CONFIDENTIAL

SET A

UNIVERSITI KUALA LUMPUR
Malaysia France Institute

FINAL EXAMINATION
SEPTEMBER 2014 SESSION

SUBJECT CODE	:	**NMB21104**
SUBJECT TITLE	:	**SOLID MECHANICS**
LEVEL	:	**BACHELOR**
TIME / DURATION	:	**9.00 PM – 12.30 PM (3.5 HOURS)**
DATE	:	**10 JANUARY 2015**

INSTRUCTIONS TO CANDIDATES

1. Please read the instructions given in the question paper CAREFULLY.
2. This question paper is printed on both sides of the paper.
3. Please write your answers on the answer booklet provided.
4. Answers should be written in blue or black ink except for sketching, graphic and illustration.
5. This question paper consists of SIX (6) questions. Answer FOUR (4) questions only.
6. Answer all questions in English.
7. Formulas, Shapes, Geometric and Properties Tables is appended

THERE ARE 4 PAGES OF QUESTIONS AND 3 PAGES OF APPENDIX, EXCLUDING THIS PAGE.

INSTRUCTION: Answer only FOUR questions.
Please use the answer booklet provided.

Question 1

A wide flange beam with cross sectional area as shown in the Figure 1 below is loaded with multiple forces.

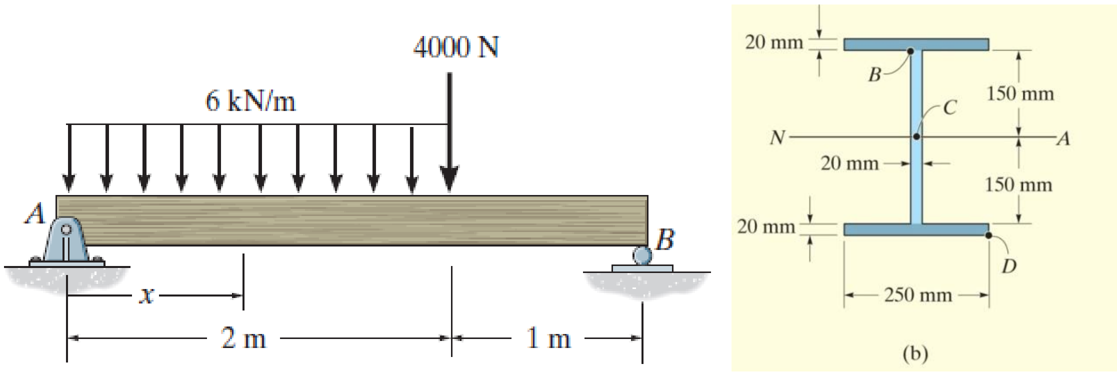


Figure 1

i. Express the internal shear and moment in terms of x.

(10 marks)

ii. Draw the shear and moment diagrams for the beam.

(8 marks)

iii. Determine the position and the magnitude of the absolute maximum bending (flexural) stress.

(7 marks)

Question 2

The rigid bar is supported by the pin-connected rod CB as shown in the Figure 2 that has a cross-sectional area of 14 mm^2 and is made from 2014-T6 aluminium. Determine the vertical deflection of the bar at D when the distributed load is applied.

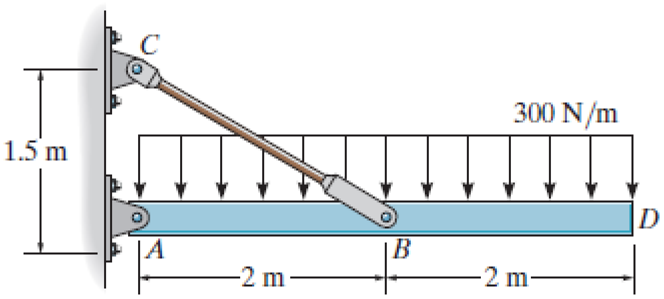


Figure 2

(25 marks)

Question 3

The state of stress at a point on the surface of loaded beam is shown on the element in the Figure 3. Use Mohr's circle to determine the principal stresses and maximum in-plane shear stress. Show all necessary sketches.

