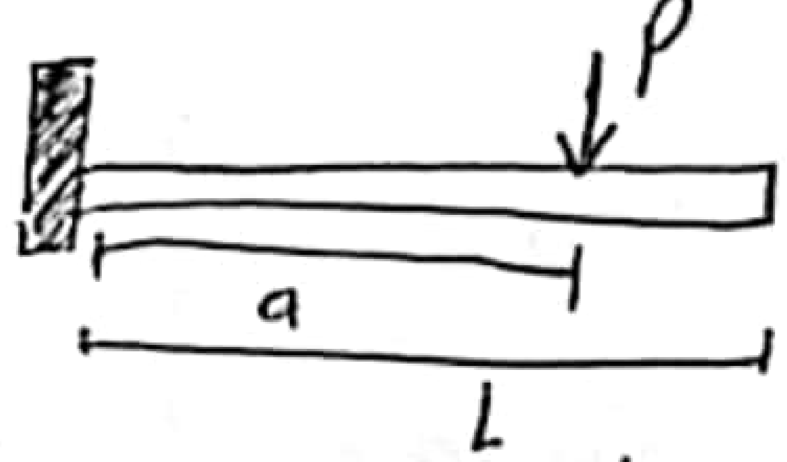
* Strength of Materials lab :-

* Deflection of beams :-

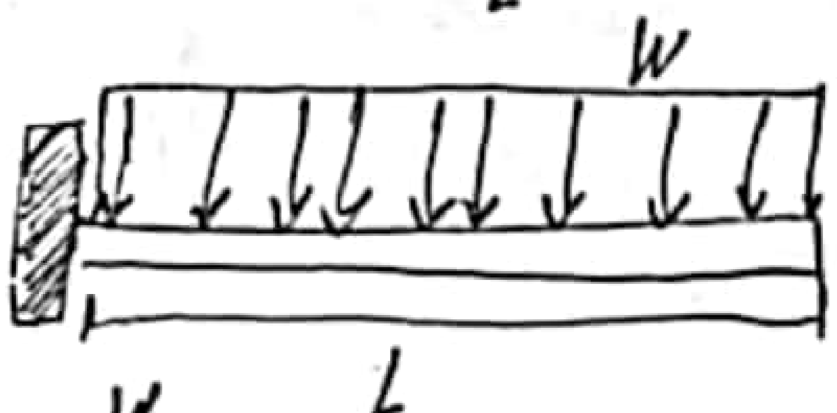
* Deflection of Cantilever beams :-

1)


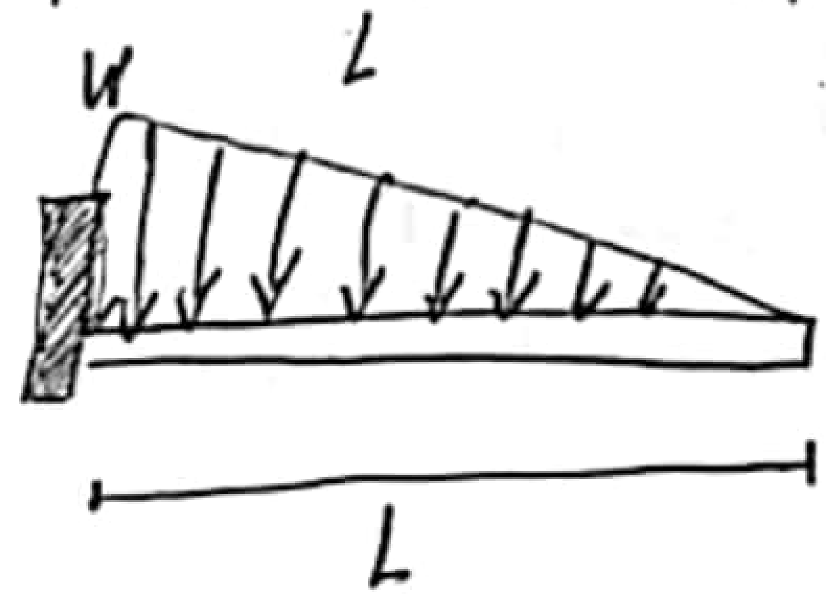
$$\delta = \frac{PL^3}{3EI}$$ → موقع القوة

2)


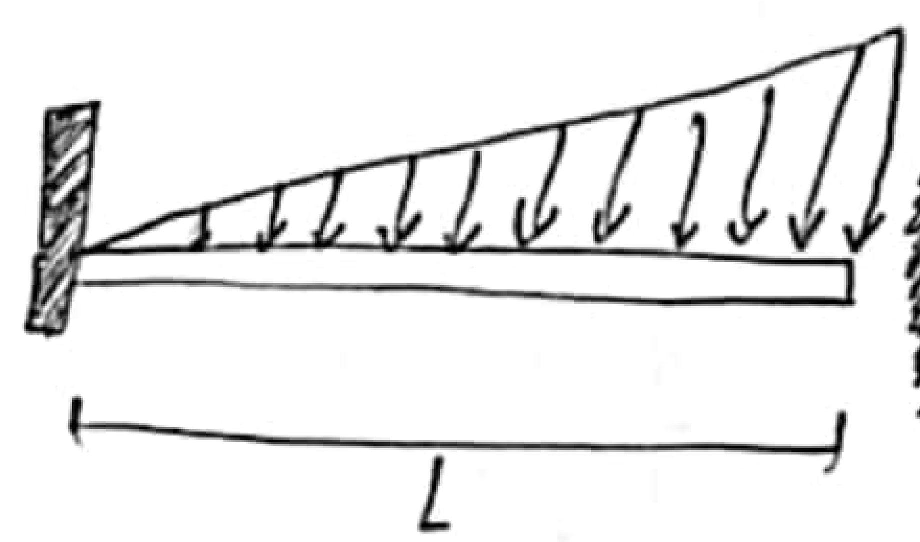
$$\delta = \frac{Pa^2(3L-a)}{6EI}$$

4)


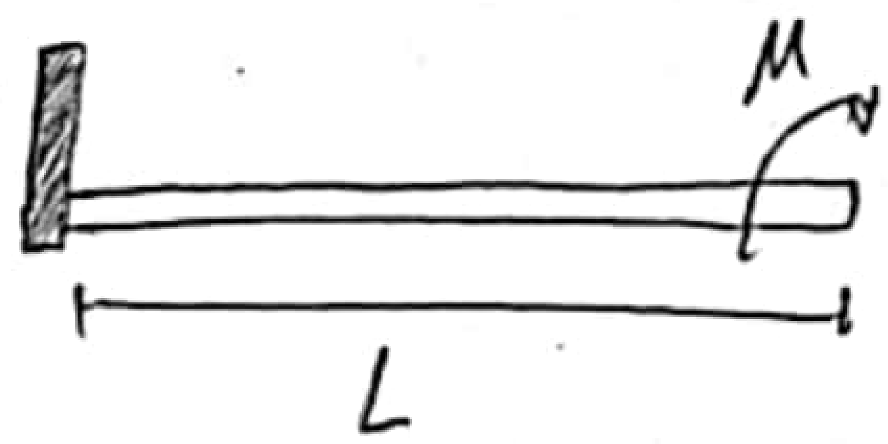
$$\delta = \frac{WL^4}{8EI}$$

5)


