UNIVERSITY OF JOHANNESBURG

PROGRAM	:	BACCALAUREUS INGENERIAE *MECHANICAL ENGINEERING*
SUBJECT	:	STRENGTH OF MATERIALS 2B
CODE	:	SLR2B21
DATE	:	SUMMER EXAMINATION 23RD NOVEMBER 2016
DURATION	:	(1-PAPER) 08:30 - 11:30
WEIGHT	:	50 : 50
TOTAL MARKS	:	100

EXAMINER	:	DR M. F. ERINOSHO
MODERATOR	:	DR D. M. MADYIRA
NUMBER OF PAGES	:	6 PAGES AND 1 ANNEXURE

INSTRUCTIONS	:	QUESTION PAPERS MUST BE HANDED IN.
REQUIREMENTS	:	ANSWER BOOKLET.

INSTRUCTIONS TO CANDIDATES:

PLEASE ANSWER ALL THE QUESTIONS.

QUESTION 1

20 Marks

EMF material testing company was awarded a contract to test the strength of a stainless steel shaft for a building construction project going on in Johannesburg metropolis. The specimen to be tested is as shown in Figure 1 and the results of the test obtained on the specimen are as follows:

Original diameter = 40 mm
Original gauge length = 80 mm
Final length between gauge point = 85.8 mm
Final minimum diameter (neck) = 25.6 mm
Proportional limit load = 120 kN
Extension at proportional limit = 0.052 mm
Yield point load = 135 kN
Maximum recorded load = 210 kN

You are required to determine the following:

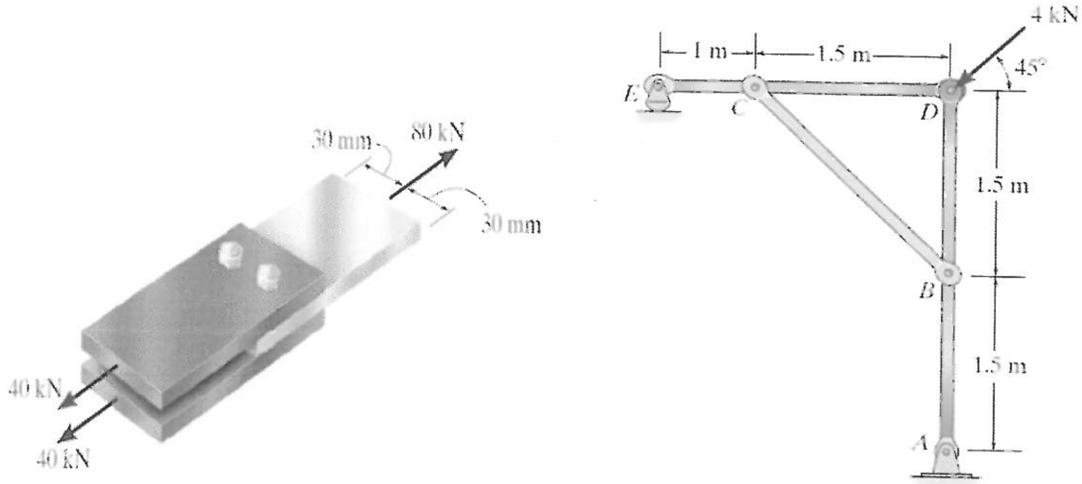
(a) The modulus of elasticity for the stainless steel,
(b) The proportional limit stress;
(c) The ultimate tensile strength;
(d) The percentage elongation;
(e) The percentage reduction in area;
(f) The modulus of toughness.
(g) Sketch and dimension the original and the fractured specimen. *(20 Marks)*

Figure 1: Stainless steel shaft

QUESTION 2 **20 Marks**

(a) The slab joint as shown in Figure 2 (a) is fastened together using two bolts. Determine the required diameter of the bolts if the failure shear stress for the bolts is $\tau_{fail} = 450$ MPa. Use a factor of safety for shear of F.S = 3.5. *(5 Marks)*

(b) The frame design is subjected to the load of 4 kN which acts on member ABD at D as shown in Figure 2 (b). If pin C is subjected to double shear and pin D is subjected to single shear, determine the required diameter of the pins at D and C if the allowable shear stress for the material is $\tau_{allow} = 45$ MPa. *(15 Marks)*



(a) (b)