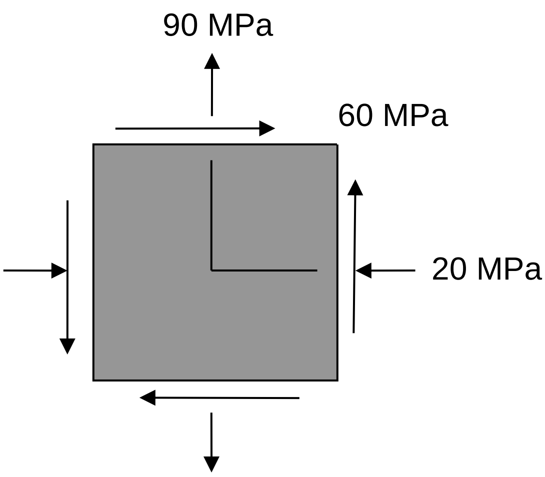


Figure 3

(25 marks)

Question 4

The steel tank (specific weight of $\gamma_{st} = 78$ kN/m^3) in shown in the Figure 4 has an inner radius of 600 mm and a thickness of 12 mm. It is filled to the top with water (specific weight of γ_w = 10 kN/m^3). Determine the state of stress at point *A.* The tank is open at the top.

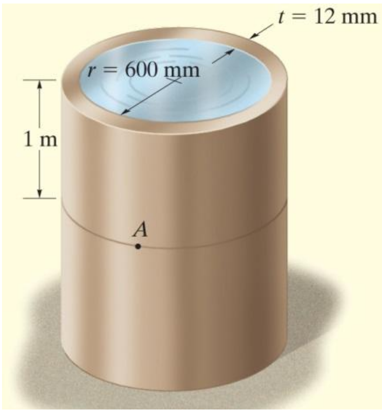


Figure 4

(25 marks)

Question 5

The steel cantilevered beam in the Figure 5 is loaded as shown. Determine:

i. The elastic curve for the cantilevered beam using the x coordinate

(13 marks)

ii. The maximum slope and the maximum deflection

(12 marks)

Use E = 200 GPa.

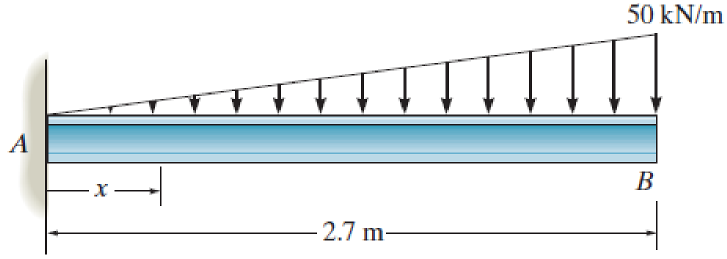


Figure 5

Question 6

a. The A-36 steel W200 x 46 member shown in the Figure 6 is to be used as a pin-connected column. Determine the largest axial load it can support before it either begins to buckle or the steel yields.

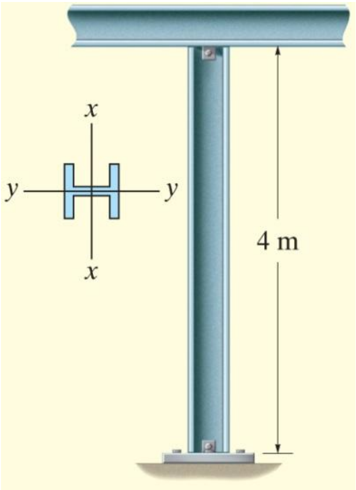


Figure 6

(15 marks)

b. A steel tube with an outer diameter of 60 mm is used to transmit 7000 W when rotating at 30 rev/min. Determine the inner diameter ***d*** of the tube to the nearest mm if the allowable shear stress is τ_{allow} = 70 MPa.

(10 marks)

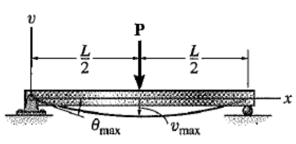
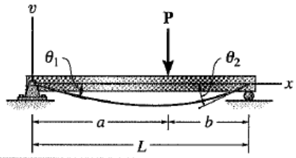
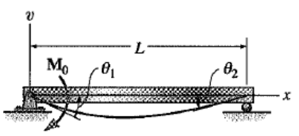
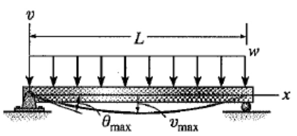
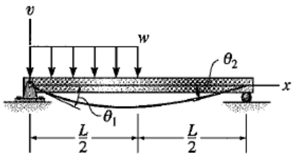
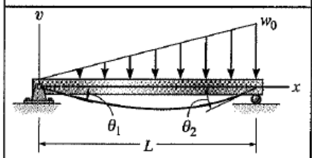
END OF QUESTION

APPENDIX

Material	Density ρ (Mg/m³)	E (GPa)	G (GPa)	Yield Strength (MPa)			Poisson's Ratio	Coef. Of Thermal Exp α (10^{-6}/°C)
				Tens.	Comp.	Shear		
Aluminium 2014-T6	2.79	73.1	27	414	414	172	0.35	23
Steel A-36	7.85	200	75	250	250	-	0.32	12

