First Semester Examination
2022/2023 Academic Session

February 2023

EEM101 – Principles and Mechanics of Materials
(Prinsip dan Mekanik Bahan)

Duration : 3 hours
(Masa : 3 jam)

Please check that this examination paper consists of **TEN (10)** pages of printed material including appendix before you begin the examination.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **SEPULUH (10)** muka surat yang bercetak termasuk lampiran sebelum anda memulakan peperiksaan ini.]*

Instructions : This paper consists of **FOUR (4)** questions. Answer **FOUR (4)** questions.

*[**Arahan** : Kertas ini mengandungi **EMPAT (4)** soalan. Jawab **EMPAT (4)** soalan.]*

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]

1. a) Explain the relationship between processing, structure, property, and performance in solid materials.

   Terangkan hubung kait antara pemprosesan, struktur, sifat, dan prestasi dalam bahan pepejal.

   (25 marks/*markah)*

   b) With the help of a suitable diagram, explain the polar molecule-induced dipole type of bond.

   Dengan bantuan gambar rajah yang bersesuaian, terangkan jenis ikatan molekul berpola-dipol teraruh.

   (25 marks/*markah)*

   c) Determine the Miller-Bravais indices for the plane in Figure 1 below:

   Tentukan indeks Miller-Bravais untuk satah dalam rajah 1 di bawah:

   (25 marks/*markah)*

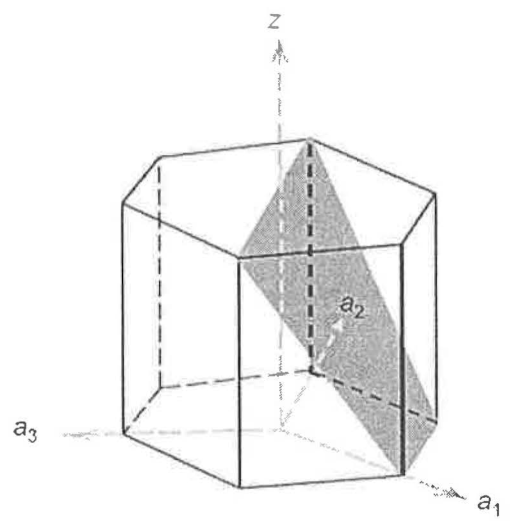

Figure 1
Rajah 1

d) Calculate the number of vacancies per cubic meter in iron at 850°C. The energy for vacancy formation is 1.08 eV/atom. Furthermore, the density and atomic weight for Fe are 7.65 g/cm^3 and 55.85 g/mol, respectively.

Hitungkan bilangan kekosongan per meter persegi dalam besi pada suhu 850°C. Tenaga untuk pembentukan kekosongan adalah 1.08 eV/atom. Tambahan pula, ketumpatan dan berat atom untuk Fe adalah 7.65 g/cm^3 dan 55.85 g/mol.

(25 marks/*markah*)

2. a) Explain the different between interstitial diffusion and vacancy diffusion. Give two reasons why interstitial diffusion is normally more rapid than vacancy diffusion.

Terangkan perbezaan antara resapan interstisial dan resapan kekosongan. Berikan dua sebab mengapa resapan interstisial kebiasaannya lebih pantas berbanding resapan kekosongan.

(25 marks/*markah*)

b) Determine the carburizing time necessary to achieve a carbon concentration of 0.45 wt% at a position 2 mm into an iron–carbon alloy that initially contains 0.20 wt% C. The surface concentration is to be maintained at 1.30 wt% C, and the treatment is to be conducted at 1000°C. The iron undergoing diffusion is of the γ-Fe type.

Tentukan masa pengkarbonan diperlukan untuk mencapai kepekatan karbon sebanyak 0.45 wt% pada kedudukan 2 mm ke dalam aloi besi-karbon yang pada permulaannya mengandungi 0.20 wt% C. Kepekatan permukaan dikekalkan pada 1.30 wt% C, dan rawatan ini dilakukan pada suhu 1000°C. Besi yang melalui proses serapan ini adalah daripada jenis γ-Fe.

(40 marks/*markah*)

c) The diffusion coefficients for iron in nickel are given at two temperatures:

Pekali resapan untuk besi dalam nikel adalah diberikan untuk dua suhu:

T(K)	D (m^2/s)
1273	9.4×10^{-16}
1473	2.4×10^{-14}

(i) Determine the values of D_0 and the activation energy Q_d.