Figure 2: (a) Slab joint design; (b) Frame design

QUESTION 3 **15 Marks**

The shaft as shown in Figure 3 is made of A992 steel with the allowable shear stress of $\tau_{allow} =$ 75 MPa. From the shaft design, Gear B supplies 15 kW of power, while gears A, C, and D withdraw 6 kW, 4 kW, and 5 kW, respectively. If the shaft is rotating at 600 rpm, determine the following:

(i) The required minimum diameter d of the shaft to the nearest millimeter,
(ii) The corresponding angle of twist of gear A relative to gear D. *(15 Marks)*

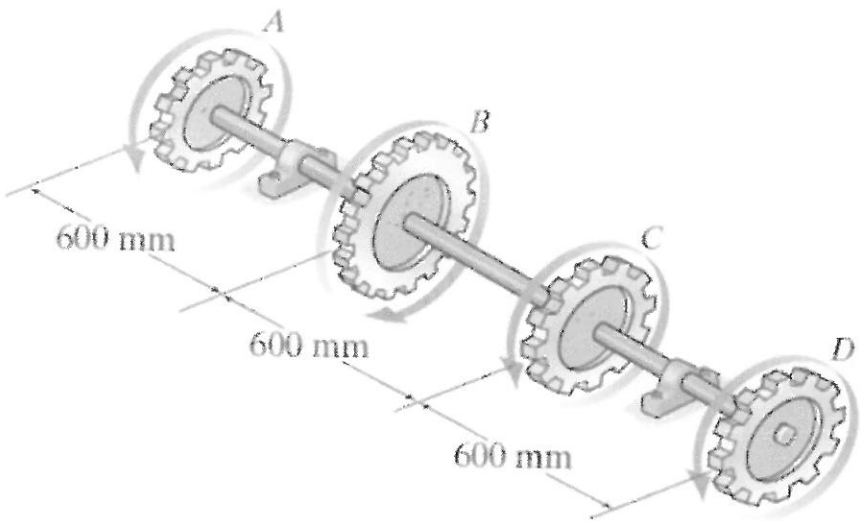


Figure 3: Shaft-gear design

QUESTION 4

20 Marks

The simply supported beam is built-up from three boards by nailing them together as shown in Figure 4. The wood has an allowable shear stress of τ_{allow} = 1.5 MPa, and an allowable bending stress of σ_{allow} = 9 MPa. The nails are spaced at s = 75 mm, and each has shear strength of 1.5 kN.

Determine:

(i) The maximum allowable force **P** that can be applied to the beam,
(ii) Draw the shear force and bending moment diagrams for the beam. *(20 Marks)*

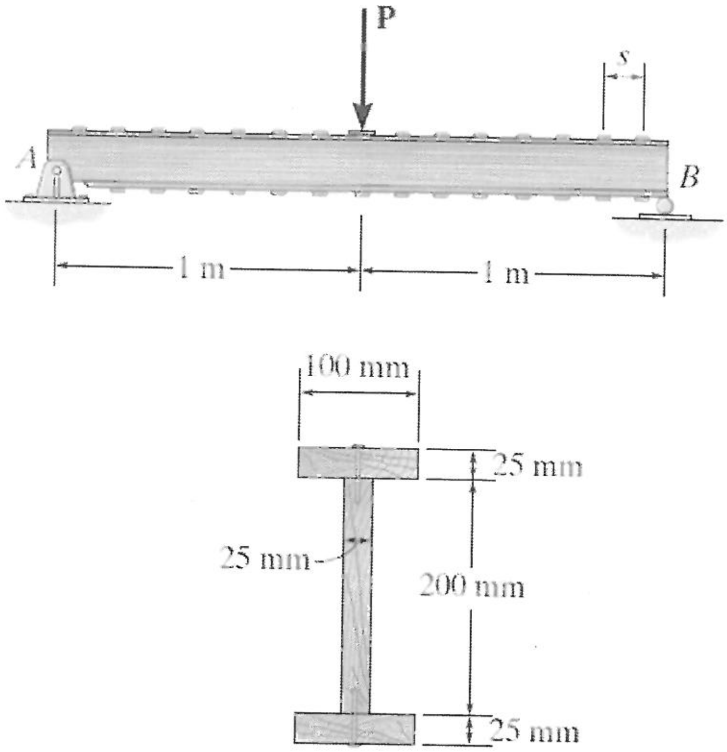


Figure 4: Simply supported beam

QUESTION 5 **25 Marks**

Figure 5 shows the equivalent state of stress at a point on the element.