Designation mm x kg/m	Area A (mm²)	Depth d (mm)	Web thickness t_w (mm)	Flange width b_f (mm)	Flange thickness t_f (mm)	x-x axis			y-y axis		
						I 10^6 mm⁴	S (10^3 mm³)	r (mm)	I 10^6 mm⁴	S (10^3 mm³)	r (mm)
W200 x 46	5890	203	7.24	203	11	45.5	448	87.9	15.3	151	51
W360 x 45	5710	352	6.86	171	9.8	121	688	146	8.16	95.4	37.8

Simply Supported Beam Slopes and Deflections

Beam	Slope	Deflection	Elastic Curve
	$\theta_{max} = \dfrac{-PL^2}{16EI}$	$v_{max} = \dfrac{-PL^3}{48EI}$	$v = \dfrac{-Px}{48EI}(3L^2 - 4x^2)$ $0 \le x \le L/2$
	$\theta_1 = \dfrac{-Pab(L+b)}{6EIL}$ $\theta_2 = \dfrac{Pab(L+a)}{6EIL}$	$v\Big\rvert_{x=a} = \dfrac{-Pba}{6EIL}(L^2 - b^2 - a^2)$	$v = \dfrac{-Pbx}{6EIL}(L^2 - b^2 - x^2)$ $0 \le x \le a$
	$\theta_1 = \dfrac{-M_0L}{3EI}$ $\theta_2 = \dfrac{M_0L}{6EI}$	$v_{max} = \dfrac{-M_0L^2}{\sqrt{243}EI}$	$v = \dfrac{-M_0x}{6EIL}(x^2 - 3Lx + 2L^2)$
	$\theta_{max} = \dfrac{-wL^3}{24EI}$	$v_{max} = \dfrac{-5wL^4}{384EI}$	$v = \dfrac{-wx}{24EI}(x^3 - 2Lx^2 + L^3)$
	$\theta_1 = \dfrac{-3wL^3}{128EI}$ $\theta_2 = \dfrac{7wL^3}{384EI}$	$v\Big\rvert_{x=L/2} = \dfrac{-5wL^4}{768EI}$ $v_{max} = -0.006563\dfrac{wL^4}{EI}$ at $x = 0.4598L$	$v = \dfrac{-wx}{384EI}(16x^3 - 24Lx^2 + 9L^3)$ $0 \le x \le L/2$ $v = \dfrac{-wL}{384EI}(8x^3 - 24Lx^2 + 17L^2x - L^3)$ $L/2 \le x < L$
	$\theta_1 = \dfrac{-7w_0L^3}{360EI}$ $\theta_2 = \dfrac{w_0L^3}{45EI}$	$v_{max} = -0.00652\dfrac{w_0L^4}{EI}$ at $x = 0.5193\,L$	$v = \dfrac{-w_0x}{360EIL}(3x^4 - 10L^2x^2 + 7L^4)$

Material Property Relations

Poisson's ratio

$$\nu = -\frac{\epsilon_{\text{lat}}}{\epsilon_{\text{long}}}$$

Generalized Hooke's Law

$$\epsilon_x = \frac{1}{E}[\sigma_x - \nu(\sigma_y + \sigma_z)]$$

$$\epsilon_y = \frac{1}{E}[\sigma_y - \nu(\sigma_x + \sigma_z)]$$

$$\epsilon_z = \frac{1}{E}[\sigma_z - \nu(\sigma_x + \sigma_y)]$$

$$\gamma_{xy} = \frac{1}{G}\tau_{xy}, \quad \gamma_{yz} = \frac{1}{G}\tau_{yz}, \quad \gamma_{zx} = \frac{1}{G}\tau_{zx}$$

where

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

Relations Between *w, V, M*

$$\frac{dV}{dx} = -w(x), \qquad \frac{dM}{dx} = V$$

Elastic Curve

$$\frac{1}{\rho} = \frac{M}{EI}$$

$$EI\frac{d^4v}{dx^4} = -w(x)$$

$$EI\frac{d^3v}{dx^3} = V(x)$$

$$EI\frac{d^2v}{dx^2} = M(x)$$

Buckling

Critical axial load

$$P_{\text{cr}} = \frac{\pi^2 EI}{(KL)^2}$$

Critical stress

$$\sigma_{\text{cr}} = \frac{\pi^2 E}{(KL/r)^2}, \; r = \sqrt{I/A}$$

Secant formula

$$\sigma_{\max} = \frac{P}{A}\left[1 + \frac{ec}{r^2}\sec\left(\frac{L}{2r}\sqrt{\frac{P}{EA}}\right)\right]$$