$$\delta = \frac{WL^4}{30EI}$$

6)


$$\delta = \frac{11WL^4}{120EI}$$

7)


$$\delta = \frac{ML^2}{2EI}$$

* Derivation :-

$$\int EI \frac{d^2y}{dx^2} = \int M(x) \rightarrow \text{integrate}$$

$$\int EI \frac{dy}{dx} = \int M(x)\, x + C_1 \rightarrow \text{integrate}$$

$$EI\, y = \tfrac{1}{2} M x^2 + C_1 x + C_2$$

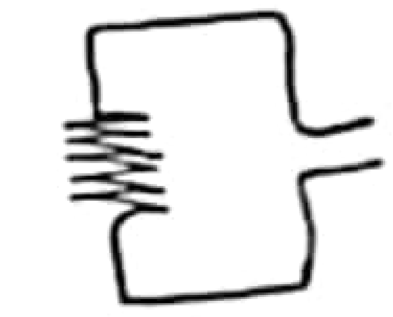
$$\text{slope} = \frac{dy}{dx} = \theta$$

$$\text{deflection} = \delta = y$$

* Strain Measurement with strain Gauges :-

* strain gauge

- → stress ⇒ $\sigma = \frac{F}{A}$
- → strain ⇒ $\varepsilon = \frac{\delta}{L}$



Resistive

$\Delta R \propto \varepsilon$

$$\frac{\Delta R}{R} = \varepsilon K$$

K = gauge factor.

$R = \frac{\rho L}{A}$

* Type of strain gauges :-

1- Metallic strain gauges :-

$\frac{\Delta R}{R} = \varepsilon K$ — length effect $\gg \rho$

2- Piezo - Resistive strain gauges

$\frac{\Delta R}{R} = \varepsilon K$ — $\rho \gg$ length effect.

* Wheatstone Bridge :- Balance Bridge.

Balance Bridge

$R_1 = R_4$, $R_2 = R_3$

$V_o = 0$.

$V_{AD} = V_o = V_{AB} + V_{BD}$.

$I_2 = \frac{V_i}{R_4 + R_3}$, $I_1 = \frac{V_i}{R_1 + R_2}$

$V_{AB} = -I_2 R_4$ ⇒ $$V_{AB} = \frac{-R_4}{R_4 + R_3} V_i$$

$V_{BD} = I_1 R_1$ ⇒ $$V_{BD} = \frac{R_1}{R_1 + R_2} V_i$$

$$V_o = \left(\frac{R_1}{R_1 + R_2} - \frac{R_4}{R_4 + R_3}\right) V_i$$ → in general.

Balance Bridge ⇒ $V_o = \text{Zero}$

linearized :-

$$V_{out} = \frac{V_{in}}{4}\left(\frac{\Delta R_1}{R_1} - \frac{\Delta R_2}{R_2} + \frac{\Delta R_3}{R_3} - \frac{\Delta R_4}{R_4}\right)$$

$$V_{out} = \frac{V_{in}}{4}\left(\varepsilon_1 K - \varepsilon_2 K + \varepsilon_3 K - \varepsilon_4 K\right)$$

* Strength of Material Lab :-

* Strain Measurement with strain gauges :-

* Wheatstone Bridge :-

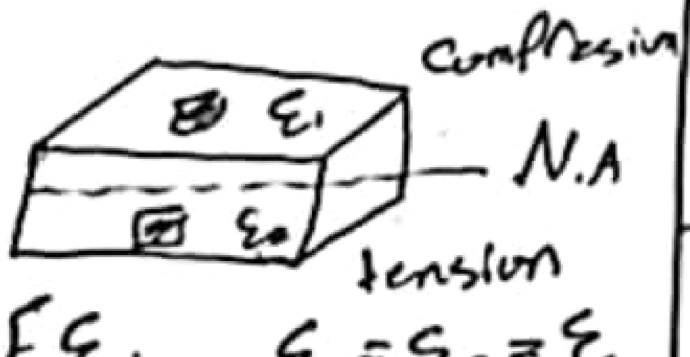
1. One single active strain gauge (quarter Bridge). → just R_1

$$\frac{V_{out}}{V_{in}} = \frac{1}{4}\left(\frac{\Delta R_1}{R_1}\right) = \frac{1}{4}\varepsilon_1 K$$

2. Two active strain gauge (half bridge)

$$\frac{V_{out}}{V_{in}} = \frac{1}{4}\left(\frac{\Delta R_1}{R_1} - \frac{\Delta R_2}{R_2}\right) = \frac{1}{4}\left(\varepsilon_1 K - \varepsilon_2 K\right)$$

$$\frac{V_{out}}{V_{in}} = \frac{1}{4}(2\varepsilon K)$$



$$= \frac{1}{2}\varepsilon K. \qquad \sigma = E\varepsilon. \qquad \varepsilon_1 = \varepsilon_2 = \varepsilon$$

$$\frac{V_{out}}{V_{in}} = \frac{1}{2}\frac{\sigma}{E}K.$$

3. Diagonal Bridge → متقابلين قبال بعض

$$\frac{V_{out}}{V_{in}} = \frac{1}{4}\left(\frac{\Delta R_1}{R_1} + \frac{\Delta R_3}{R_3}\right) = \frac{1}{4}\left(\varepsilon_1 K + \varepsilon_3 K\right)$$

$$\frac{V_{out}}{V_{in}} = \frac{1}{2}\varepsilon K.$$

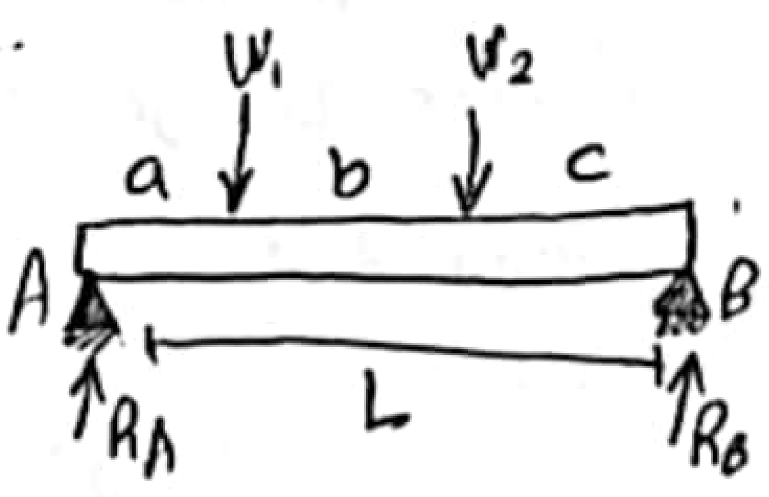
4. Full Bridge ⇒ كل المقاومات شغالة

$$\frac{V_{out}}{V_{in}} = \frac{1}{4}\left(\frac{\Delta R_1}{R_1} - \frac{\Delta R_2}{R_2} + \frac{\Delta R_3}{R_3} - \frac{\Delta R_4}{R_4}\right).$$

$$\varepsilon_1 = \varepsilon_3 = \varepsilon \qquad \varepsilon_2 = \varepsilon_4 = -\varepsilon$$

$$\frac{V_{out}}{V_{in}} = \varepsilon K.$$

Find Reaction force (R).