Tentukan nilai D_0 dan tenaga pengaktifan Q_d.

(20 marks/*markah)*

(ii) What is the magnitude of D at 1100°C (1373 K)?

Apakah nilai D pada 1100°C (1373 K)?

(15 marks/*markah)*

3. A simple supported beam is loaded as shown in Figure 3.

Satu rasuk mudah dikenakan beban seperti Rajah 3.

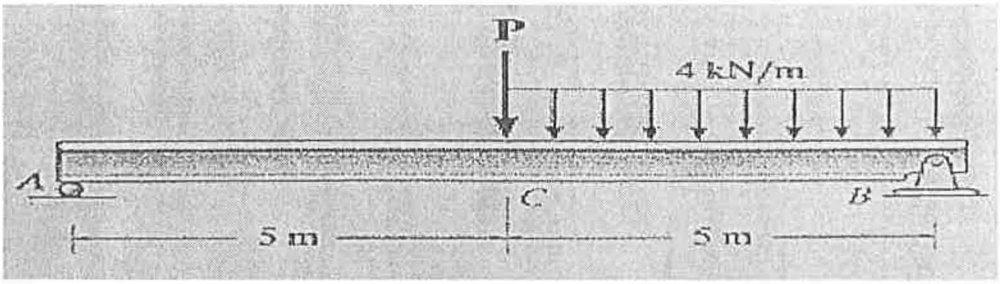

Figure 3
Rajah 3

a) Sketch a free body diagram for beam as in Figure 3 and calculate the reaction force if $P = 20kN$

Lakarkan gambarajah jasad bebas bagi rasuk seperti Rajah 3 dan kirakan daya tindak balas, sekiranya $P = 20kN$

(20 marks/*markah)*

b) Calculate the shear force and bending moment diagram.

Kirakan daya ricih dan diagram momen lentur.

(30 marks/*markah)*

c) Analyze the bending moment maximum and its position from the left of the beam based on shear force and bending moment diagram.

Analisa momen lentur maksima dan kedudukannya dari kiri rasuk berdasarkan gambarajah daya ricih dan momen lentur.

(50 marks/*markah)*

4. A solid circular shaft of a series of compound made from steel is shown in Figure 4. Length AB and BC are 400mm and 200mm, diameter AB and BC are 50mm and 30mm. If torque of 200 Nm is imposed at end of BC. Given $G = 70\ GN/m^2$

Sebatang aci bulat padu siri dibuat daripada keluli seperti ditunjukkan dalam rajah 4. Panjang AB dan BC adalah 400mm dan 200mm, diameter AB dan BC adalah 50mm dan 30mm. Daya kilasan 200Nm dikenakan pada hujung BC. Diberi $G = 70\ GN/m^2$

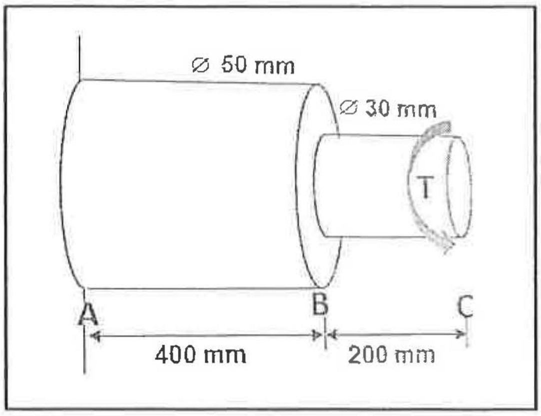

Figure 4
Rajah 4

a) Define torque and give FIVE (5) torque's application in engineering.

Takrifkan daya kilasan dan berikan LIMA (5) aplikasi daya kilasan dalam kejuruteraan.

(15 marks/*markah)*

b) Calculate the Polar second moment area of the shaft and angle of twist.

Kirakan luas momen kedua kutub aci dan sudut putaran.

(40 marks/*markah)*

c) A solid steel shaft 5m long is stressed at 80 Mpa when twisted through 4°. Using $G = 83\ Gpa$, calculate:

Sebuah aci keluli padu dengan 5m panjang dikenakan tegasan 80 Mpa apabila dipiuh pada 4°.
Menggunakan $G = 83\ GPa$, *kirakan;*

(i) The shaft diameter

Diameter aci

(30 marks/*markah)*

(ii) Power transmitted by the shaft at 20 rpm.

