ملخص :

مختبر مقاومة المواد

Strength Lab

للطالب : أنس البرغوث

اللجنة الأكاديمية لقسم الهندسة الصناعية

2023

LAB strength ((Mid))

Anas Barghouth

- Tensile test
- Compression test
- Torsion test
- stubility of column test
- Deflection of Beam test
- Impact test
- strain gauge test

① Tensile Test

=> UTM
"unevical Testing Machine"

two part → loading
→ Measuring

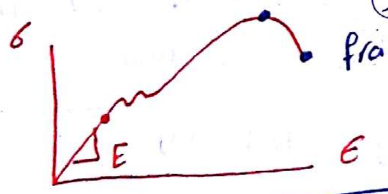
نظري

ductile (steel)

شكل الكسر: cupe and cone "بزاوية 45°"

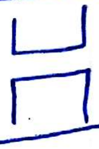
السبب: shear stress

الرسمة:



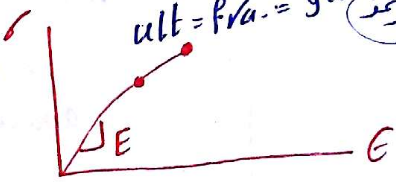
brittle (brass, concrete)

شكل الكسر: flat بزاوية 90°



السبب: Normal stress

الرسمة:



	ductile	brittle
Carbonic steel	low	high
deformation "strain"	أكبر ε	أقل

الحل

σ-ε انها بشيك +

طريقة الحل
الرسمة

نعم → (σ, ε)
لا → 1) (F, δ) 2) (F/A₀, δ/L₀)

نقاط مميزة

- proportional limit → نهاية الخط المستقيم
- yeild stress "point" → offset (موازي 0.001) / avg ($\frac{up + down}{2}$)
- ultimate → أعلى نقطة
- fracture → نهاية الرسمة

القوانين

Hock's law $\sigma = E\,\epsilon$

ΔE

- → modulus of elasticity $E = slope = \frac{\sigma}{\epsilon}$
- → modulus of Resilience $U_R = \frac{1}{2}\sigma_y \epsilon_y$ (J/m^3)
- → modulus of Toughness $U_T = \frac{2}{3}\sigma_{max}\epsilon_{max}$
- → % elongation $= \left|\frac{l_f - l_o}{l_o}\right| \times 100\% = \epsilon_{max} \times 100\%$
- → Reduction of Area $= \left|\frac{A_f - A_o}{A_o}\right| \times 100\%$
  - to find A_f :- $A_f = \frac{A_o}{1+\epsilon_{max}}$
  - Area at fracture ← $A_f l_f = A_o l_o$ (plastic region)
- → bulk modules of elasticity $k = \frac{E}{3(1-2\nu)}$
  - shear .— $G = \frac{E}{2(1+\nu)}$
  - $\nu = 0.33$: $-\frac{\epsilon_{lateral}}{\epsilon_{axial}}$

F, x , work done

P, δ, P

work done → بتخزن بالمادة على شكل energy

ductility → % elongation, Reduction of Area

Note

معلومة عامة

1) True / actual ⇒ $\epsilon_T = \ln(1+\epsilon)$, $\sigma_T = \sigma(1+\epsilon)$

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2) % elongation → ductile $> 5\%$; brittle $< 5\%$

شرط [~]

uniaxial Load

$\nu = \frac{-\epsilon_{lateral}}{\epsilon_{axial}} = \frac{-\bigcirc}{\text{مادة مع}} =$

~~reduction of area or~~ $\left|\frac{d_f - d_o}{d_o}\right|$ *

② Compression test

عينة ← حزم

- الطول، يقل
- Area : تزيد

Buckling لتجنب D > L

⇒ UTM

Q₁: ليش عملنا التجربة : ten. أكثر من comp. بتأثر بـ brittle

Q₂ :: شو الفرق بين comp. ten. : - yeild ⟶ فنسو
- ult. ⟶ يختلف

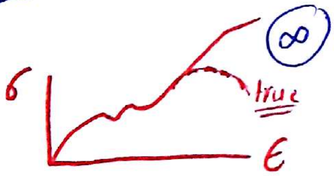
النظري

ductile

شكل الكسر: no facture

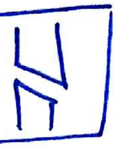
السبب: ______

الرسمة:



brittle

شكل الكسر:

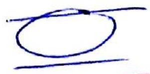


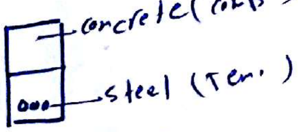
السبب : Normal stress

σ_u comp > σ_u ten.

Note :-

1) lubricate (oil)
   1) To less the friction (so we have uniform inc ↑ in Area)
   2) To avoid Barrel shape

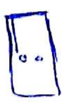


2) 

load بتحمل أكبر

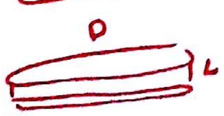
3) خصائص
brittle :- comp.
ductile :: Ten.