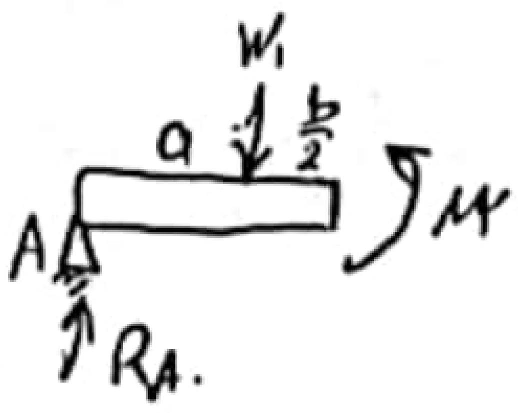
$\Sigma M_B = 0.$

$W_2(c) + W_1(b+c) - R_A(L) = 0$

$\Sigma F_y = 0.$

$R_A + R_B + W_1 - W_2 = 0.$

Find Moment M.



$M + W_1\left(\frac{b}{2}\right) - \left(\frac{1}{2}L\right)R_A = 0.$

$\sigma = \frac{Mc}{I}$ — c → centroid, I → moment of inertia

$$I = \frac{1}{12}bh^3.$$

* Stability of Columns :-

(Buckling of Columns) :-

Long Columns with Central loading

$$EI\frac{d^2y}{dx^2} = M \qquad M = -Py$$

$$EI\frac{d^2y}{dx^2} + Py = 0$$

$$\frac{d^2y}{dx^2} + \frac{P}{EI}y = 0 \qquad y'' + ay = 0$$

$$y = C_1\sin(Kx) + C_2\cos(Kx) \quad \text{homogenuous equation}$$

Boundary Conditions at $x = ??$

* Euler load (P) :

$$P = \frac{n^2\pi^2EI}{L^2}$$

when $n = 1$ then $P \to P_{cr}$.

$$P_{cr} = \frac{\pi^2EI}{L^2}$$

* Critical Buckling stress :-

$$\left(\frac{P}{A}\right)_{cr} = \sigma_{cr} = \frac{\pi^2EI}{AL^2} = \frac{\pi^2E}{(L/r)^2}$$

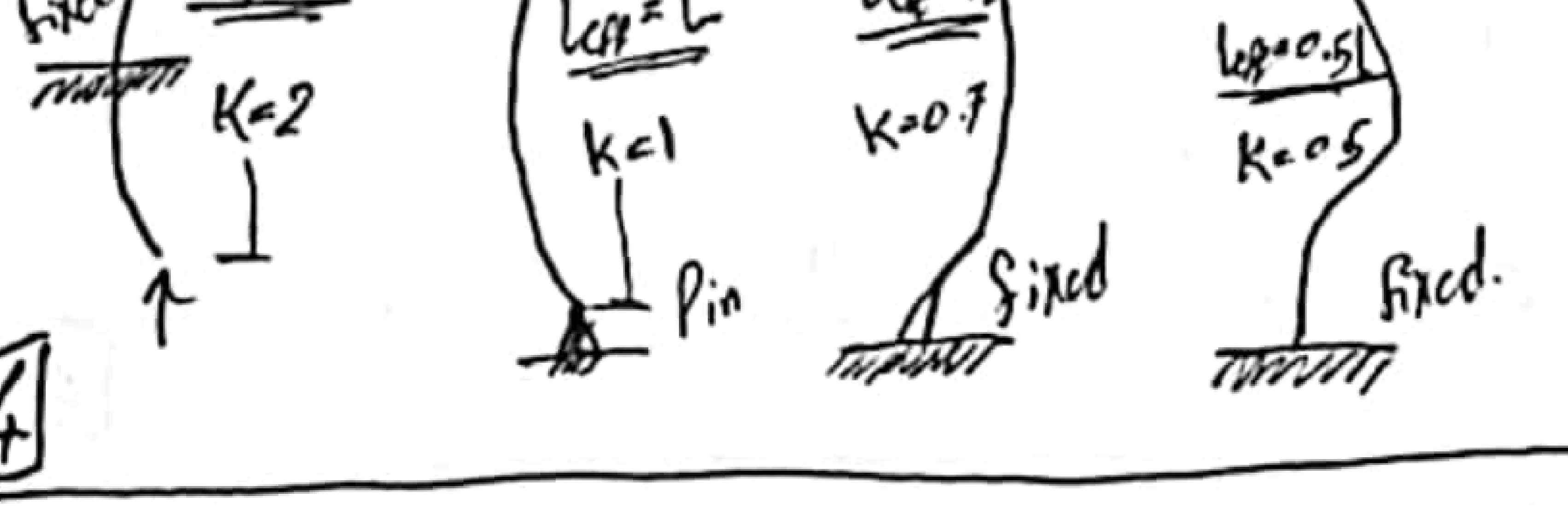
$r = \sqrt{\frac{I}{A}}$ ⇒ r : radius of gyration.

L/r ⇒ slenderness ratio

* Effective length :- $L_{eff} = KL$

$$P_{cr} = \frac{\pi^2EI}{(KL)^2} = \frac{\pi^2E}{(KL/r)^2}.$$

end Condition of Columns (K value) :-



* Strength of Material Lab :-

* Impact test :- إختبار التصادم

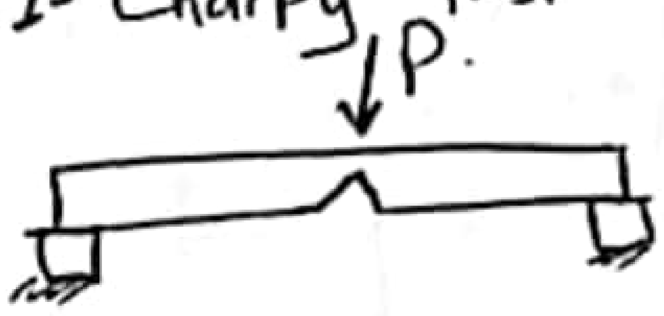
Material Property from this test
Toughness of Material.

* Types of Notch :-

Type	V	U
Toughness	Low	Hight
stress concentration	Hight	Low
energy absorbed	Low	Hight

* Types of impact test :-

1- Charpy test.



1- Notch opposes the hammer
2- specimen is simply supported
3- Simple and fast.
4- Low Toughness.
5- Two shearing area.

2. Izod test.

1- Notch faces the hammer
2- Cantilever type specimen (Clamped).
3. More Complicated
4- Hight Toughness.
5- One shear area.

energy absorb $= mg(h_1 - h_2)$.

Max Velocity $\rightarrow h_1 = zero \quad h_2 = \frac{V^2}{2g}$.

$V = \sqrt{2gh_2}$

* Tensile and Impact test :

Test	Tensile	Impact.
Type of load	Static load	shock dynamic load
strain Rate	Low	Hight
specimen's Notch	No notch	V and U notch

* Thin - Walled Cylinder :-

Inner diameter of Vessel (d)

Thickness of Vessel (t)

if ratio $(\frac{d}{t})$ greter than 20 ⇒ thin Walled.
else ⇒ thick Walled Vessel.