Determine:

(i) The principal stress.
(ii) The orientation of the principal stress.
(iii) The maximum in-plane shear stress.
(iv) The associated average normal stress.
(v) The corresponding orientation of the maximum in-plane shear stress
(vi) Sketch the results on each element. *(25 Marks)*

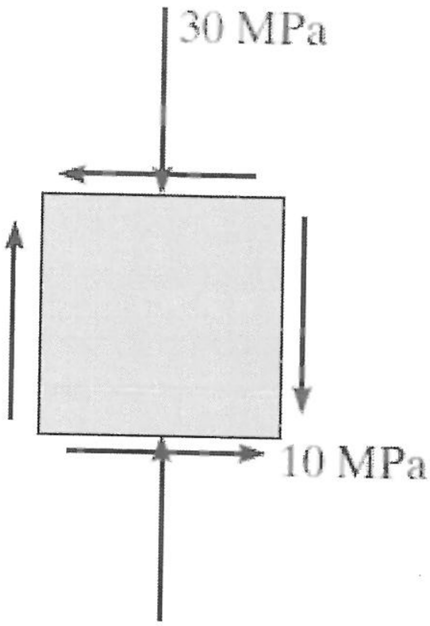


Figure 5: An element

ANNEXURE
FORMULA SHEET

$$\sigma = \frac{P}{A} \quad ; \quad \tau_{avg} = \frac{V}{A} \quad ; \quad \sigma = E\varepsilon \quad ; \quad \tau = G\gamma \, ; \quad \epsilon = \frac{\Delta l}{l} \times 100\% \, ; \quad P = T\omega$$

$$\nu = \frac{-\varepsilon_{lat}}{\varepsilon_{long}} \quad ; \quad G = \frac{E}{2(1+\upsilon)} \quad ; \quad \tau = \frac{VQ}{It} \quad ; \quad U_r = \frac{1}{2}\frac{\sigma^2}{E} \quad ; \quad \delta = \sum \frac{PL}{AE}$$

$$q = \frac{VQ}{I} \quad ; \quad \phi = \sum \frac{TL}{JG} \quad ; \quad -w = \frac{dV}{dx} \, ; \, V = \frac{dM}{dx} \, ; \, \%\Delta A = \frac{A_0 - A_f}{A_0} \times 100\% ;$$

$$\sigma_b = \frac{Mc}{I} \quad ; \quad I = \frac{1}{12} bD^3 \quad ; \quad \sigma_{x^1} = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2}\cos 2\theta + \tau_{xy}\sin 2\theta$$

$$\tau_{x^1y^1} = -\frac{\sigma_x - \sigma_y}{2}\sin 2\theta + \tau_{xy}\cos 2\theta \quad ; \quad \sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{(\frac{\sigma_x - \sigma_y}{2})^2 + \tau_{xy}^{\ 2}}$$

$$\tau_{\max\_in\_plane} = \sqrt{(\frac{\sigma_x - \sigma_y}{2})^2 + \tau_{xy}^{\ 2}} \quad ; \quad \sigma_{avg} = \frac{\sigma_x + \sigma_y}{2} ; \quad \delta_t = \alpha\Delta TL$$

$$\varepsilon_{x^1} = \frac{\varepsilon_x + \varepsilon_y}{2} + \frac{\varepsilon_x - \varepsilon_y}{2}\cos 2\theta + \frac{1}{2}\gamma_{xy}\sin 2\theta \, ; \quad \varepsilon_{1,2} = \frac{\varepsilon_x + \varepsilon_y}{2} \pm \sqrt{(\frac{\varepsilon_x - \varepsilon_y}{2})^2 + \frac{\gamma_{xy}^2}{4}}$$

$$\varepsilon_{y^1} = \frac{\varepsilon_x + \varepsilon_y}{2} - \frac{\varepsilon_x - \varepsilon_y}{2}\cos 2\theta - \frac{1}{2}\gamma_{xy}\sin 2\theta \, ; \quad \frac{\gamma_{x^1y^1}}{2} = -(\frac{\varepsilon_x - \varepsilon_y}{2})\sin 2\theta + \frac{\gamma_{xy}}{2}\cos 2\theta$$