4) الفراغ — كل عينة فيها شوائب



Ten — بأثر
comp — ما بأثر

5) sample المستخدمة ⟶ D > L — 1/D cccc 1
↳ To avoid (less) Buckling



الحل "نفس" tensile test

③ Torsion test

every cross-section → remain plane and undistorted
→ rotates as a rigid disc

قديش لف ، ϕ, Twist angle

قديش طلع ، γ, shear strain

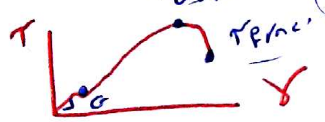
$$\gamma = \frac{\phi r}{L}$$

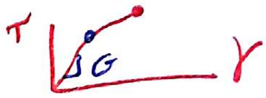
دائماً
بالطول

$$\phi = \frac{TL}{JG}$$
$$\gamma = \frac{Tr}{JG}$$

نظري

ductile	brittle
شكل الكسر: flat بزاوية 90 → ناعم	a) pure (الطبشور) — شكل الكسر: بزاوية 45° → خشن
السبب: shear stress	السبب: Normal stress
τ_{ult}, τ_{frac} — مميز	b) not pure → ductile (brass) ult = frac = yield — الجير

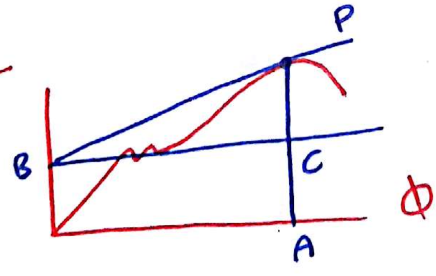




بشيك ⇐ انها τ, γ

الحل

الرسمة ⇐ نخيرذلك



shear strain (γ) ⇒ $\gamma = \frac{\phi r}{L}$

shear stress (τ) → elastic → $\tau = \frac{TC}{J}$ — $\frac{\pi}{32}(d^4 - d_i^4)$

(الـ C: ابعد نقطة بالمقطع ، الـ d_i: الجوف)

shear stress (τ) → plastic → باخذ مماس وبنزل عمودي

slope المماس

$$T = \quad , \phi = \quad , \frac{dT}{d\phi} = \frac{\overline{PC}}{\phi}$$

الأسهل

$$\tau = \frac{\overline{PC} + 3\overline{PA}}{2\pi r^3}$$

حالات خاصة: $\frac{dT}{d\phi} = 0$

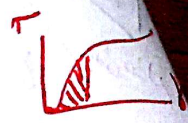
$$\tau = \frac{1}{2\pi r^3}\left[\phi \frac{dT}{d\phi} + 3T\right]$$

القوانين

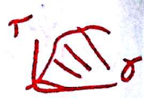
Hock's law $\tau = G\gamma$ — rad

- modulus of rigidity $G = slope = \frac{\tau}{\gamma}$

- modulus of resilience $U_R = \frac{1}{2}\tau_y \gamma_y$



- modulus of rapture (Toughness) $U_T = \frac{2}{3}\tau_{max}\gamma_{max}$



④ stability of column

axial Load ⇒ P

column (L >> D) $L/D > 5$

sample

1- P_{cr} : The load at which the Buckling will occur or = point

→ lateral deflection [بسبب failure قبل الوصول ل Normal strength للمادة]

3- الاستطرمة

2- y : Max deflection

حسب [P] إلى بطبقها

نظري

- stable: $P < P_{cr}$ — التواء طبيعي ويعود بدون failure
- unstable: $P \geq P_{cr}$ — failure Buckling

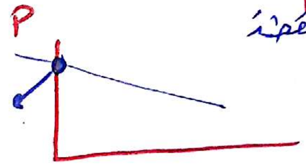
الحل — ايجاد P_{cr}

الرسمة

P (N)
y (mm)
P/y

① نوجدها

② نرسم



⇒ $P = m\left(\frac{P}{y}\right) + P_{cr}$ — slope (ذو نقطتين), بعد النقطة

⇒ P_{cr} (y-intersept) $\frac{P}{y} = 0 \Rightarrow y = \infty$

$\frac{\pi}{64} D^4$; $\frac{1}{12} b h^3$

القانون

Euler formula →

$$P_{cr} = \frac{n^2 \pi^2 E I}{(KL)^2}$$

n : عدد الانحناءات وغالبًا = 1

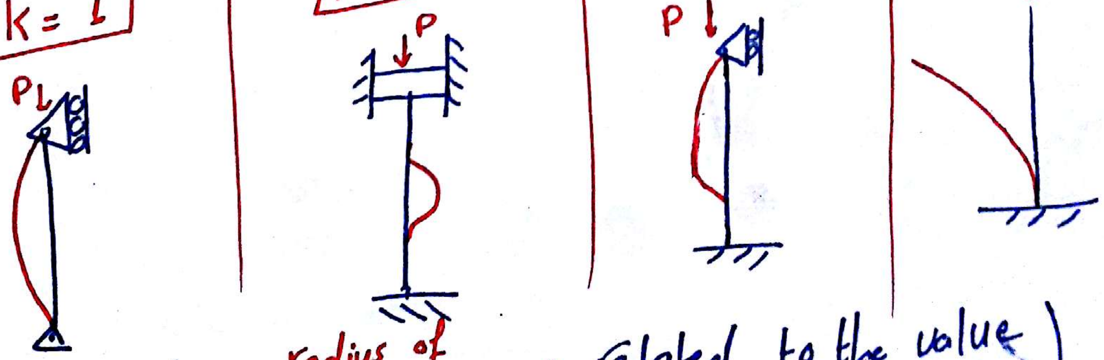
Le : effictive length

[الطول تركيب يؤثر على Buckling لكن بصير تطبيق]