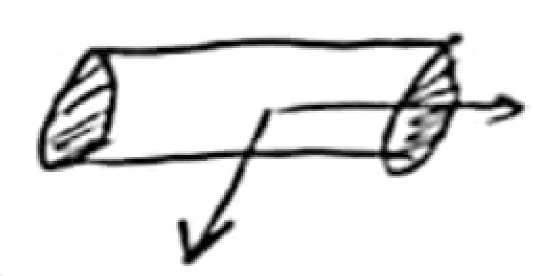
$t \ll d$ t → thickness , d → diameter

$\frac{d}{t} > 20 \Rightarrow \frac{r}{t} > 10.$

$\frac{t}{d} < \frac{1}{20} \Rightarrow \frac{t}{r} < \frac{1}{10}.$

* stress and strain :-

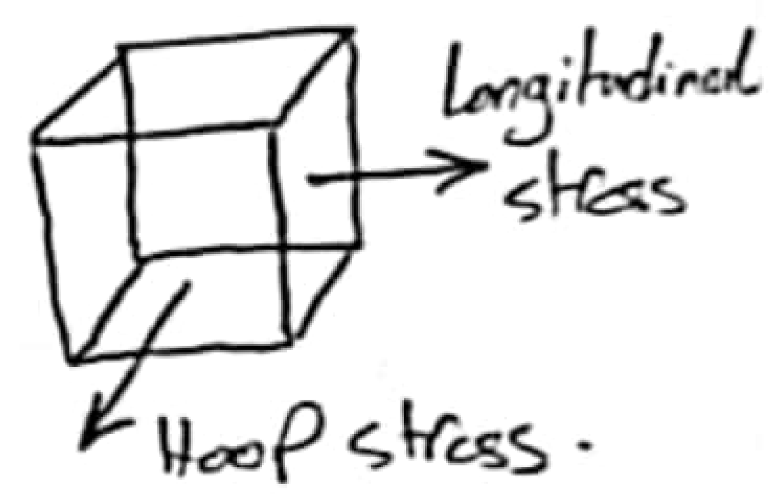
for (closed end condition)



1- stress :-

Hoop stress (tangential stress)

$\sigma_H = \frac{Pr}{t} = \frac{Pd}{2t}.$



longitudinal stress

$\sigma_L = \frac{Pr}{2t} = \frac{Pd}{4t}.$

$\boxed{\sigma_H = 2\sigma_L}$

P → Pressure.
d → diameter
r → radius.
t → thickness.
E → Modulus of Elasticity
V → Poision's ratio.

2. strain :-

Hoop strain (ε_H).

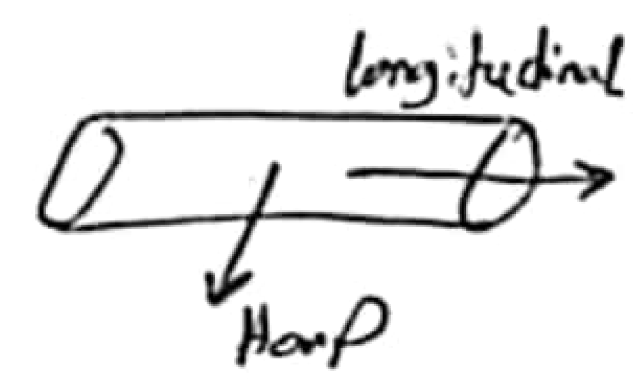
$(\varepsilon_H) = \frac{\sigma_H}{E} - V\frac{\sigma_L}{E}.$

longitudinal strain (ε_L)

$\varepsilon_L = \frac{\sigma_L}{E} - V\frac{\sigma_H}{E}.$

$R_{mohr's\ circle} = \sqrt{\left(\frac{\sigma_H - \sigma_L}{2}\right)^2 + (\tau_{xy})^2}$

* stress and strain for (open end condition).



$\sigma_H = \frac{Pr}{t} = \frac{Pd}{2t}.$

$\boxed{\sigma_L = zero}$.

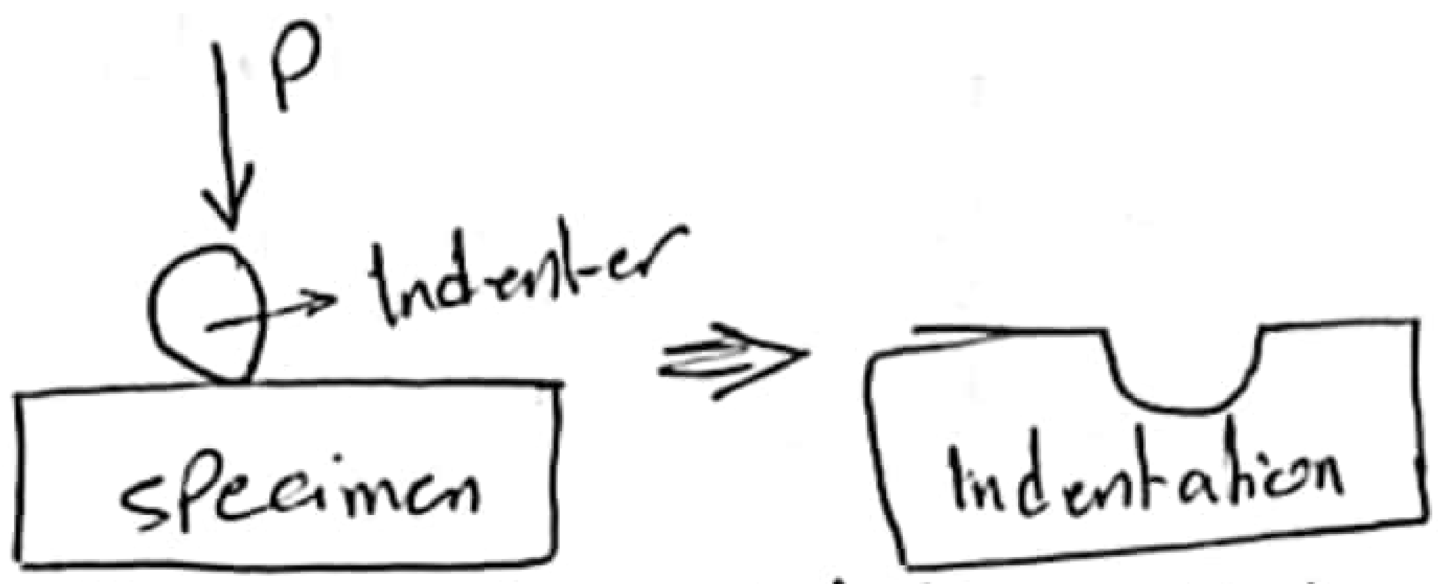
$\varepsilon_H = \frac{\sigma_H}{E}$

$\varepsilon_L = -V\frac{\sigma_H}{E}.$

* Strength of material Lab :-

* Hardness Test :-

* Hardness ⇒ resistance to surface indentation under standard test condition and its non destructive test.



