UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2007/2008
Peperiksaan Semester Pertama
Sidang Akademik 2007/2008

October / November 2007
Oktober / November 2007

EMM 331/3 – Mechanics of Solids
Mekanik Pepejal

Duration : 3 hours
Masa : 3 jam

INSTRUCTIONS TO CANDIDATE:
ARAHAN KEPADA CALON :

Please check that this paper contains **SEVEN (7)** printed pages, **FOUR (4)** pages appendixes and **SIX (6)** questions before you begin the examination.
*Sila pastikan bahawa kertas soalan ini mengandungi **TUJUH (7)** mukasurat bercetak, **EMPAT (4)** halaman lampiran dan **ENAM (6)** soalan sebelum anda memulakan peperiksaan.*

Answer **FIVE (5)** questions.
*Jawab **LIMA (5)** soalan.*

Answer all questions in **English** OR **Bahasa Malaysia** OR a combination of both.
*Calon boleh menjawab semua soalan dalam **Bahasa Malaysia** ATAU **Bahasa Inggeris** ATAU kombinasi kedua-duanya.*

Appendix/*Lampiran*:

1. Formula for Mechanics of Solids [1 page/*mukasurat*]
2. Beam Deflection Formulas [1 page/*mukasurat*]
3. Shear and Moment Formulas for Some Simple Loadings [1 page/*mukasurat*]
4. Stress concentration factors for grooves, holes and fillets [1 page/*mukasurat*]

Each question must begin from a new page.
Setiap soalan mestilah dimulakan pada mukasurat yang baru.

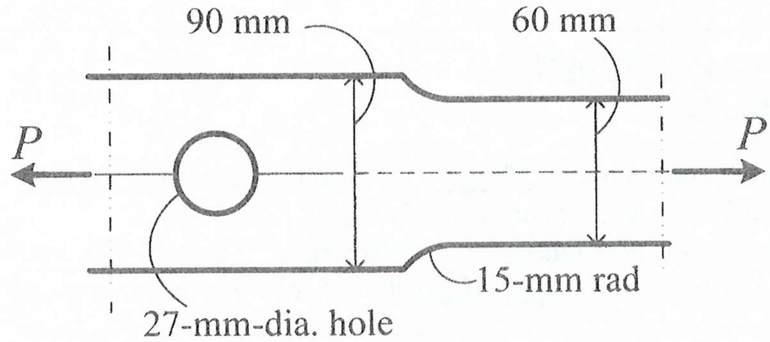
S1. [a] **Dalam banyak rekabentuk kejuruteraan, penumpuan tegasan adalah perkara yang biasa berlaku. Terangkan dengan ringkas fenomena ini dan keadaan-keadaan ia berlaku. Gunakan lakaran jika perlu.**

In many engineering designs, the stress concentration usually exists. Briefly explain this phenomenon and the conditions for stress concentration to occur. Use illustration if necessary.

(20 markah)

[b] **Satu bahagian mesin yang ditunjukkan dalam Rajah S1[b] mempunyai ketebalan 25 mm dan diperbuat daripada keluli lembut. Tentukan beban maksimum P yang selamat jika tegasan normal maksimum tidak melebihi 150 MPa. (Guna geraf penumpuan tegasan seperti yang dilampirkan dalam lampiran 4)**

The machine part shown in Figure Q1[b] is 25 mm thick and is made of mild steel. Determine the maximum safe load P if the maximum normal stress is not to exceed 150 MPa. (Use graph of stress concentration as attached in the attachment 4)

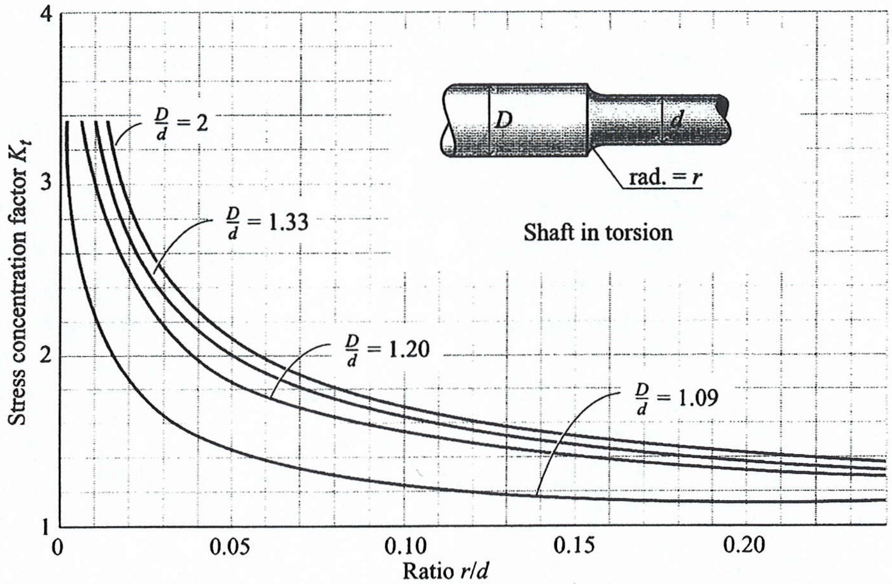


Rajah S1[b]
Figure Q1[b]