[moment of inertia الي عندو أقل axis]

K ↓ Le = length الي بجبر عليه half sin wave

- pin-pin: K = 1
- fixed-fixed: K = 0.5
- fixed-pin: K = 0.7
- fixed-free: K = 2



Note (slenderness ratio (L/K) radius of generation → related to the value of critical force)

Lateral load (axial لعمودي على) load P . Beam

⑤ Deflection of Beam

(at elastic zone)

نظري

a- الأجهزة → Dynamometer ⟹ Reaction (N)

→ Dialguage ⟹ deflection (mm)

الموقع : نفس مكان force .

القراءة : كل لفة كاملة 1mm وكل لفة 100 جزء

Ex: 3 لفات و 7 أجزاء ⟸ 3.07

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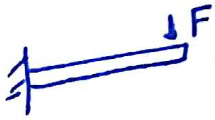
b- Notes

1) لا نحسب وزن Beam ⟹ مصغر مع التثبيت

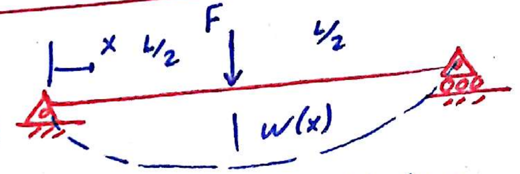
(عند force)

2) Max deflection → (عند free end)



الحل — حساب deflection

1



(بالنص Force)

Reaction

$\circlearrowleft + \Sigma M_A = 0$

$\uparrow \Sigma F_y = 0$

$R_B = \frac{Fx}{L}$

$R_A = F(1 - \frac{x}{L})$

deflection

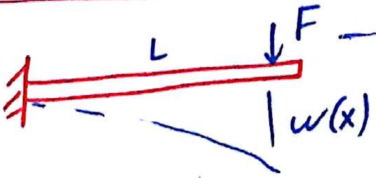
$0 < x < L/2$ $\quad w(x) = \frac{FL^3}{48EI}\left[\frac{3x}{L} - \frac{4x^3}{L^3}\right]$

$x = L/2$ $\quad w(x) = \frac{FL^3}{48EI}$

مو كالصفة

2 ↓ 2   x=3 → 3-2 = 1 موجب

2 Cantilevar



(deflection كبير مما قد يؤدي إلى تلف الجهاز وتلف Dial gauge)

$w(x) = \frac{FL^3}{3EI}$ (where load is exist)

فكرة

F

مو بالنص

Find موقع F ← w(x) ومعطيك

$w(x) \rightarrow w'(x) = 0$

$x =$

② Impact test

وجود Impact load (shock ") → زمن التأثير قليل جداً ⇒ $\Delta t < 1/3$ natural freq. of the Material

الهدف حساب energy absorbed ⇒ (Toughness) ↓ ال energy بتخزنها العينة لحد الكسر

تعتمد على → ductility + Geomtry

Note ⇝ لا تستخدم القيم بال Design → لوجود عيب Notch

نظري

① Notch → V — stress Conc. كبير — energy قليلة
→ U — قليل — عالية جداً

الهدف → تسهيل عملية الكسر عن طريق inc↑ stress concentration

شرط → Notch يكون على جهة tension

	IZod	charpy (أنواع الشارة)
② تركيب العينة support	canti liver	simply support Beam
اتجاه ال load بالنسبة لل Notch	same side	opposit side
Toughness	أقل ← لأنو بتكسر شي ...	أكبر ← لأنو بتكسر أبطأ

[one shearing Area] — [two shearing Area]

$$E_{IZod} = \frac{1}{2} E_{charpy}$$

③ تأثير temp [Temp ∝ toughness]

السبب ⇒ ↑temp → ↑ductility → ↑ toughness

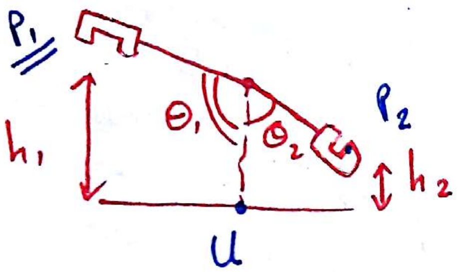
(*) التجربة مرحلتين

① بدون عينة → friction

② عينة → قراءة

⇒ toughness = القراءة − friction

الحل



$P_1 = U + P_2 + \text{friction}$ (تحولت)