specimen ⇒ العينة التي اريد خرشها

Indenter ⇒ المادة التي اريد الخدش بها

Indentation ⇒ الأثر الذي تركه القوة

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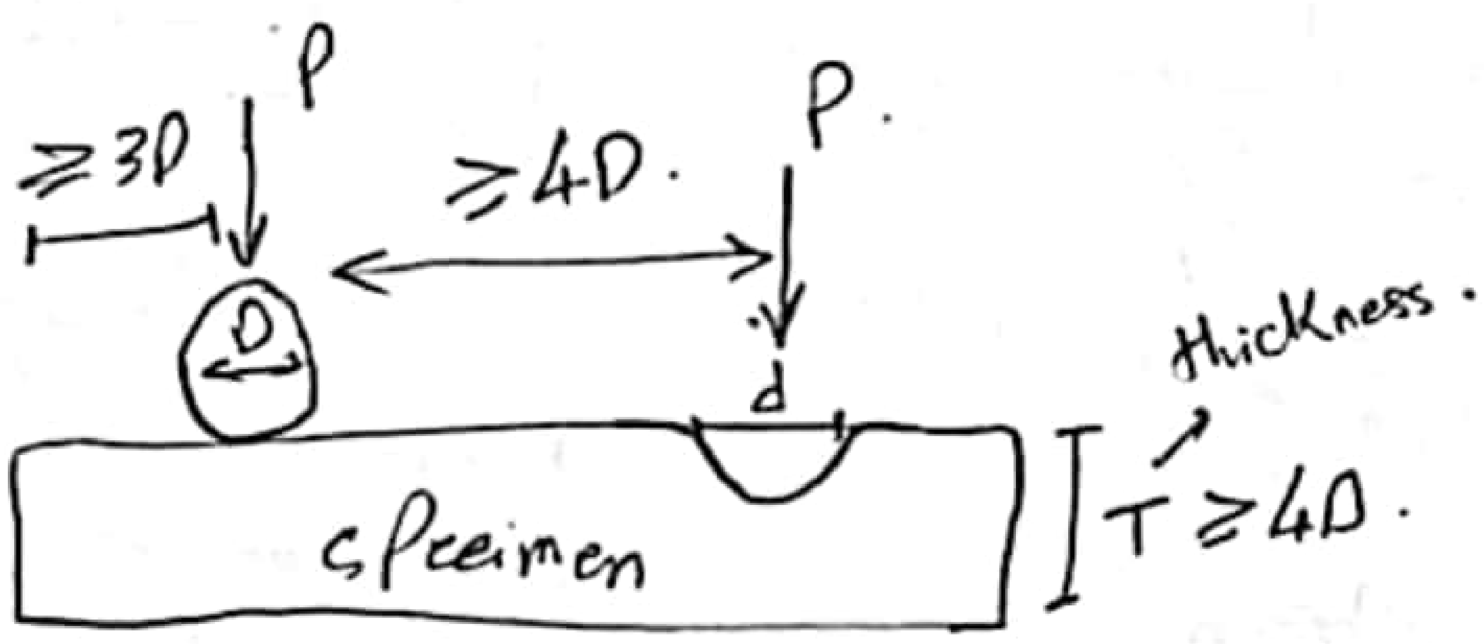
* Test Methode :-

1- Brinell harness number (HBN) :-



Hardness ball ≥ 1.7 Hardness of speimen.

$$HBN = \frac{P}{\frac{\pi}{2} D (D - \sqrt{D^2 - d^2})} \quad Kg/m^2.$$

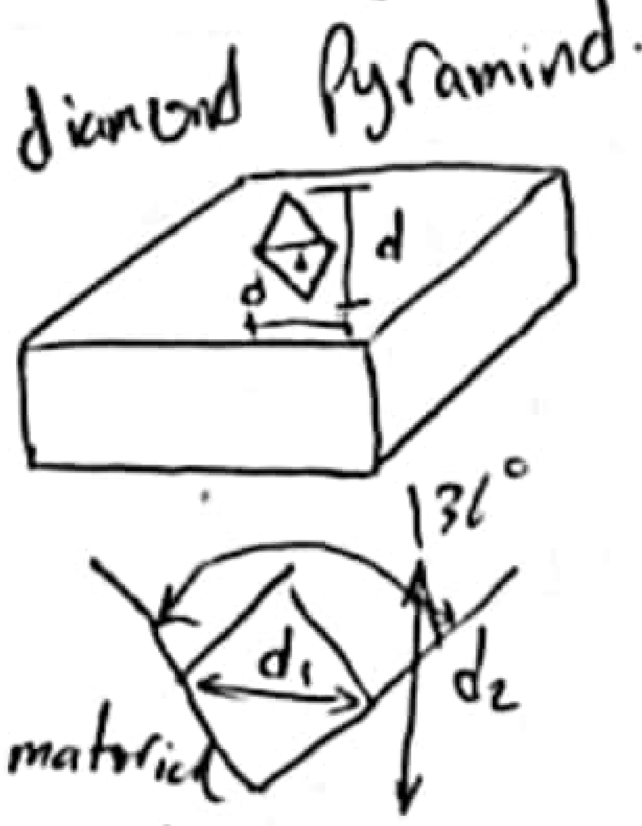
P → force , D → diameter of indenter.

d → diameter of indentation.

2- Vickers hardness number (HVN) diamond Pyramind.

$$HVN = \frac{P}{\frac{D^2}{2} \sin(\frac{136°}{2})}$$

$$HVN = \frac{1.854 P}{D^2}$$



main load = 10 for smooth material

main load = 30 for hard materials.

$d_1 = d_2 = D$

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* Hardness test :-

3- Rock well hardness (HRC, HRB) :-

1. Diamond cone :- (Type c) :-

HRC = (100 ~ 500) t

main load = 150 N

Indenter → diamond cone

2. Steel balls :- (Type B) :-

HR

main load = 100N

Indenter → steel ball ($\frac{1}{16}$" , $\frac{1}{8}$").