(40 markah)

[c] **Aci bertingkat mempunyai diameter 32 mm untuk satu bahagian (D) dan 25 mm untuk satu bahagian yang lain (d) seperti yang dilakarkan dalam Rajah S1[c]. Jika tegasan ricih maksima dalam aci tersebut dihadkan kepada 800 MPa apabila aci memindahkan kilasan sebanyak 768 Nm, tentukan jejari kambi minima (r) yang diperlukan pada sambungan di antara dua bahagian aci tersebut.**

A stepped shaft has a 32 mm diameter for one half of its length (D) and a 25 mm diameter for the other half (d) as illustrated in Figure Q1[c]. If the maximum shearing stress in the shaft must be limited to 800 MPa when the shaft is transmitting a torque of 768 N.m, determine the minimum fillet radius (r) needed at the junction between the two portions of the shaft.



Rajah S1[c]

Figure Q1[c]

(40 markah)

S2. [a] Lukiskan kriteria Tresca dan Von Mises pada satah 2D.

Draw Tresca and Von Mises criteria on the 2D plane.

(10 markah)

[b] Sebatang aci bulat bergarispusat *d* dikenakan momen lenturan M dan kilasan T secara serentak.

A solid circular shaft of diameter d is subjected to a bending moment M and a torque T simultaneously.

(i) Terbitkan tegasan ricih maksimum dengan menggunakan teori Tresca

Derive the maximum shear stress by using Tresca theory

(20 markah)

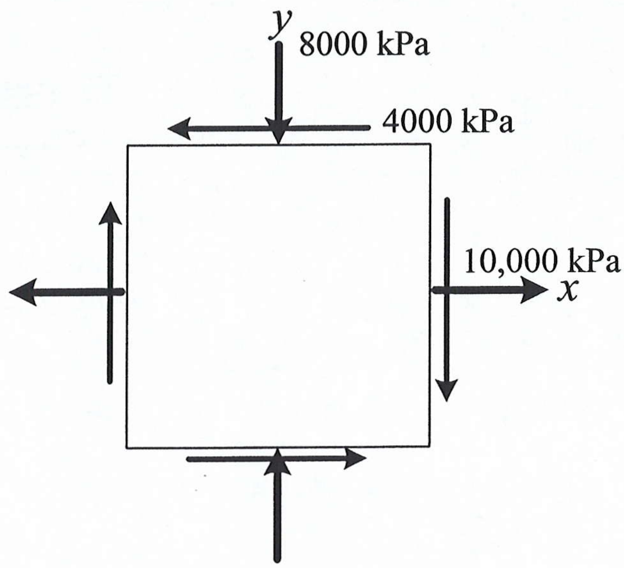
(ii) Terbitkan tegasan ricih maksimum dengan menggunakan teori Von Mises

Derive the maximum shear stress by using Von Mises theory

(20 markah)

[c] **Pada satu titik dalam anggota struktur yang dikenakan tegasan satah, keadaan tegasan adalah seperti yang ditunjukkan dalam Rajah S2[c]. Tentukan yang mana satu teori kegagalan, iaitu Rankine, Tresca dan Von Mises akan meramalkan kegagalan untuk keadaan tegasan ini. Kekuatan alah bahan ini ialah 18 MPa dalam ketegangan dan mampatan.**

At a point in a structural member subjected to plane stress, the state of stress is as shown in Figure Q2[c]. Determine if any of the theories of failure, i.e., Rankine, Tresca and Von Mises will predict failure for this state of stress. The yield strength of the material in tension and compression test is 18 MPa.



Rajah S2[c]
Figure Q2[c]

(50 markah)

S3. [a] **Terangkan perbezaan di antara rayapan dalam logam dan rayapan dalam plastik. Gunakan lakaran jika perlu.**

Describe the difference between creep in metal and creep in plastics. Use illustration if necessary.

(30 markah)

[b] **Tiub Ni-Cr-Mo keluli aloi bergaris pusat 100 mm dan mempunyai dinding setebal 3 mm akan beroperasi pada suhu 350^{O}C dengan tekanan dalaman hayat servis sebanyak 120 000 jam. Tentukan tekanan yang dibenarkan untuk had terikan rayapan 0.5%. Angkatap pada persamaan rayapan minimum pada 350^{O}C ialah n = 3 dan B = 1.45 x 10^{-25}/ jam / MN/m^2.**

An Ni-Cr-Mo alloy steel tube of 100 mm diameter and 3 mm wall thickness is to operate at 350^{O}C with internal pressure for a service life of 120 000 hours. Determine the allowable pressure for a creep strain limit of 0.5%.
The constants in the minimum creep equation at 350^{O}C are n = 3 and B = 1.45 x 10^{-25}/ hour / MN/m^2.

