UNIVERSITI SAINS MALAYSIA

First Semester Examination
2012/2013 Academic Session

January 2013

EEM 101 – PRINCIPLES AND MECHANICS OF MATERIALS
[PRINSIP DAN MEKANIK BAHAN]

Duration : 3 hours
[Masa : 3 jam]

Please check that this examination paper consists of ELEVEN (11) pages including Appendices SIX (6) of printed material before you begin the examination.
[Sila pastikan bahawa kertas peperiksaan ini mengandungi SEBELAS (11) mukasurat beserta Lampiran ENAM (6) muka surat bercetak sebelum anda memulakan peperiksaan ini.]

Instructions: This question paper consists SIX (6) questions. Answer **FIVE** (5) questions. All questions carry the same marks.
[***Arahan:*** *Kertas soalan ini mengandungi ENAM (6) soalan. Jawab **LIMA** (5) soalan. Semua soalan membawa jumlah markah yang sama.]*

Answer to any question must start on a new page.
[Mulakan jawapan anda untuk setiap soalan pada muka surat yang baru]

In the event of any discrepancies, the English version shall be used.
[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]

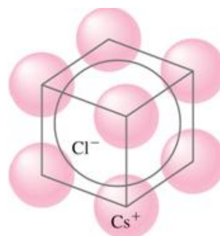
1. (a) Kira faktor pemadatan atom bagi struktur kristal kubik berpusat jasad.

Calculate the atomic packing factor (APF) for the BCC unit cell.

(15 markah /marks)

(b) Struktur unit sel bagi pepejal ionik, CsI ialah sama dengan dalam Rajah 1(b).

The unit cell structure of the ionic solid, CsI is similar to that in Figure 1(b).



Rajah 1(b)

Figure 1(b)

Kira nilai faktor pemadatan atom bagi struktur ini dan bandingkan dengan APF bagi logam BCC.

Compute the atomic packing factor and compare it with the APF of BCC metals.

Diberi R_{Cs} =0.19 nm dan R_I=0.216 nm

Given R_{Cs} =0.19 nm and R_I=0.216 nm

(25 markah/marks)

(c) (i) Bandingkan kepadatan linear dan kepadatan satah bagi struktur kristalografi

Compare between linear density and planar density parameters for crystallographic structure

(ii) Terbitkan ungkapan kepadatan linear bagi BBC [110] dalam sebutan jejari atomik, R.

Derive linear density expressions for BCC [110] in terms of the atomic radius, R.

(iii) Terbitkan ungkapan kepadatan satah bagi FCC (111) dalam sebutan jejari atomik, R.

Derive planar density expressions for FCC (111) planes in terms of the atomic radius R.

(35 markah/marks)

(d) Nyatakan dan terangkan beberapa kriteria penting yang perlu diambil kira dari perspektif alam persekitaran. Beri satu contoh dalam setiap kriteria yang dinyatakan.

List and describe several important criterias of material to be considered from the environmental perspective. Give an example in each case.

(25 markah/*marks*)

2. (a) (i) Takrifkan polimorfisme atau kealotropan bagi logam.

Define what is polymorphism or allotrophy with respect to metal.

(10 markah/*marks*)

(ii) Besi asli melalui perubahan polimorfisme daripada BCC ke FCC melalui pemanasan sehingga 912^{o}C. Kira perubahan isipadu yang berlaku dengan perubahan struktur kristal tersebut jika pada suhu 912^{O}C, sel unit BCC mempunyai pemalar kekisi, *a*=0.293 nm dan sel unit FCC, *a*=0.363 nm.

Pure iron goes through a polymorphic change from BCC to FCC upon heating through 912^{o}C. Calculate the volume change associated with the change in crystal structure if at 912^{O}C, the BCC unit cell has a lattice constant of a=0.293 nm and the FCC unit cell, a=0.363 nm.

(20 markah/ marks)

(b) (i) Tukarkan satah (0 1 0) kepada nilai skema 4 indeks Miller-Bravais bagi unit sel heksagonal.