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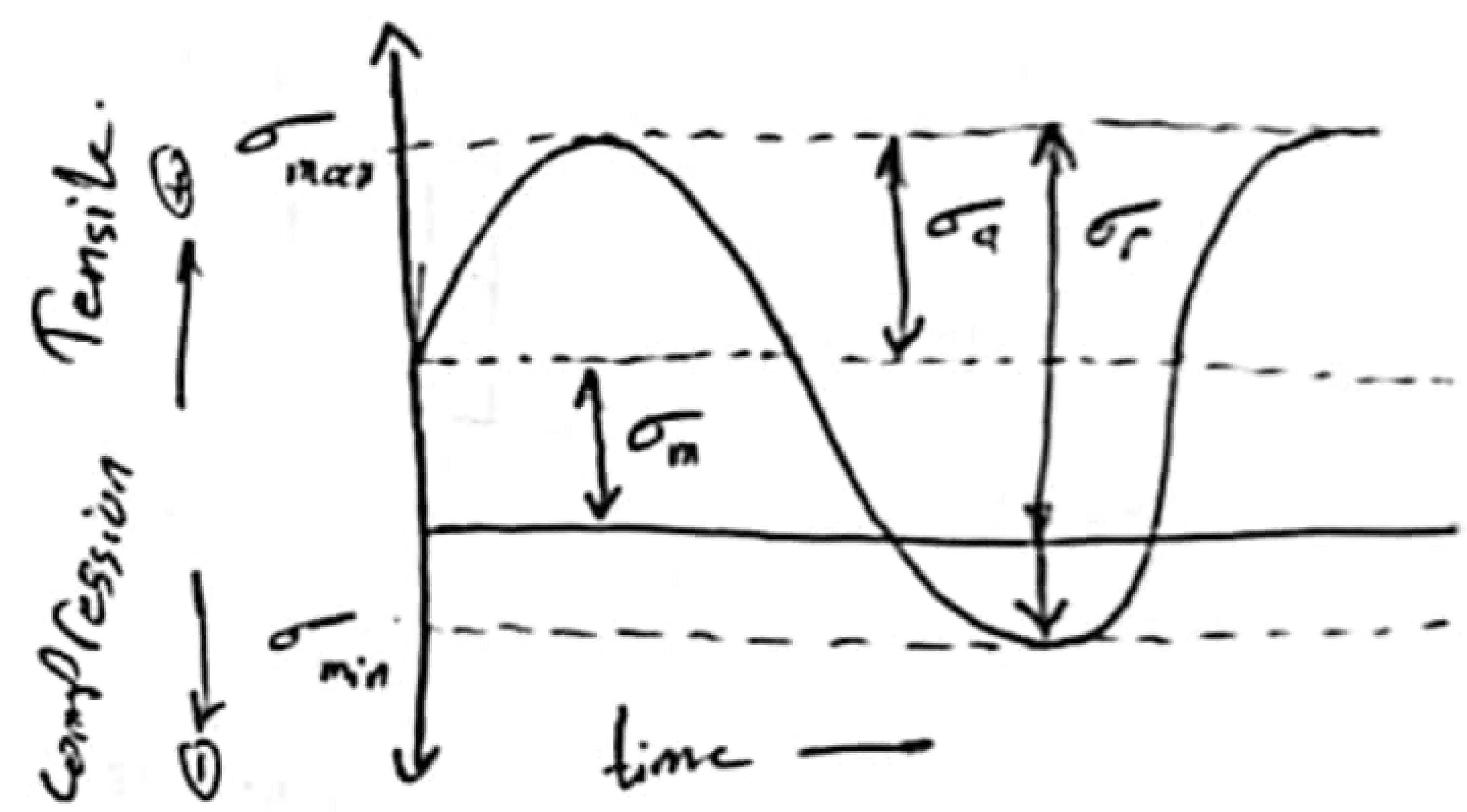
* Fatigue Test :- الاجهاد

* Cyclic stresses :-



$\sigma_m = (\sigma_{max} + \sigma_{min})/2$. Mean stress

$\sigma_r = \sigma_{max} - \sigma_{min}$ Range of stress

$\sigma_a = \sigma_r/2 = (\sigma_{max} - \sigma_{min})/2$ stress amplitude

$R = \sigma_{min} / \sigma_{max}$ stress ratio

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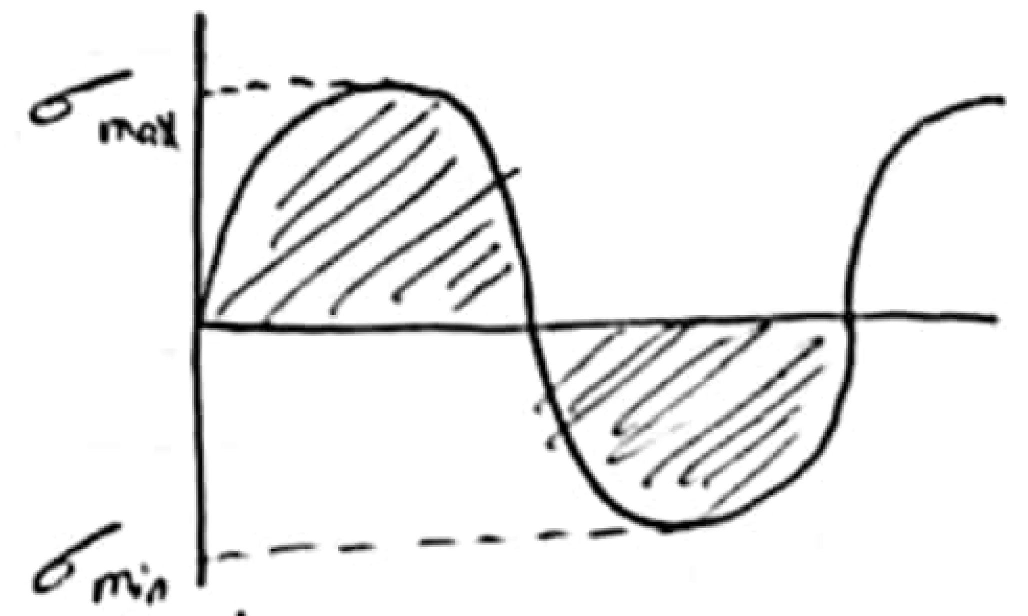
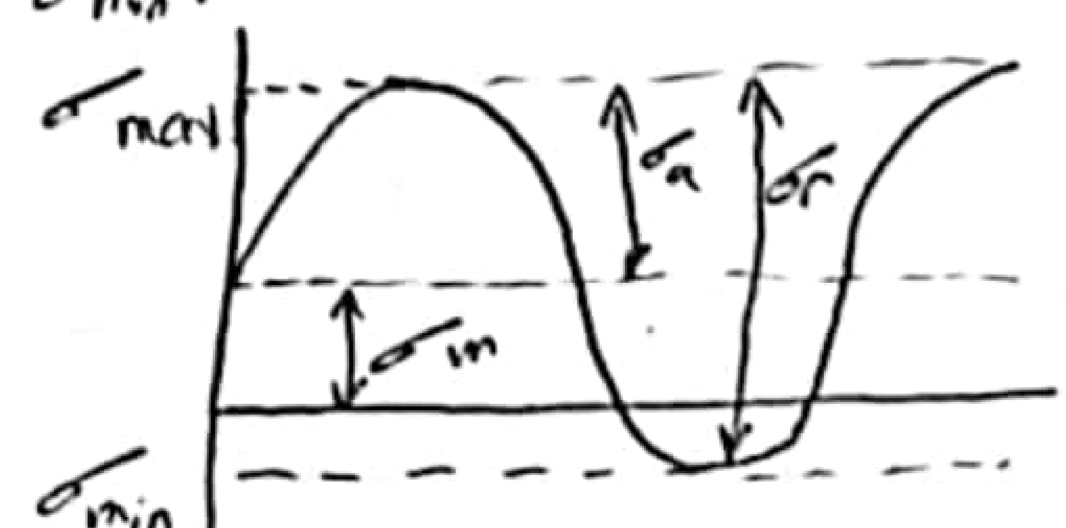
* Fatigue : Cyclic stresses



① Periodic and symmetrical about zero stress.



② Periodic and asymmetrical about zero stress.