Kuasa yang dihantar oleh aci pada 20 ppm

(15 marks/*markah)*

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Appendix
Lampiran

$$E = \int F dr$$

$$F = \frac{dE}{dr}$$

$$E_A = -\frac{A}{r}$$

$$E_R = \frac{B}{r^n}$$

$$F_A = \frac{1}{4\pi\varepsilon_0 r^2}(|Z_1|e)(|Z_2|e)$$

$$\%IC = \{1 - \exp[-(0.25)(X_A - X_B)^2]\} \times 100$$

$$N_v = N \exp\left(-\frac{Q_v}{kT}\right)$$

$$N = \frac{N_A \rho}{A}$$

$$a = 2R\sqrt{2}$$

$$APF = \frac{\text{volume of atoms in a unit cell}}{\text{total unit cell volume}} = \frac{V_S}{V_C}$$

$$a = \frac{4R}{\sqrt{3}}$$

$$\rho = \frac{nA}{V_C N_A}$$

$$q = \frac{a}{P_x}$$

$$u = n\left(\frac{x_2 - x_1}{a}\right)$$

$$u = \frac{1}{3}(2U - V)$$

$$U = n\left(\frac{a_1'' - a_1'}{a}\right)$$

$$h = \frac{na}{A}$$

$$J = \frac{M}{At}$$

$$J = -D\frac{dC}{dx}$$

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2}$$

$$\frac{C_x - C_0}{C_s - C_0} = 1 - \text{erf}\left(\frac{x}{2\sqrt{Dt}}\right)$$

$$D = D_0 \exp\left(-\frac{Q_d}{RT}\right)$$

R = 8.31 J/mol·K
k = 8.62×10^{-5} eV/atom·K
N_A = 6.022×10^{23} atoms/mole

2. POLAR MOMENT OF INERTIA

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

3. SERIES COMPOSITE SHAFT

$$T = \frac{G_1\theta_1 J_1}{L_1} = \frac{G_2\theta_2 J_2}{L_2}$$

$$\theta_{AC} = \theta_{AB} + \theta_{BC} = \frac{T_1L_1}{G_1J_1} + \frac{T_2L_2}{G_2J_2} = T\left(\frac{L_1}{G_1J_1} + \frac{L_2}{G_2J_2}\right)$$

4. PARALLEL COMPOSITE SHAFT

$$T = T_1 + T_2$$

$$\theta = \left(\frac{T_1L_1}{G_1J_1}\right) = \left(\frac{T_2L_2}{G_2J_2}\right)$$

z	$erf(z)$	z	$erf(z)$	z	$erf(z)$
0	0	0.55	0.5633	1.3	0.9340
0.025	0.0282	0.60	0.6039	1.4	0.9523
0.05	0.0564	0.65	0.6420	1.5	0.9661
0.10	0.1125	0.70	0.6778	1.6	0.9763
0.15	0.1680	0.75	0.7112	1.7	0.9838
0.20	0.2227	0.80	0.7421	1.8	0.9891
0.25	0.2763	0.85	0.7707	1.9	0.9928
0.30	0.3286	0.90	0.7970	2.0	0.9953
0.35	0.3794	0.95	0.8209	2.2	0.9981
0.40	0.4284	1.0	0.8427	2.4	0.9993
0.45	0.4755	1.1	0.8802	2.6	0.9998
0.50	0.5205	1.2	0.9103	2.8	0.9999