Convert the (0 1 0) plane into the four-index Miller–Bravais scheme for hexagonal unit cells.

(10 markah/ *marks*)

(ii) Lakarkan satah (1 1 0 1) bagi unit sel heksagonal

Sketch the (1 1 0 1) plane in a hexagonal unit cell.

(15 markah/ *marks*)

(c) Satu tegasan bernilai 75 MPa dikenakan pada arah [0 0 1] ke atas kristal tunggal FCC. Kirakan tegangan ricih peleraian bagi sistem gelincir berikut:

A stress of 75 MPa is applied in the [0 0 1] direction on FCC single crystal. Calculate the resolved shear stress acting on the below slip systems:

(i) (1 1 1) $[\bar{1}\ 0\ 1]$

(ii) (1 1 1) $[\bar{1}\ 1\ 0]$

Berdasarkan nilai-nilai tegangan ricih peleraian yang diperolehi, sistem gelincir yang manakah yang paling baik terhala?

Based on the calculated resolved shear stress values, which slip systems is most favorably oriented?

(45 markah/*marks*)

3. (a) Bandingkan patah mulur dan patah rapuh. Dengan memberikan contoh yang bersesuaian, terangkan mengapa mod patah mulur lebih diutamakan berbanding dengan patah rapuh.

Compare ductile fracture and brittle fracture. By giving an appropriate example, explain why ductile fracture mode is almost always preferred to brittle fracture.

(15 markah/*marks)*

(b) Satu rod 20 cm panjang dengan diameter 0.250 cm dikenakan beban sebanyak 5000 N. Jika diameternya berkurang kepada 0.210 cm, tentukan

A 20-cm-long rod with a diameter of 0.250 cm is loaded with a 5000 N weight. If the diameter decreases to 0.210 cm, determine

(i) Tegasan dan terikan pada beban tersebut
The engineering stress and strain at this load

(ii) Tegasan dan terikan sebenar pada beban tersebut
The true stress and strain at this load

(25 markah/ marks)

(c) Pertimbangkan resapan bendasing galium ke dalam wafer silikon.
Consider the impurity diffusion of gallium into a silicon wafer.

Jika galium diresap ke dalam wafer silikon dengan keadaan asalnya tanpa sebarang galium pada suhu 1100^{o}C selama 3 jam, berapakah kedalaman di bawah permukaan di mana kepekatannya ialah 10^{22} atom/m^{3}?

If gallium is diffused into a silicon wafer with no previous gallium in it at a temperature of 1100^{o}C for 3 hours, what is the depth below the surface at which the concentration is 10^{22} atom/m^{3}.

Diberi bahawa kepekatan permukaan ialah 10^{24} atoms/m^{3} dan D_{1100C}=7.0 X 10^{-17} m^{2}/s.

Given that the surface concentration is 10^{24} atoms/m^{3} and D_{1100C}=7.0 X 10^{-17} m^{2}/s

(35 markah/ marks)

(d) Sains bahan ialah bidang pelbagai disiplin yang menggunakan ciri-ciri bahan dalam pelbagai bidang sains dan kejuruteraan. Pilih dan bincangkan salah satu ciri-ciri di bawah (sekitar 200-250 patah perkataan).

Materials science is an interdisciplinary field applying the properties of materials to various areas of science and engineering. Choose one of the listed properties below and discuss it (up to 200-250 words):

i. Ciri-ciri elektrik
Electrical properties

ii. Ciri-ciri terma
Thermal properties

iii. Ciri-ciri magnetik
Magnetic properties

iv. Ciri-ciri optikal
Optical properties

(25 markah/marks)

4. (a) (i) Lukiskan gambarajah daya ricih dan momen lenturan bagi rasuk yang ditunjukkan dalam rajah 4(a).