* Strength of Material Lab :-

* Fatigue Test :-

* Fatigue: Cyclic stresses :-

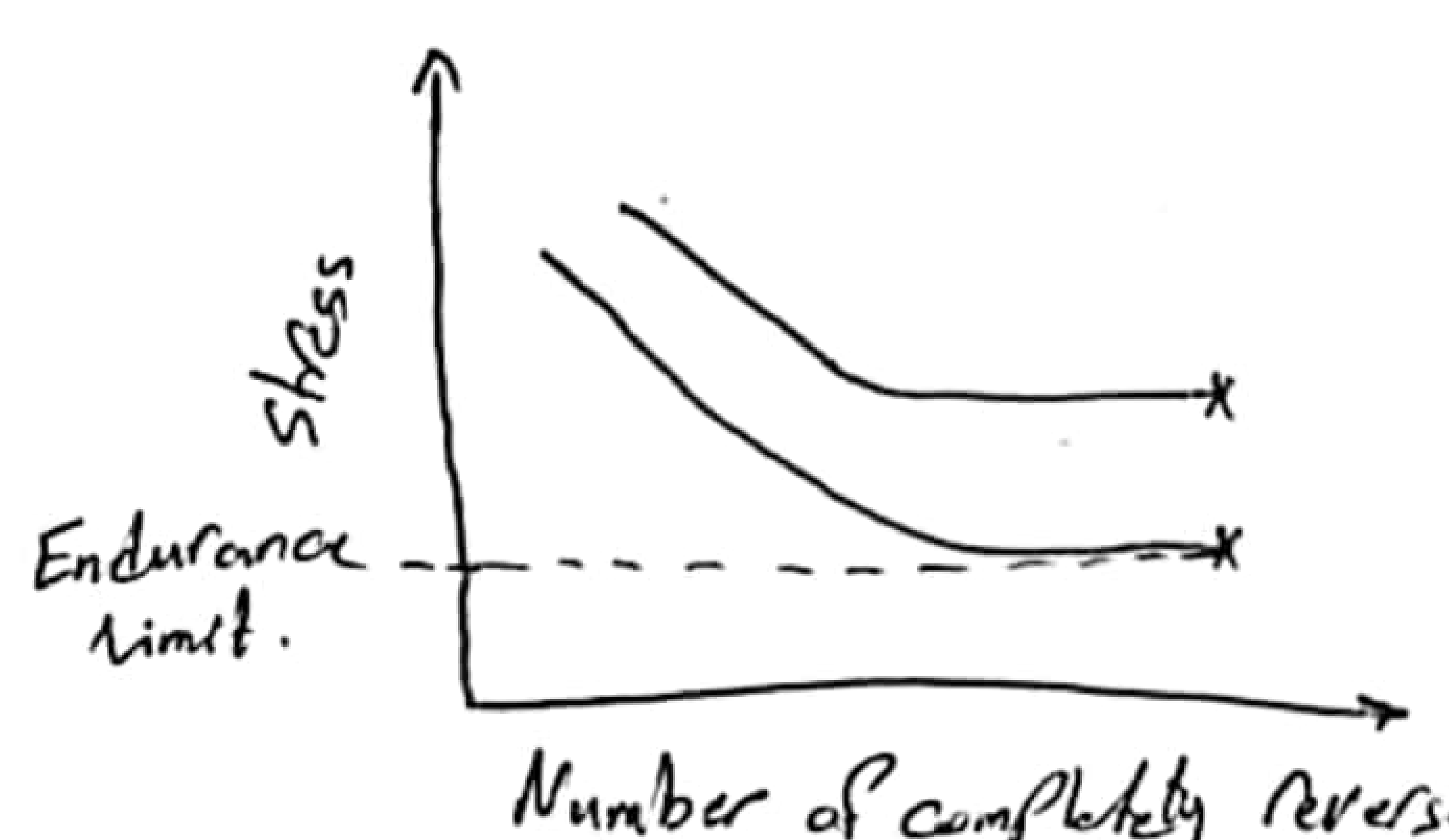
(3) Random stress fluctuation

* Number of Cycles to failure :-

1. low Cycle fatigue :-
   high loads , Plastic and elastic deforma
2. High Cycle fatigue :-
   law loads , elastic deformation ($N > 10^5$)

* Fatigue strength and Fatigue Life :-

1. Fatigue strength :-
   stress at which fracture occurs after a specified number of cycles.
   ال stress الي بصير عنده ال (failure).
2. Fatigue life :-
   Number of cycles to fail at a specified stress level.
3. Endurance limit :-
   is the stress for which failure will never occur.



* Crack initiation and Propagation :-

stages of fatigue failure :-

1. Crack initiation in the area of stress concentration
2. incremental crack Propagation.
3. final. rapid crack Propagation.

* Total number of Cycles to failure :-

is the sum of cycles at the first and the second stages :-

$$N_f = N_i + N_P$$

N_f → number of cycles to failure.
N_i → number of cycles for crack initiation
N_P → number of cycles for crack Propagation

* Factors that affect fatigue life :-

1. Magnitude of stress.
2. Quality of the surface.

* Factors that affect fatigue life (environmental effects) :-

1. Thermal fatigue.
2. Corrosion fatigue. الخ.

* Used specimens :-

1. Ferrous material (steel).
2. non ferrous material (aluminum).

* Calculations :-

bending stress

$$\sigma = \frac{Mc}{I}$$

$I = \frac{\pi}{4}R^4$ $I = \frac{\pi}{8}R^4$ $I = \frac{\pi}{16}R^4$

M = moment = F.L.

$c = \frac{d}{2} = R.$

I : moment of Inertia.