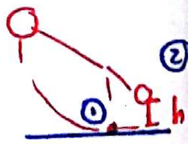
$\therefore U = P_1 - P_2 - \text{friction}$ ($P_1 = mgh_1$, $P_2 = mgh_2$)

حالتين:

→ h_1, h_2: $U = mg(h_1 - h_2) - \text{friction}$

→ l, θ: $U = mgl(\cos\theta_1 - \cos\theta_2) - \text{friction}$

حالة خاصة → h_2, Max Velocity → at $h = 0$



energy cons. $E_1 = E_2$

$\frac{1}{2}mv^2 = mgh_2$

$h_2 = \frac{v^2}{2g}$

Ex1 : which higher toughness ⓐ alm ↑ ductility ⓑ steel

Geometry الهم نفس ال

Ex

Ex2 :- rank toughness ↓ steel U , steel V, brass V , brass U

① حسب ductility ② حسب Geometry

steel → U ① , V ②

brass → U ③ , V ④

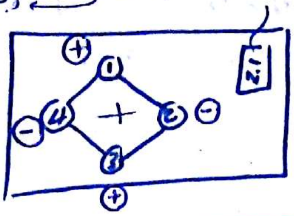
6 strain gauge [strain بقيس]

Piezoelectric matrials — مواد حساسة جداً للتغير في المقاومة الكهربائية

نظري

- wheatstone Bridge — 4- resistores, 2- channel

القراءة (Voltage) بتتحول



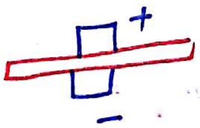
strain gauge — مقاومة بطلعها ←

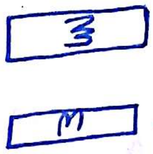
اذا طلعت

- مقاومة → quarter
- مقاومتين ورا بعض → half
- Diagonal
- كل المقاومات → fully

strain الفعلي = quarter (القراءة) ; half $\left(\frac{\text{القراءة}}{2}\right)$; Diagonal $\left(\frac{\text{القراءة}}{2}\right)$; fully $\left(\frac{\text{القراءة}}{4}\right)$

تركيب strain gauge





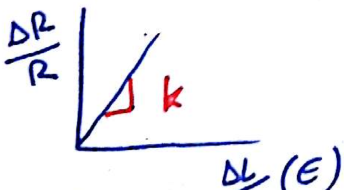
// parallel → ϵ axial

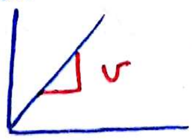
⊥ perpendicular → ϵ lateral

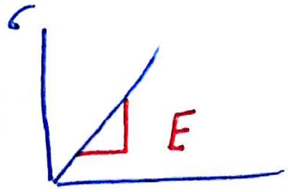
Ex: half → ⊕, ⊖ , Diagonal ⊕⊕ ⊖⊖

تتنفذ فوق أو تشتركهن وحدة فوق ووحدة تحت

∝ الرسمات







K: sensitivity Factor

معلومات عامة

$$\frac{\Delta R}{R} = K\left(\frac{\Delta L}{L}\right) \quad (\epsilon) , \quad \frac{V_{out}}{V_{in}} = \frac{1}{4}\left[\frac{\Delta R_1}{R_1} - \frac{\Delta R_2}{R_2} + \frac{\Delta R_3}{R_3} - \frac{\Delta R_4}{R_4}\right] , \quad R = \frac{\rho L}{A}$$

الحل

① $\nu = \frac{-\epsilon_{lateral}}{\epsilon_{axial}}$

Ex₁ parallel = 0.2
perpendicular = -0.1

$\epsilon_{axial} = 0.2$

$\epsilon_{lateral} = -0.1$

$\nu = ..$

Ex₂ perpendicular (full) = 0.12
parallel (quarter) = 0.7

$\epsilon_{lateral} = \frac{0.12}{4} = 0.3$

$\epsilon_{axial} = 0.7$

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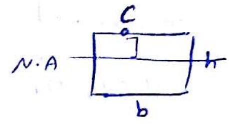
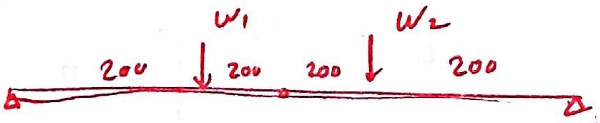
② Max bending stress

$\sigma = \frac{MC}{I}$ →





① Reaction

② برسم shear - Moment → Max. Moment

⟹ بطبق عالقانون

لو طلب عند نقطة معينة → 1) Reaction
2) بأخذ section → moment

⟹ بطبق عالقانون

Tensile

proportional limit :- Is the point on the curve bet. σ, ε where it deviates First time from a straight line

2] Elastic limit :- The Max load that can be applied. to the speamen without Permanetly deformation.

3] yeild stress :- The elongation occurs for the first time without inc↑ in load.