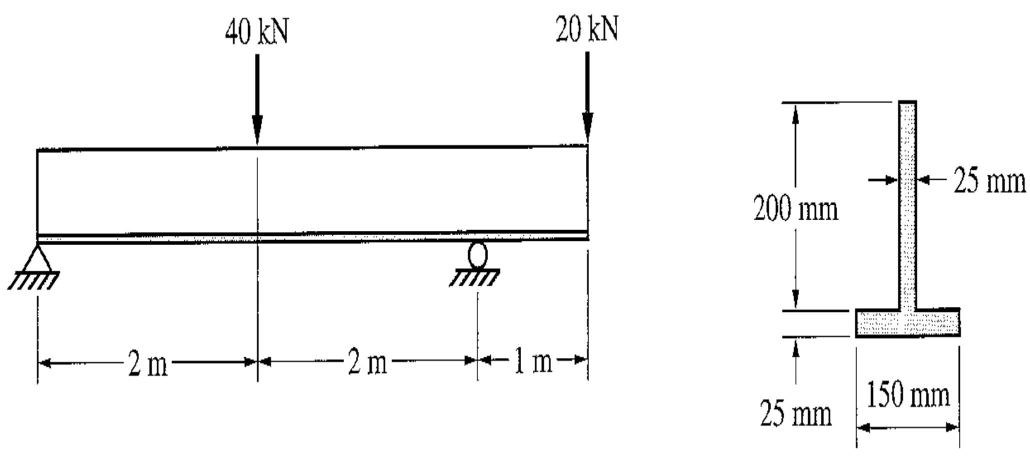
Draw the shear force and bending moment diagrams of the beam shown in figure 4(a).

(40 markah/marks)

(ii) Tentukan tegasan tegangan maksima dan tegasan mampat maksima di dalam rasuk. Abaikan berat rasuk tersebut.

Determine the maximum tensile and compressive stresses in the beam. Neglect the weight of the beam.

(20 markah/marks)



Rajah 4(a)

Figure 4(a)

(b) Terangkan hubungan antara beban, ricih dan momen. Lukis lakaran yang sesuai.

Explain the relationship between load, shear and moment. Draw suitable sketches.

(40 markah/*marks*)

5. (a) Tiga 50-mm $\times$ 100-mm papan keping diikat oleh 5-mm-diameter bolt yang mana jarak antara satu sama lain ialah 40 mm seperti ditunjukkan dalam rajah 6(c). Tegasan ricih yang dibenarkan ialah 100 MPa. Tentukan beban tertumpu maksima yang boleh dikenakan pada titik tengah bagi 3-m rentang mudah. Abaikan berat rasuk tersebut.

Three 50-mm $\times$ 100-mm planks are fastened by 5-mm-diameter bolts spaced at a pitch of 40 mm as shown in figure 6(c). The allowable shear stress for the bolts is 100 MPa. Determine the maximum concentrated load that can be applied at the mid point of 3-m simple span. Neglect the weight of the beam.

Diberikan sebutan bagi daya ricih yang mesti ditanggung oleh bolt:-
Given the expression for the shear force that must be carried by the bolt:-

$$F_s = p\frac{VQ}{I}$$

Iaitu
Where

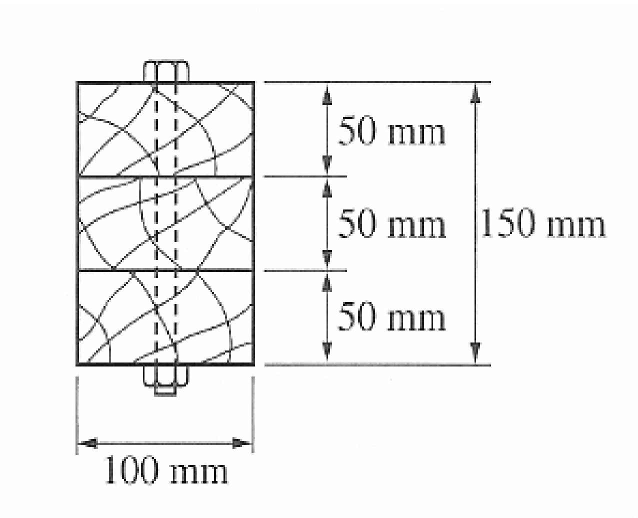
p ialah the jarak antara bolt
p is the pitch of the bolts