$$\gamma_{\max\_in\_plane} = 2\sqrt{(\frac{\varepsilon_x - \varepsilon_y}{2})^2 + \frac{\gamma_{xy}^{\ 2}}{4}} \quad ; \quad \varepsilon_{avg} = \frac{\varepsilon_x + \varepsilon_y}{2} ; \quad \sigma = -\frac{M_z y}{I_z} + \frac{M_y z}{I_y}$$

$$\varepsilon_x = \frac{1}{E}(\sigma_x - \nu(\sigma_y + \sigma_z)) \; ; \; \varepsilon_y = \frac{1}{E}(\sigma_y - \nu(\sigma_x + \sigma_z)) \; ; \; \varepsilon_z = \frac{1}{E}(\sigma_z - \nu(\sigma_x + \sigma_y))$$

$$\tan 2\theta_p = \frac{2\tau_{xy}}{(\sigma_x - \sigma_y)} ; \quad \tan 2\theta_s = -(\frac{\varepsilon_x - \varepsilon_y}{\gamma_{xy}}) ; \quad F.S. = \frac{\sigma_y}{\sigma_{calculated}}$$

$$\sigma_1 = \frac{\Pr}{t} \quad ; \quad \sigma_2 = \frac{\Pr}{2t} ; \quad EI\frac{d^2y}{dx^2} = M \, ; \quad EI\frac{d^3y}{dx^3} = V \, ; \quad EI\frac{d^4y}{dx^4} = -w$$

$$J = \frac{\pi}{32}\left[D^4 - d^4\right] ; \quad \tau_{allow} = \frac{Tc}{J} \; ; \quad J = \frac{\pi}{2}C^4 \quad ; \; K = \frac{\sigma_{max}}{\sigma_{avg}} \; ; \quad \text{UTS} = \frac{P_{max}}{A}$$

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QUESTION 1 **18 Marks**

(a) Provide the definition for the following:

(i) Shear force,
(ii) Modulus of Toughness,
(iii) Poisson's ratio,
(iv) Strain hardening,
(v) Necking. *(5 Marks)*

(b) As shown in Figure 1, member ***CB*** has a square cross section of 25 mm on each side. Determine the largest load **P** that can be applied to the frame without causing either the average normal stress or the average shear stress at section ***a-a*** to exceed σ = 150 MPa and τ = 450 MPa, respectively. *(13 Marks)*

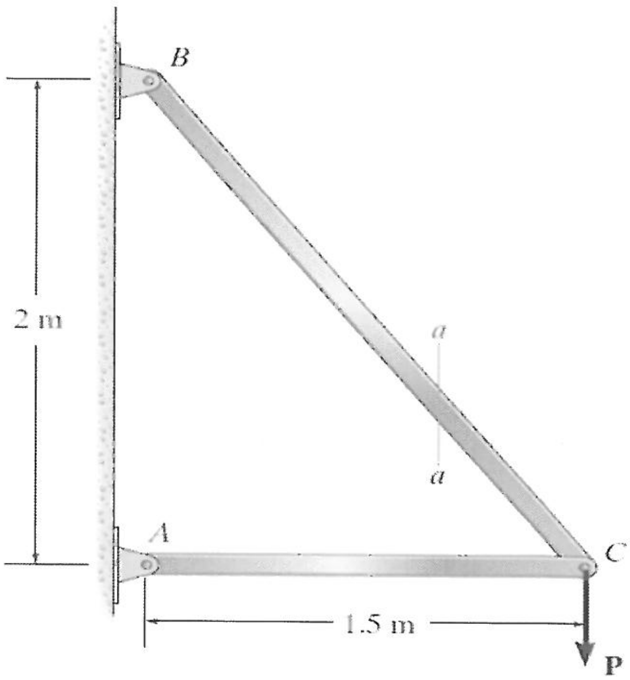

Figure 1: Frame

QUESTION 2 **20 Marks**

(a) The 500 kg engine is suspended from the jib crane at the position as shown in Figure 2. Determine the state of stress at point ***B*** on the cross section of the boom at section ***a-a***. Note that point ***B*** is just above the bottom flange. *(20 Marks)*