4] Ultimate stress :- ... that represent the Max stress that can applied before fracture.

5] Modulus of resillience :- (U_R) is the amount of energy stored in stressing the material to the Elastic curve.

6] modulus of Toughness :- (U_T) The total energy absorption capabilities of the Material to failure.

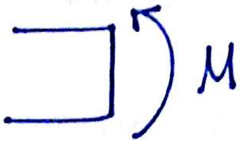
7] The ductility of Material :- It is the ability of material to deform under load. ⇒ "" indicated from percentage in:-

1) elongation of length
2) reduction of Area

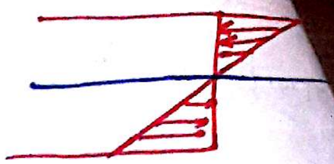
$$\% \text{Error} = \left| \frac{Th - exp}{Th} \right| \times 100\%$$

Scanned by CamScanner

1) Bending stress



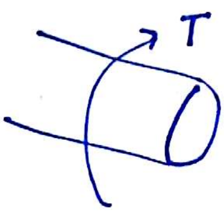
$$\sigma = \frac{MC}{I}$$



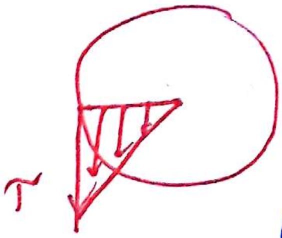
Max (outer surface)

Min = Zero (N.A)

2) Torsion



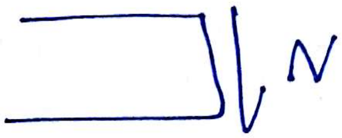
$$\tau = \frac{Tr}{J}$$



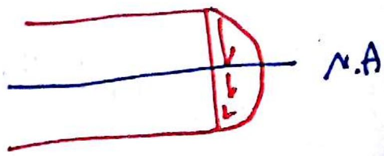
Max (outer surface)

Min = Zero (center)

3) Shear stress



$$\tau = \frac{VQ}{Ib}$$

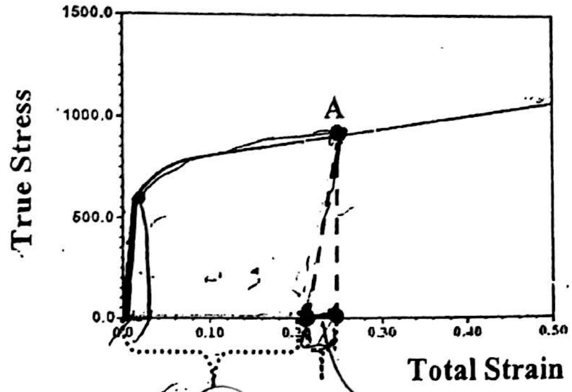


Max (N.A)

Min = Zero (outer surface)

STUDENT NAME: **STUDENT NO.:** 631372 **Inst. Name:**

Consider the following tension stress - strain diagram for ductile material.
(Answer items 1 & 2)



1. The elastic and plastic strain of point A are
a) 1& 2, respectively b) 2.
c) 2 & 1, respectively d) The whole strain axis.

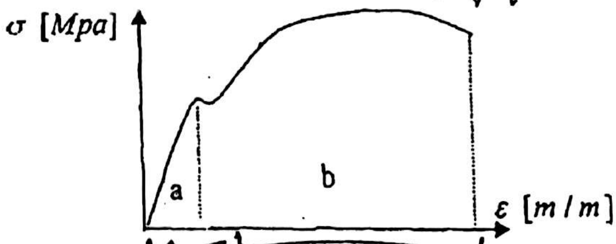
2. If the fracture occurred at $\varepsilon = 0.5$, The ductility of the material is
a) 10.0 μm b) 50.0 %.
c) 5.0 μm. d) 0.5 %.

3. In the strain gauge experiment both axially and laterally oriented strain gauges were attached to simply supported beam to be able to estimate experimentally.
a) The modulus of elasticity E.
b) The shear modulus G.
c) The Poisson's ratio ν.
d) Longitudinal and radial strains.

4. The strain gauge technique is used to measure
a) Stress. b) Deflection. c) Resistance. d) Strain

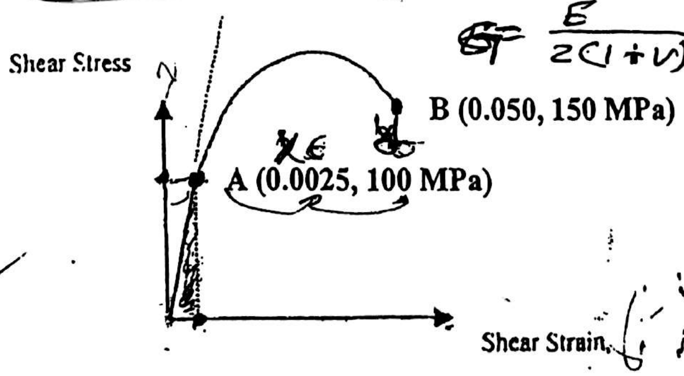
5. In the strain gauge, small change in dimensions are translated into equivalent change in:
a) Resistance. b) Conductivity c) Sensitivity d) Heat

6. In the typical tensile test curve shown aside, the area under the curve is the energy absorbed by the test specimen per unit volume, the modulus of toughness is
a) Area a b) Area a + Area b
c) Area b. d) Area b - Area a



7. Poisson's ratio is defined as
a) The ratio of lateral stain to axial strain
b) The ratio of change of the axial length to the change of the transverse length when the element is
c) The ratio of lateral stain to axial strain when the member is loaded just axially
just loaded axially
d) b and c above are correct.