(70 markah)

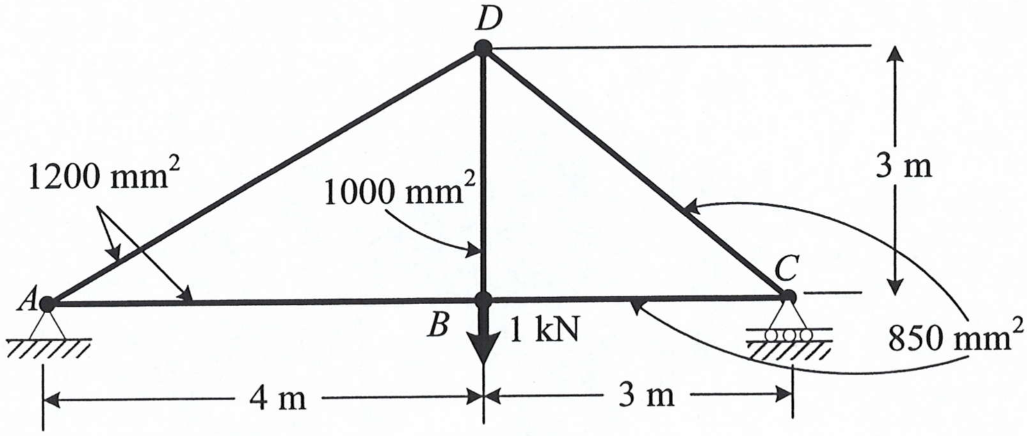
S4. **Anggota kekuda seperti yang ditunjukkan dalam Rajah S4 diperbuat daripada keluli dan mempunyai luas keratan rentas seperti yang diberikan. Dengan menggunakan E = 200 GPa, tentukan**

Members of the truss shown in Figure Q4 are made of steel and have the cross sectional areas as given. Using E = 200 GPa, determine

(i) **Pesongan menegak pada B**
The vertical deflection at B

(40 markah)

(ii) **Pesongan menegak pada D**
The vertical deflection at D



Rajah S4
Figure Q4

(60 markah)

S5. **[a]** **Terangkan dengan ringkas perkara-perkara di bawah yang diaplikasikan dalam mekanik patah.**

Briefly describe the following terms as applied in fracture mechanics:

(i) **Faktor keamatan tegasan**
Stress intensity factor

(10 markah)

(ii) **Kekuatan patah**
Fracture toughness

(10 markah)

(iii) **Kadar lepasan tenaga terikan**
Strain energy release rate

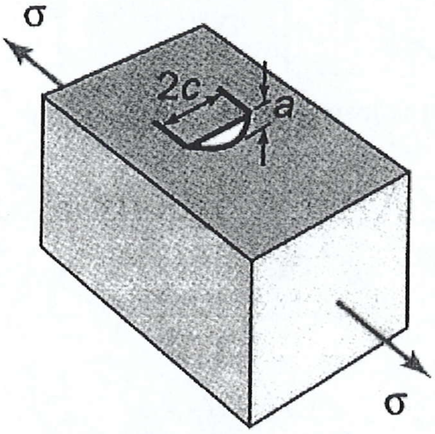
(10 markah)

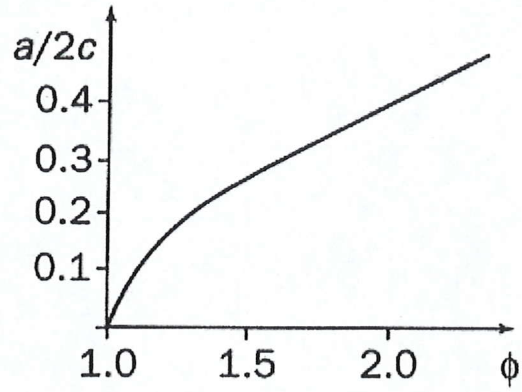
(iv) **Pembetulan zon plastik**
Plastic zone correction

(10 markah)

[b] **Sekeping kaca yang mempunyai ukuran lebar 0.75 m dan tebal 15 mm didapati mempunyai beberapa retak permukaan sedalam 4 mm dan panjang 12 mm. Jika kepingan kaca ini diletakkan secara mendatar di atas 2 penyokong, kirakan jarak maksima di antara penyokong untuk mengelak kepingan kaca ini daripada patah disebabkan beratnya sendiri. Untuk kaca, faktor keamatan kritikal, K_C = 0.3 MN $m^{-3/2}$ and isipadu = 2600 kg/m^3. Gunakan konfiguri retak seperti yang ditunjukkan dalam Rajah S5[b].**

A sheet of glass 0.75 m wide and 15 mm thick is found to contain a number of surface cracks 4 mm deep and 12 mm long. If the glass is placed horizontally on two supports, calculate the maximum spacing of the supports to avoid fracture of the glass due to its own weight. For glass, the critical stress intensity factor, K_C = 0.3 MN $m^{-3/2}$ and density = 2600 kg/m^3. Use crack configuration as shown in Figure Q5[b].