V ialah daya ricih pada bahagian itu
V is the shear force at the section

Q ialah moment pertama bagi kawasan terhadap paksi neutral
Q is the first moment of area about the neutral axis

I ialah momen inersia
I is the moment of inertia

(30 markah/*marks*)



Rajah 5(a)
Figure 5(a)

5. (b) Kayu Southern Pine dengan 150 × 360 keratan rentas segiempat digunakan sebagai julur sepanjang 3 m. Kira lenturan maksima dan cerun maksima disebabkan beban seragam sebanyak 15 kN/m menggunakan:-

A 150 × 360 rectangular Southern pine section is used in a 3-m cantilever span. Compute the maximum deflection and the maximum slope due to a uniform load of 15 kN/m using:-

(i) Kaedah Formula
Formula Method

(20 markah/*marks*)

(ii) Kaedah Momen Luas
Moment Area Method

(50 markah/*marks*)

6. (a) Terbitkan formula untuk ricih bagi satu rasuk. Lukis lakaran yang sesuai.
Derive the shear formula for a beam. Draw suitable sketches.

(30 markah/*marks*)

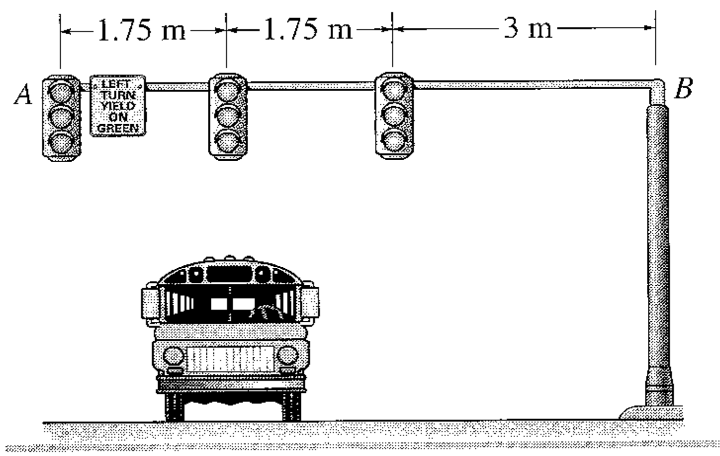
(b) Terbitkan formula untuk tegasan lenturan dalam satu rusuk. Lukis lakaran yang sesuai.

Derive the flexural stress formula in a beam. Draw suitable sketches.

(30 markah/*marks*)

(c) Tiga lampu trafik ditunjukkan dalam Rajah 6(c) mempunyai jisim 10 kg setiap satu dan dijulurkan oleh paip AB yang mempunyai jisim 1.5 kg/m. Lukis rajah ricih dan momen bagi paip. Abaikan jisim papan tanda.

The three traffic lights shown in Figure 6(c), each have a mass of 10 kg, and the cantilevered pipe AB has a mass of 1.5 kg/m. Draw the shear and moment diagrams for the pipe. Neglect the mass of the sign.



Rajah 6(c)

Figure 6(c)

(40 markah/*marks*)

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APPENDIX I

CONSTANT VALUES
R – Gas constant (8.31 J/mol · K)

k – Boltzmann's constant
(1.38 x 10^{-23} J/atom · K , 8.62 x 10^{-5} eV/atom · K)

N_A – Avogadro's number (6.022 x 10^{23} atom/mol)