strength of material lab :-

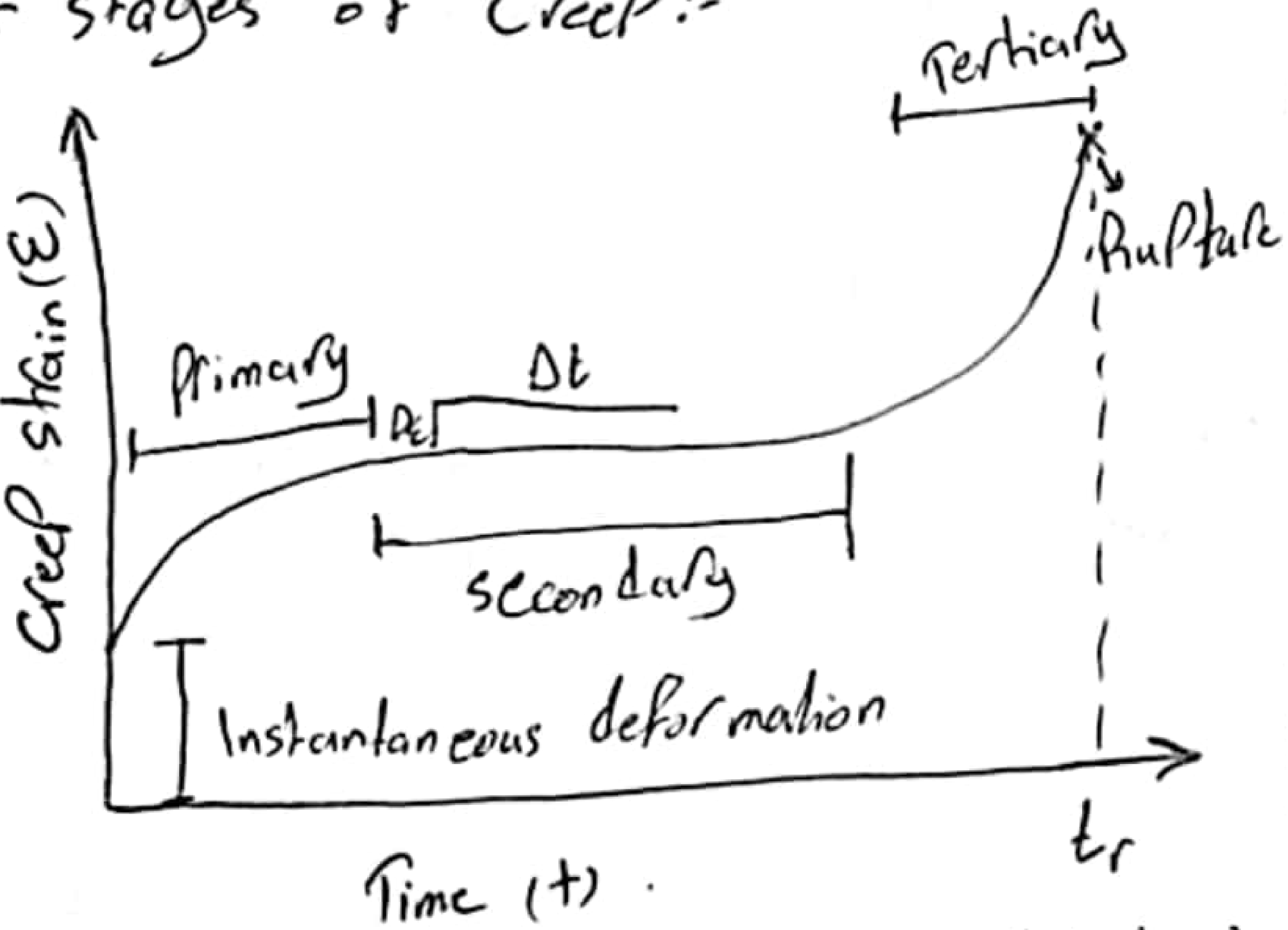
Creep Test of Metallic materials :-

*** Creep :-**
is time-dependent and Permanent deformation of matirials when subjected to a constant load at a high temperature

*** Mechanisms of Creep :-**

1. stress-assisted vacancy diffusion.
2. Grain bound sliding.
3. Grain bound diffusion.
4. Dislocation motion.

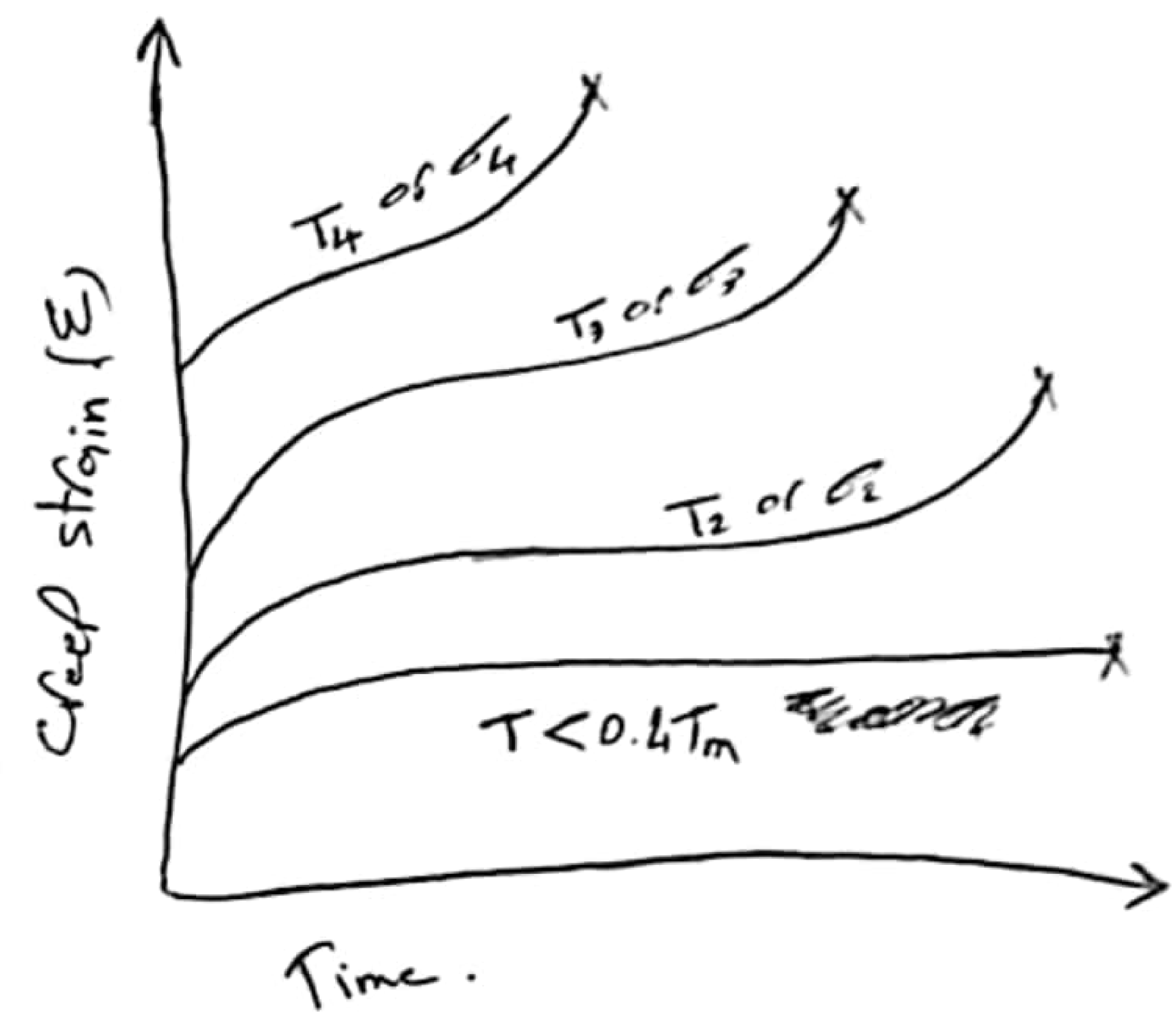
*** stages of Creep :-**



1. Instantaneous deformation → (elastic)
2. Primary / transient Creep.
   slop of strain vs. time decreases with time (work-hardening).
3. Secondary / stedy-state Creep.
   Rate of straining is constant.
   balance of work-hardening and recovery
4. Tertiary.
   Rapidly accelerating strain rate up to failure.

*** Creep :- stress and temperature effects :-**
With increasing stress and Temperature

1. The Instantaneous strain increases.
2. The steady state creep rate increases.
3. The time to rupture decreases.



$T_4 > T_3 > T_2$.

$\sigma_4 > \sigma_3 > \sigma_2$.