Consider the following torsion shear stress - shear strain diagram for ductile material.
(Answer 8& 9)



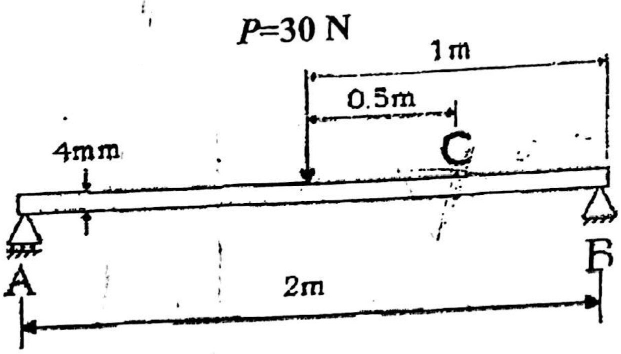
8. The modulus of rigidity G is
a) 40.0 MPa. b) 50.0 MPa
c) 100 GPa d) 40.0 GPa.

9. The modulus of Resilience is
a) 0.125 MPa. b) 0.125 GPa. c) 0.250 GPa d) 0.250 MPa.

$\frac{1}{2} * 100 * 0.0025 = 0.125$

$E = \frac{0.0025 - 0}{100 - 0}$

A rectangular cross sectional area **(20mm x 4 mm)** *is simply supported and loaded as shown.*
(Answer items 10-14)



10. The reaction at support *A* and *B* is:
a) 30 and 30 N
b) 15 and 15 N
c) 15 and 30 N
d) 30 and 15 N

11. The maximum deflection occurs at point:
a) B
b) *A*
c) Center of the beam
d). C

12. The moment at point C is equal to:
a) 15.0 N.m
b) 10.0 N.m
c) 30.0 N.m
d) 7.5 N.m

13. If the beam is replaced by another one of same material, same length and same loading but with circular cross sectional area of diameter 10 mm, then:
a) Beam of rectangular cross section will deflect more than circular one.
b) Beam of circular cross section will deflect more than rectangular one.
c) Both beams have same deflection.
d) Cannot be determined

14. The stress at point C is equal to:
a) 14.063 MPa.
b) 140.63 MPa.
c) 9.75 Mpa.
d) 18.75 MPa.

15. For a column subjected to a compressive load. If the length of the column is reduced by one half, the critical buckling load will be
a) Reduced by one half
b) Doubled
c) Increase 4-times
d)The same

16. One off the following is an example for buckling of column:
a) Walking stick
b) Column in a building
c) A beam loaded by an axial compressive force only
d) All of above

17. For the same specimen size, compression test usually requires _____ energy per unit volume than that tensile test
a) More
b) Less
c) Equal
d) Don't know

18. To reduce or eliminate barreling in compression test, we must
a) Increase the load
b) Decrease the friction
c) Decrease the load
d) Increase the friction

19. For the specimen shown the mode under which failure took place for ductile material is
a) Tensile load
b) Compressive load
c) Torsional Load
d) Buckling

20. In the tension test, the property which is an indication of the stiffness of a material is:
a) Ultimate strength
b) Elastic limit
c) Proportional limit
d) Modulus of elasticity

Good Luck

$A_f L_f = A_o L_o$

$$A_f = \frac{A_o}{1+\varepsilon_{max}}$$

Usually find but can give it in mid — Find d_f

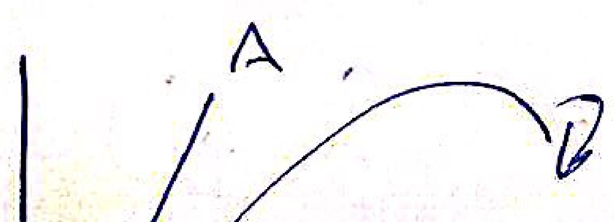
Elastic

$$\nu = -\frac{\varepsilon_{lateral}}{\varepsilon_{axial}} \rightarrow \frac{d_f - d_o}{d_o}$$

$$\frac{L_f - L_o}{L_o}$$

Plastic

$$A_f = \frac{A_o}{1+\varepsilon_{max}}$$



① higher E
② most ductile

[3.5 points] 1. ***The engineering stress-strain curves of three materials A, B, and C obtained from a tensile test vis shown in Fig. 1. Answer Qs. (1-1 ~ 1-10):***

1-1. The material..A.....has the highest elastic modulus.