EQUATIONS

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

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

$$C_1 = \frac{m_1}{m_1 + m_2} \times 100$$

$$C_1' = \frac{n_{m1}}{n_{m1} + n_{m2}} \times 100$$

$$C_1' = \frac{C_1A_2}{C_1A_2 + C_2A_1} \times 100$$

$$C_1 = \frac{C_1'A_1}{C_1'A_1 + C_2'A_2} \times 100$$

$$C_1'' = \left(\frac{C_1}{\frac{C_1}{\rho_1} + \frac{C_2}{\rho_2}}\right) \times 10^3$$

$$\rho_{ave} = \frac{100}{\frac{C_1}{\rho_1} + \frac{C_2}{\rho_2}}$$

$$A_{ave} = \frac{100}{\frac{C_1}{A_1} + \frac{C_2}{A_2}}$$

$$N = 2^{n-1}$$

Equation

$$\tau_R = \sigma \cos\phi \cos\lambda$$

$$\tau_{crss} = \sigma_y(\cos\phi \cos\lambda)_{max}$$

$$\sigma_y = \sigma_0 + k_y d^{-1/2}$$

$$\%CW = \left(\frac{A_0 - A_d}{A_0}\right) \times 100$$

$$d^n - d_0^n = Kt$$

$$\sigma_c = \frac{K_{Ic}}{Y\sqrt{\pi a}}$$

$$a_c = \frac{1}{\pi}\left(\frac{K_{Ic}}{\sigma Y}\right)^2$$

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

$$\sigma_r = \sigma_{\max} - \sigma_{\min}$$

$$\sigma_a = \frac{\sigma_{\max} - \sigma_{\min}}{2}$$

$$R = \frac{\sigma_{\min}}{\sigma_{\max}}$$

$$\sigma = \alpha_l E \Delta T$$

$$\dot{\epsilon}_s = K_1 \sigma^n$$

$$\dot{\epsilon}_s = K_2 \sigma^n \exp\left(-\frac{Q_c}{RT}\right)$$

$$T(C + \log t_r)$$

Equation

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

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

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

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

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

Table 5.1 Tabulation of Error Function Values

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

Table 5.2 A Tabulation of Diffusion Data

Diffusing Species	*Host Metal*	$D_0(m^2/s)$	*Activation Energy* Q_d		*Calculated Value*	
			kJ/mol	*eV/atom*	*T*(°*C*)	$D(m^2/s)$
Fe	α-Fe (BCC)	2.8×10^{-4}	251	2.60	500 900	3.0×10^{-21} 1.8×10^{-15}
Fe	γ-Fe (FCC)	5.0×10^{-5}	284	2.94	900 1100	1.1×10^{-17} 7.8×10^{-16}
C	α-Fe	6.2×10^{-7}	80	0.83	500 900	2.4×10^{-12} 1.7×10^{-10}
C	γ-Fe	2.3×10^{-5}	148	1.53	900 1100	5.9×10^{-12} 5.3×10^{-11}
Cu	Cu	7.8×10^{-5}	211	2.19	500	4.2×10^{-19}
Zn	Cu	2.4×10^{-5}	189	1.96	500	4.0×10^{-18}
Al	Al	2.3×10^{-4}	144	1.49	500	4.2×10^{-14}
Cu	Al	6.5×10^{-5}	136	1.41	500	4.1×10^{-14}
Mg	Al	1.2×10^{-4}	131	1.35	500	1.9×10^{-13}
Cu	Ni	2.7×10^{-5}	256	2.65	500	1.3×10^{-22}

Source: E. A. Brandes and G. B. Brook (Editors), *Smithells Metals Reference Book,* 7th edition, Butterworth-Heinemann, Oxford, 1992.

Table 6.1 Room-Temperature Elastic and Shear Moduli and Poisson's Ratio for Various Metal Alloys

	Modulus of Elasticity		*Shear Modulus*		
Metal Alloy	***GPa***	***10^6 psi***	***GPa***	***10^6 psi***	***Poisson's Ratio***
Aluminum	69	10	25	3.6	0.33
Brass	97	14	37	5.4	0.34
Copper	110	16	46	6.7	0.34
Magnesium	45	6.5	17	2.5	0.29
Nickel	207	30	76	11.0	0.31
Steel	207	30	83	12.0	0.30
Titanium	107	15.5	45	6.5	0.34
Tungsten	407	59	160	23.2	0.28