Diffusing Species	*Host Metal*	D_0 (m^2/s)	Q_d (J/mol)
	Interstitial Diffusion		
C[b]	Fe (α or BCC)[a]	1.1×10^{-6}	87,400
C[c]	Fe (γ or FCC)[a]	2.3×10^{-5}	148,000
N[b]	Fe (α or BCC)[a]	5.0×10^{-7}	77,000
N[c]	Fe (γ or FCC)[a]	9.1×10^{-5}	168,000
	Self-Diffusion		
Fe[c]	Fe (α or BCC)[a]	2.8×10^{-4}	251,000
Fe[c]	Fe (γ or FCC)[a]	5.0×10^{-5}	284,000
Cu[d]	Cu (FCC)	2.5×10^{-5}	200,000
Al[c]	Al (FCC)	2.3×10^{-4}	144,000
Mg[c]	Mg (HCP)	1.5×10^{-4}	136,000
Zn[c]	Zn (HCP)	1.5×10^{-5}	94,000
Mo[d]	Mo (BCC)	1.8×10^{-4}	461,000
Ni[d]	Ni (FCC)	1.9×10^{-4}	285,000
	Interdiffusion (Vacancy)		
Zn[c]	Cu (FCC)	2.4×10^{-5}	189,000
Cu[c]	Zn (HCP)	2.1×10^{-4}	124,000
Cu[c]	Al (FCC)	6.5×10^{-5}	136,000
Mg[c]	Al (FCC)	1.2×10^{-4}	130,000
Cu[c]	Ni (FCC)	2.7×10^{-5}	256,000
Ni[d]	Cu (FCC)	1.9×10^{-4}	230,000

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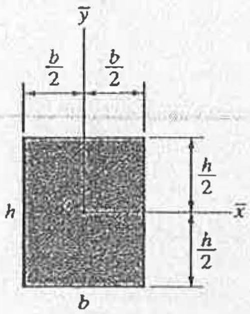
Properties of Areas of Common Shapes

Rectangle



$A = bh$

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

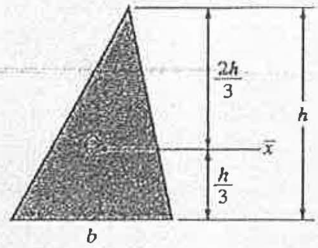
$\bar{I}_y = \frac{1}{12}hb^3$

$\bar{J} = \frac{1}{12}bh(h^2 + b^2)$

$\bar{r}_x = \frac{h}{\sqrt{12}}$

$\bar{r}_y = \frac{b}{\sqrt{12}}$

Triangle

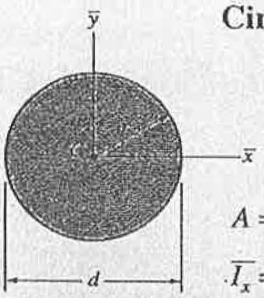


$A = \frac{1}{2}bh$

$\bar{I}_x = \frac{1}{36}bh^3$

$\bar{r}_x = \frac{h}{\sqrt{18}}$

Circle



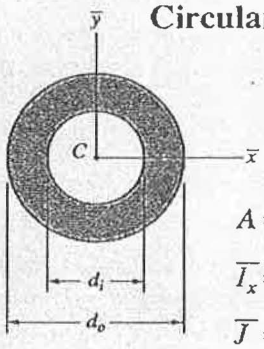
$A = \frac{1}{4}\pi d^2 = \pi r^2$

$\bar{I}_x = \bar{I}_y = \frac{1}{64}\pi d^4 = \frac{1}{4}\pi r^4$

$\bar{J} = \frac{1}{32}\pi d^4 = \frac{1}{2}\pi r^4$

$\bar{r}_x = \bar{r}_y = \frac{1}{4}d$

Circular Ring



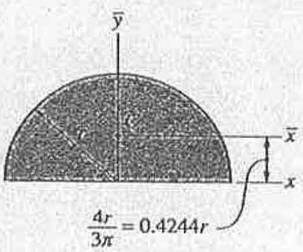
$A = \frac{1}{4}\pi(d_o^2 - d_i^2)$

$\bar{I}_x = \bar{I}_y = \frac{1}{64}\pi(d_o^4 - d_i^4)$

$\bar{J} = \frac{1}{32}\pi(d_o^4 - d_i^4)$

$\bar{r}_x = \bar{r}_y = \frac{1}{4}\sqrt{d_o^2 + d_i^2}$

Semicircle



$A = \frac{1}{2}\pi r^2$

$\bar{I}_x = 0.1098r^4$

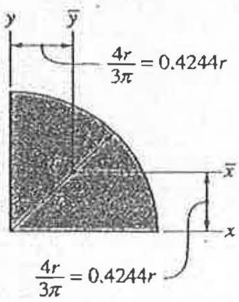
$\bar{I}_y = \bar{I}_x = \frac{1}{8}\pi r^4$