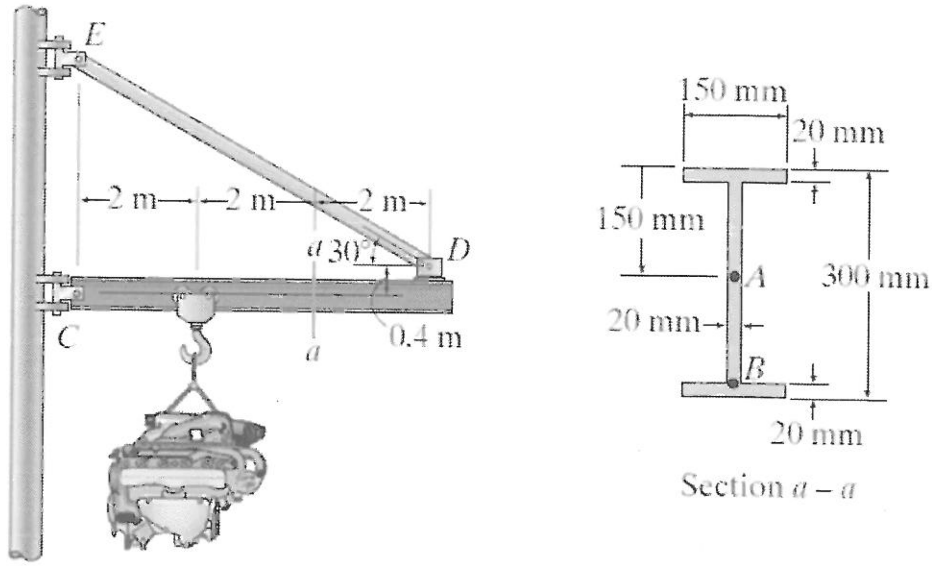

Figure 2: An engine suspension

QUESTION 3 **17 Marks**

A spring-supported pipe hanger as shown in Figure 3 consists of two springs, which are originally unstretched and have a stiffness of k = 60 kN/m, three 304 stainless steel rods, ***AB*** and ***CD***, which have a diameter of 5 mm, and ***EF***, which has a diameter of 12 mm, and a rigid beam ***GH***. If the pipe is displaced 82 mm when it is filled with fluid, determine the weight of the fluid. *(17 Marks)*

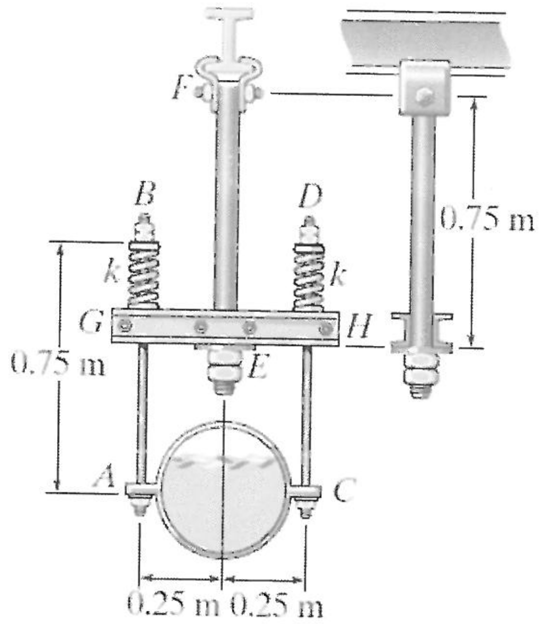

Figure 3: A spring- supported pipe hanger

QUESTION 4 **25 Marks**

The state of strain at a point as shown in Figure 4 has components of $\epsilon_x = -300(10^{-6})$, $\epsilon_y = 0$, and $\gamma_{xy} = -150(10^{-6})$.

Use the strain-transformation equations to determine:

(a) The in-plane principal strains,

(b) The orientation of the principal plane,

(c) The maximum in-plane shear strain,

(d) The orientation of the maximum in-plane shear strain,

(e) The average normal strain,

(f) Show how the strains deform the element within the x-y plane. *(25 Marks)*

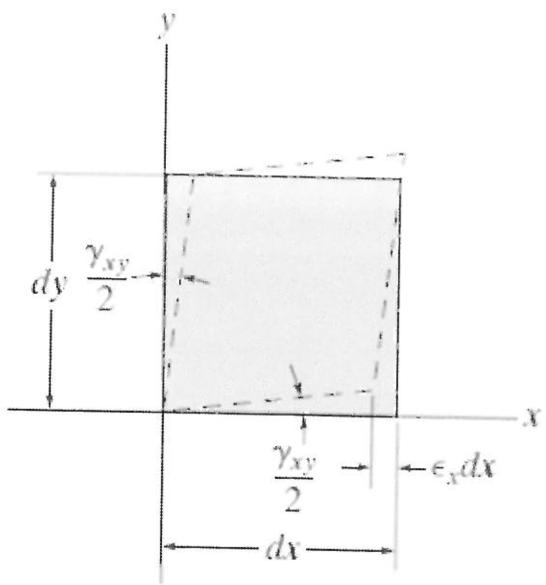

Figure 4: A component

QUESTION 5

20 Marks

The beam as shown in Figure 5 is supported by a pin at ***A***, a roller at ***B***, and a post having a diameter of 50 mm at ***C***. The post and the beam are made of the same material having a modulus of elasticity E = 200 GPa, and the beam has a constant moment of inertia $I = 255(10^6)\ mm^4$. Determine the support reactions at ***A***, ***B***, and ***C***. *(20 Marks)*

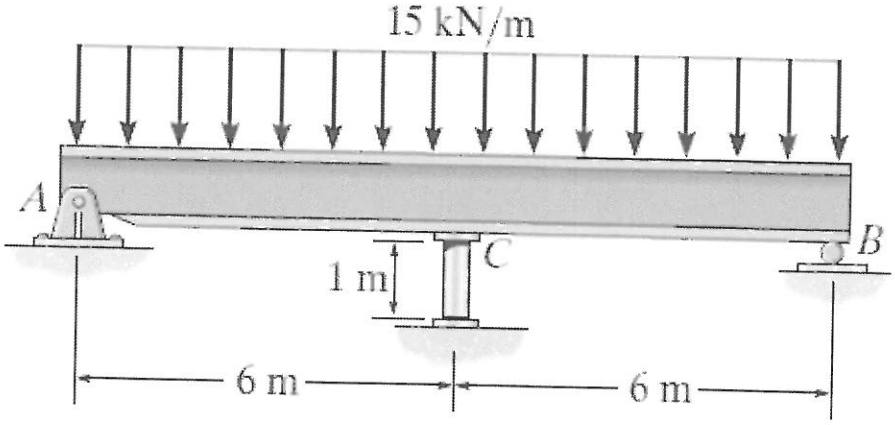

Figure 5: A supported beam

ANNEXURE
FORMULA SHEET

$\sigma = \frac{P}{A}$; $\tau_{avg} = \frac{V}{A}$; $\sigma = E\varepsilon$; $\tau = G\gamma$; $\epsilon = \frac{\Delta l}{l} \times 100\%$; $P = T\omega$

$\nu = \frac{-\varepsilon_{lat}}{\varepsilon_{long}}$; $G = \frac{E}{2(1+\upsilon)}$; $\tau = \frac{VQ}{It}$; $U_r = \frac{1}{2}\frac{\sigma^2}{E}$; $\delta = \sum \frac{PL}{AE}$

$q = \frac{VQ}{I}$; $\phi = \sum \frac{TL}{JG}$; $-w = \frac{dV}{dx}$; $V = \frac{dM}{dx}$; $\%\Delta A = \frac{A_0 - A_f}{A_0} \times 100\%$;

$\sigma_b = \frac{Mc}{I}$; $I = \frac{1}{12}bD^3$; $\sigma_{x^1} = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2}\cos 2\theta + \tau_{xy}\sin 2\theta$

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$\gamma_{\max\_in\_plane} = 2\sqrt{(\frac{\varepsilon_x - \varepsilon_y}{2})^2 + \frac{\gamma_{xy}^{\ 2}}{4}}$; $\varepsilon_{avg} = \frac{\varepsilon_x + \varepsilon_y}{2}$; $\sigma = -\frac{M_z y}{I_z} + \frac{M_y z}{I_y}$

$\varepsilon_x = \frac{1}{E}(\sigma_x - \nu(\sigma_y + \sigma_z))$; $\varepsilon_y = \frac{1}{E}(\sigma_y - \nu(\sigma_x + \sigma_z))$; $\varepsilon_z = \frac{1}{E}(\sigma_z - \nu(\sigma_x + \sigma_y))$

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