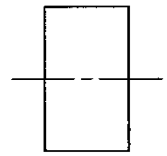
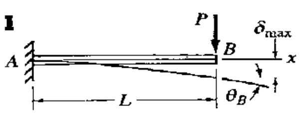
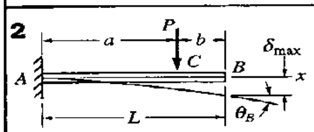
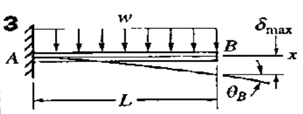
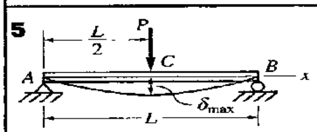
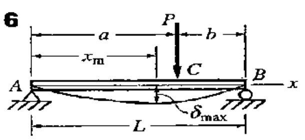
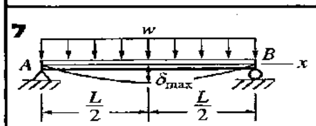
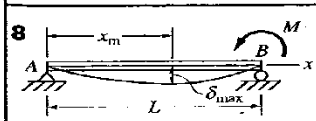


TABLE A–6(b) Properties of Structural Timber: SI Units

Nominal Size (mm)	Standard Dressed Size (mm)	Area of Section A ($\times 10^{-3}$ m^2)	Moment of Inertia I ($\times 10^{-6}$ m^4)	Section Modulus S ($\times 10^{-3}$ m^3)	Weight per ft w (kN/m)
50 × 100	38.1 × 88.9	3.39	2.23	0.0502	0.0213
× 150	× 140	5.32	8.66	0.124	0.0334
× 200	× 184	7.03	19.8	0.215	0.0441
× 260	× 235	8.97	41.2	0.351	0.0562
80 × 100	63.5 × 88.9	5.65	3.72	0.0836	0.0355
× 150	× 140	8.90	14.4	0.207	0.0557
× 200	× 184	11.7	33.0	0.359	0.0735
× 250	× 235	14.9	68.7	0.585	0.0937
× 300	× 286	18.1	124	0.864	0.114
100 × 100	88.9 × 88.9	7.94	5.20	0.117	0.0496
× 150	× 140	12.5	20.2	0.288	0.0781
× 200	× 184	16.4	46.2	0.503	0.103
× 250	× 235	20.9	96.1	0.818	0.130
× 300	× 286	25.4	173	1.21	0.159
× 360	× 337	29.9	282	1.67	0.188
150 × 150	140 × 140	19.5	31.8	0.454	0.123
× 200	× 191	26.6	80.3	0.851	0.168
× 250	× 241	33.7	164	1.36	0.212
× 300	× 292	40.8	290	1.98	0.257
× 360	× 343	47.9	469	2.74	0.301
× 410	× 394	55.0	710	3.61	0.346
× 460	× 445	62.1	1022	4.601	0.390
200 × 200	191 × 191	36.3	110	1.15	0.226
× 250	× 241	46.0	223	1.85	0.289
× 300	× 292	55.7	396	2.70	0.350
× 360	× 343	65.2	640	3.74	0.410
× 410	× 394	74.8	968	4.92	0.471
× 460	× 445	84.5	1390	6.28	0.533
× 510	× 495	94.2	1929	7.79	0.592
250 × 250	241 × 241	58.3	283	2.34	0.366
× 300	× 292	70.3	501	3.43	0.442
× 360	× 343	82.6	811	4.74	0.519
× 410	× 394	94.8	1230	6.23	0.597
× 460	× 445	107	1770	7.95	0.674
× 510	× 495	119	2440	9.87	0.751
× 560	× 546	132	3270	12.0	0.827

Note: Properties and weights are for dressed sizes. Weight per unit foot is based on an assumed average weight of 6.28 kN/m^3. Moment of inertia and section modulus are about the strong axis.

Formula untuk Lenturan Rasuk

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 $x_m = \frac{L}{\sqrt{3}}$	$\theta_A = \frac{ML}{6EI}$ $\theta_B = \frac{ML}{3EI}$	$\delta = \frac{Mx}{6EIL}(L^2 - x^2)$