Energy Methods

Conservation of energy

$$U_e = U_i$$

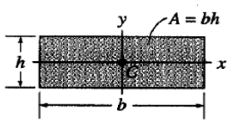
Strain energy

$$U_i = \frac{N^2L}{2AE} \quad \text{constant axial load}$$

$$U_i = \int_0^L \frac{M^2dx}{EI} \quad \text{bending moment}$$

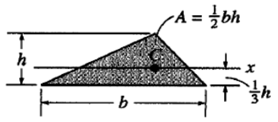
$$U_i = \int_0^L \frac{f_sV^2dx}{2GA} \quad \text{transverse shear}$$

$$U_i = \int_0^L \frac{T^2dx}{2GJ} \quad \text{torsional moment}$$



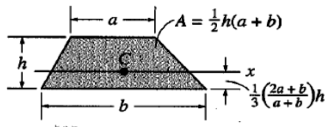
Rectangular area

$I_x = \frac{1}{12}bh^3$
$I_y = \frac{1}{12}hb^3$

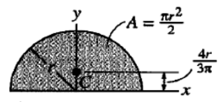


Triangular area

$I_x = \frac{1}{36}bh^3$

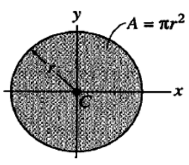


Trapezoidal area



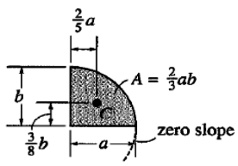
Semicircular area

$I_x = \frac{1}{8}\pi r^4$
$I_y = \frac{1}{8}\pi r^4$

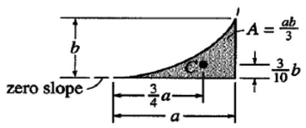


Circular area

$I_x = \frac{1}{4}\pi r^4$
$I_y = \frac{1}{4}\pi r^4$
$J = I_x + I_y$
$= \frac{1}{2}\pi r^4$



Semiparabolic area



Exparabolic area

Axial Load

Normal Stress

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

Displacement

$$\delta = \int_0^L \frac{P(x)dx}{A(x)E}$$

$$\delta = \Sigma \frac{PL}{AE}$$

$$\delta_T = \alpha \Delta T L$$

Torsion

Shear stress in circular shaft

$$\tau = \frac{T\rho}{J}$$

where

$$J = \frac{\pi}{2}c^4 \text{ solid cross section}$$

$$J = \frac{\pi}{2}(c_o^4 - c_i^4) \text{ tubular cross section}$$

Power

$$P = T\omega = 2\pi f T$$

Angle of twist

$$\phi = \int_0^L \frac{T(x)dx}{J(x)G}$$

$$\phi = \Sigma \frac{TL}{JG}$$

Average shear stress in a thin-walled tube

$$\tau_{avg} = \frac{T}{2tA_m}$$

Shear Flow

$$q = \tau_{avg}t = \frac{T}{2A_m}$$

Bending

Normal stress

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

Unsymmetric bending

$$\sigma = -\frac{M_z y}{I_z} + \frac{M_y z}{I_y}, \qquad \tan\alpha = \frac{I_z}{I_y}\tan\theta$$

Shear

Average direct shear stress

$$\tau_{avg} = \frac{V}{A}$$

Transverse shear stress

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

Shear flow

$$q = \tau t = \frac{VQ}{I}$$

Stress in Thin-Walled Pressure Vessel

Cylinder

$$\sigma_1 = \frac{pr}{t} \qquad \sigma_2 = \frac{pr}{2t}$$

Sphere

$$\sigma_1 = \sigma_2 = \frac{pr}{2t}$$

Stress Transformation Equations

$$\sigma_{x'} = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2}\cos 2\theta + \tau_{xy}\sin 2\theta$$

$$\tau_{x'y'} = -\frac{\sigma_x - \sigma_y}{2}\sin 2\theta + \tau_{xy}\cos 2\theta$$

Principal Stress

$$\tan 2\theta_p = \frac{\tau_{xy}}{(\sigma_x - \sigma_y)/2}$$

$$\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

Maximum in-plane shear stress

$$\tan 2\theta_s = -\frac{(\sigma_x - \sigma_y)/2}{\tau_{xy}}$$

$$\tau_{max} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\sigma_{avg} = \frac{\sigma_x + \sigma_y}{2}$$

Absolute maximum shear stress

$$\tau_{\substack{abs\\max}} = \frac{\sigma_{max} - \sigma_{min}}{2}$$

$$\sigma_{avg} = \frac{\sigma_{max} + \sigma_{min}}{2}$$