$\bar{J} = 0.5025r^4$

$\bar{r}_x = 0.2644r$

$\bar{r}_y = r_x = \frac{1}{2}r$

Quarter-Circle



$A = \frac{1}{4}\pi r^2$

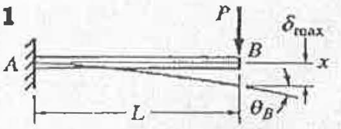
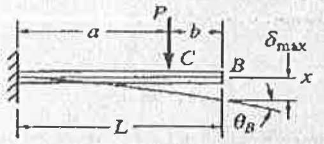
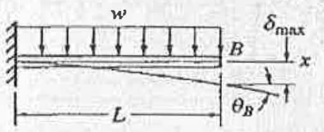
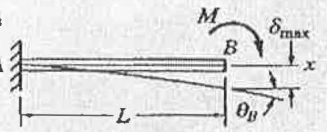
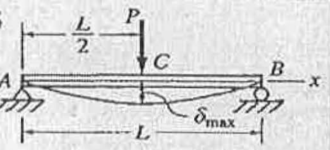
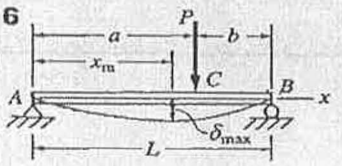
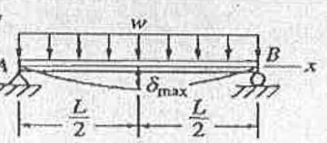
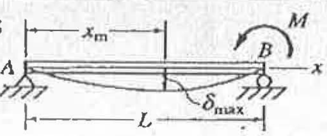
$\bar{I}_x = \bar{I}_y = 0.0549r^4$

$I_x = I_y = \frac{1}{16}\pi r^4$

$\bar{J} = 0.1098r^4$

$\bar{r}_x = \bar{r}_y = 0.2644r$

$r_x = r_y = \frac{1}{2}r$

Beam Loading and Deflection	Maximum Deflection	Slope at End(s)	Deflection Equations
1 	$\delta_{max} = \frac{PL^3}{3EI}$	$\theta_B = \frac{PL^2}{2EI}$	$\delta = \frac{Px^2}{6EI}(3L - x)$
2 	$\delta_{max} = \frac{Pa^2}{6EI}(3L - a)$	$\theta_B = \frac{Pa^2}{2EI}$	$\delta_{AC} = \frac{Px^2}{6EI}(3a - x)$ $\delta_{CB} = \frac{Pa^2}{6EI}(3x - a)$
3 	$\delta_{max} = \frac{wL^4}{8EI}$	$\theta_B = \frac{wL^3}{6EI}$	$\delta = \frac{wx^2}{24EI}(x^2 - 4Lx + 6L^2)$
4 	$\delta_{max} = \frac{ML^2}{2EI}$	$\theta_B = \frac{ML}{EI}$	$\delta = \frac{Mx^2}{2EI}$
5 	$\delta_{max} = \frac{PL^3}{48EI}$	$\theta_A = \theta_B = \frac{PL^2}{16EI}$	$\delta_{AC} = \frac{Px}{48EI}(3L^2 - 4x^2)$
6 	For $a > b$: $\delta_{max} = \frac{Pb(L^2 - b^2)^{3/2}}{9\sqrt{3}EIL}$ at $x_m = \sqrt{\frac{L^2 - b^2}{3}}$	$\theta_A = \frac{Pb(L^2 - b^2)}{6EIL}$ $\theta_B = \frac{Pa(L^2 - a^2)}{6EIL}$	$\delta_{AC} = \frac{Pbx}{6EIL}(L^2 - x^2 - b^2)$ $\delta_{CB} = \frac{Pb}{6EIL}\left[\frac{L}{b}(x - a)^3 + (L^2 - b^2)x - x^3\right]$
7 	$\delta_{max} = \frac{5wL^4}{384EI}$	$\theta_A = \theta_B = \frac{wL^3}{24EI}$	$\delta = \frac{wx}{24EI}(L^3 + x^3 - 2Lx^2)$
8 	$\delta_{max} = \frac{ML^2}{9\sqrt{3}EI}$ at $x_m = \frac{L}{\sqrt{3}}$	$\theta_A = \frac{ML}{6EI}$ $\theta_B = \frac{ML}{3EI}$	$\delta = \frac{Mx}{6EIL}(L^2 - x^2)$