1-2. The material.....C.....is the most ductile.

1-3. The material...A....is most brittle.

1-4. The material....B....has the highest tensile strength.

1-5. The material....C....has highest toughness.

1-6. The material....A....has highest resilience.

1-7. The material....A...can carry the highest load without permanent deformation.

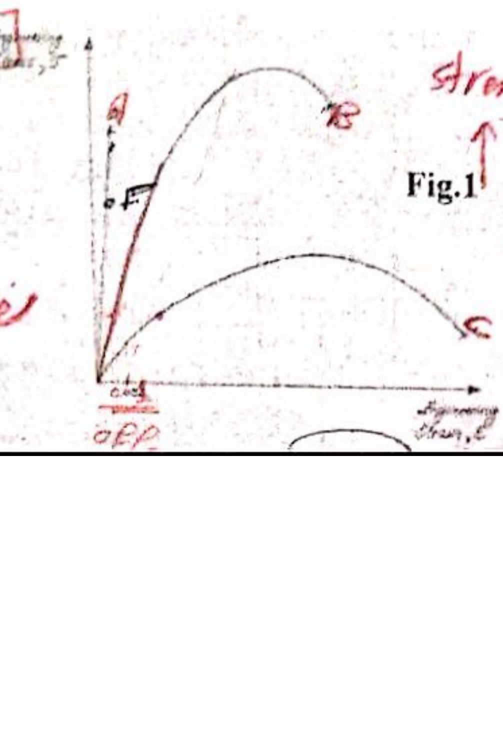
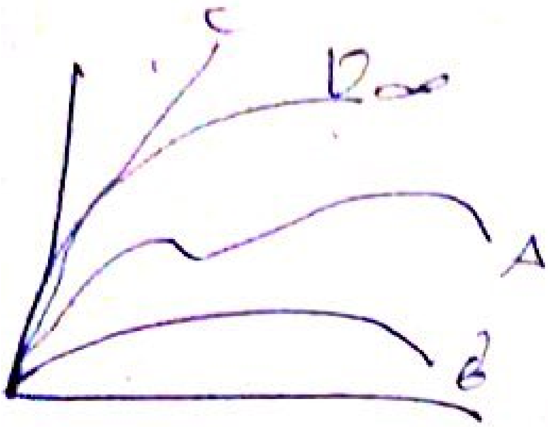


Fig.1

[10 points] 2. ***For the tensional bar given in Fig. 2 answer Qs. (2-1 ~ 2-10)***

2-1. The reaction at the support is.....800.....N

فخ - الاوزين ...



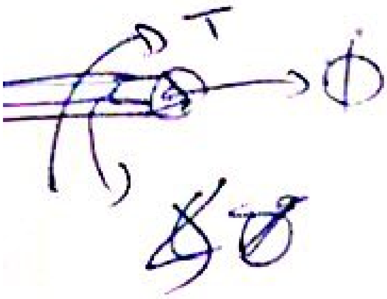
If that Tensile test what is ductile

ductile A, B, D
Brittle C
true D

If them curve:
ductile A, B, D
Brittle C
true A, B

* Back to Page of [Cup test] and distinguish between True & Engineering graphs

ion T



$\frac{TL}{JG}$

(i - d_i^4)

and inner

$= \frac{\phi r}{L}$

$= \frac{Tr}{JG}$ | remember it

Two steel shaft $G = 80\,GPa$ $D_1 = 20\ mm$ $D_2 = 10\ mm$

under the same applied Torque find $\frac{\gamma_1}{\gamma_2}$??

$$\gamma = \frac{\phi r}{L} = \frac{T r}{J G}$$

$$\frac{\gamma_1}{\gamma_2} = \frac{\frac{T r}{J G}}{\frac{T r}{J G}} = \frac{\frac{r_1}{J_1}}{\frac{r_2}{J_2}} = \frac{\frac{D_1}{J_1}}{\frac{D_2}{J_2}}$$

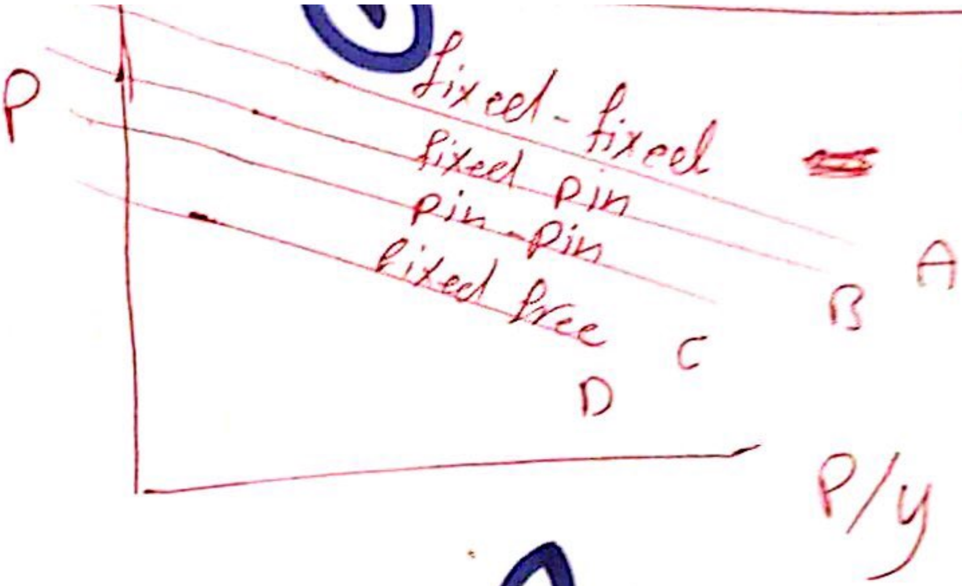
$$= \frac{\frac{D_1}{\frac{\pi}{64} D_1^{4}}}{\frac{D_2}{\frac{\pi}{64} D_2^{4}}} = \frac{\left(\frac{1}{D_1^3}\right)}{\left(\frac{1}{D_2^3}\right)}$$

$$= \frac{D_2^3}{D_1^3}$$

$$= 0.125$$

5

↑ $P_{cr} = \frac{}{K\downarrow}$



fixed-fixed — A
fixed-free — D
Pin - Pin — C
Pin - fixed — B

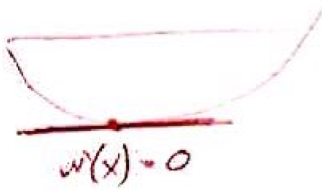
find deflection at $x =$ ~~[illegible]~~ 9

1) L $12 - 9 = 3$

$w(x) =$

---

2) $w(x) = 4x^3 + 2x^2 + 5x$ find ~~x~~ at which max deflection



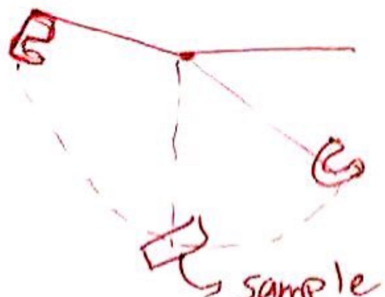
$w'(x) = 12x^2 + 4x + 5 = 0$

$X =$

4

بعد الفرق وصل

Pendol is released from rest final hight 15m if you know that friction 35 J and Max velocity 5 m/s find toughness



$\longrightarrow h_1, h_2$: $U = mg(h_1 - h_2) - \text{friction}$

energy conservation

$$h_1 = \frac{v^2}{2g}$$

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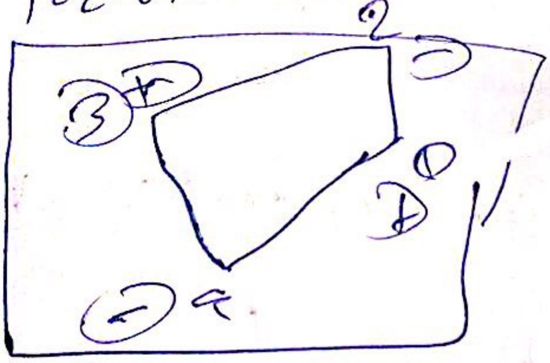
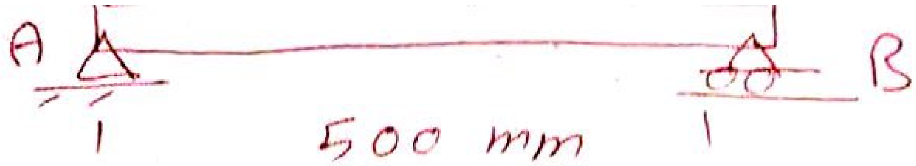
Strain gage (6)

- بيقيس → Strain
- كهربى → Resistance
  - بحولها → Weaston Bridge → Voltage
- كنوع ال resistance
  ↓
  Piezoelectric





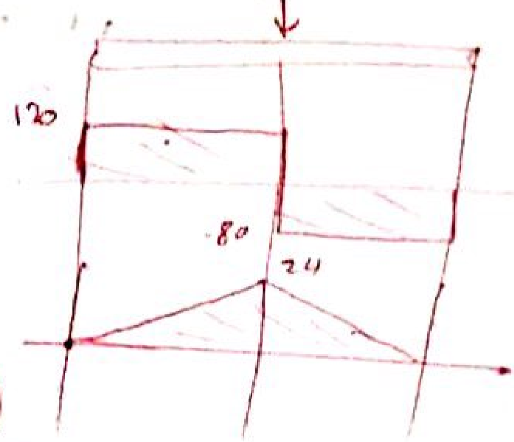
(a) Reaction $R_A = 120\ N$

$R_B = 80\ N$

ممكن مايطلبه

(b) Max Moment

$M = 24$



(c) Max bending stress

$$\sigma_{max} = \frac{M_c}{I} = \frac{M\,(5 \times 10^{-3})}{\frac{1}{12} bh^3 \times 10^{-12}} =$$