Semi-elliptical surface flaw

$$K = \sigma(\pi a)^{1/2}\left(\frac{1.12}{\phi^{1/2}}\right)$$

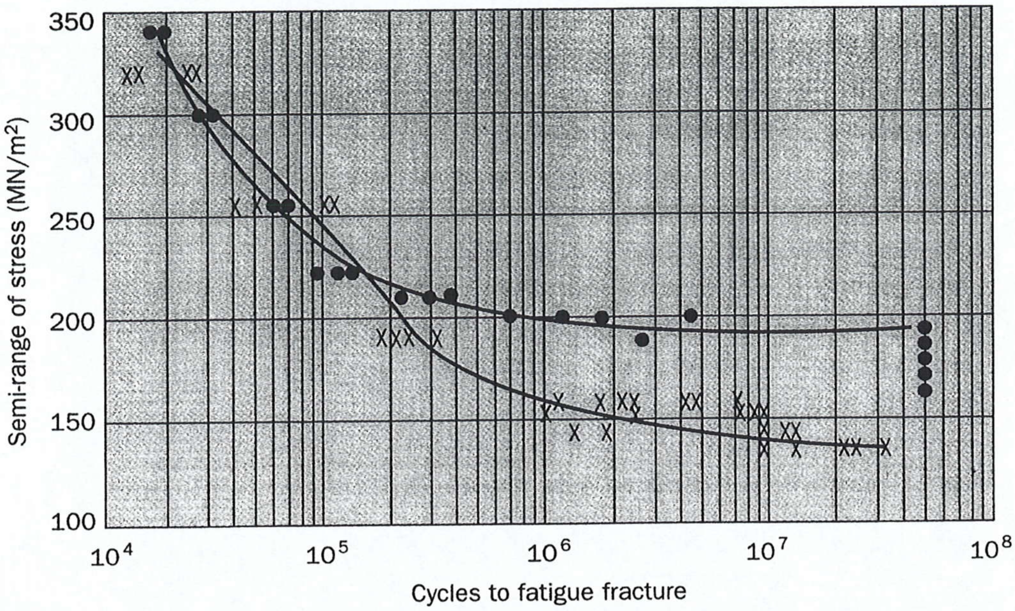
Rajah S5[b]

Figure Q5[b]

(60 markah)

S6. **[a]** **Satu mekanisma kekunci terdiri daripada rasuk julur berkeratan rentas segiempat sama dan panjangnya ialah 200 mm dan lebarnya ialah 30 mm. Operasi lenturan yang diperlukan pada hujung bebas ialah ± 3 mm dan hayat servis ialah 1 000 000 kitaran. Dengan menggunakan lengkuk lesu seperti dalam Rajah S6[a] dan faktor keselamatan 6, tentukan ketebalan yang diperlukan oleh rasuk julur jika diperbuat daripada (i) keluli lembut (ii) aluminium. Modulus Young untuk keluli ialah 208 GPa dan aluminium ialah 79 GPa.**

A switching device consists of a rectangular cross-section of metal cantilever 200 mm in length and 30 mm in width. The required operating displacement at the free end is ± 3 mm and the service life is to be 1 000 000 cycles. Using the fatigue curve given in Figure Q6[a] and a factor of safety 6, determine the required thickness of the cantilever if made from (i) mild steel (ii) aluminium alloy. Young's modulus for steel is 208 GPa and that of aluminium is 79 GPa.



Aluminium alloy 24S-T3 reversed axial stress fatigue curve (X); mild steel reversed axial stress fatigue curve (•)

Rajah S6[a[
Figure Q6[a]

(50 markah)

[b] **Sebatang aci yang berkeratan rentas bulat dikenakan momen lentur tidak berubah sebanyak 1400 Nm dan pada masa yang sama dikenakan dengan momen rasuk berubah-ubah sebanyak 1100 Nm pada tempat yang sama (jadi jumlah momen berubah di antara 2500 Nm dan 300 Nm). Dengan menggunakan aturan Soderberg, kirakan garis pusat aci jika faktor keselamatan ialah 3.0. Tegasan alah untuk bahan ini ialah 210 MPa dan had lesu dalam lentur timbal balik ialah 170 MPa.**

A shaft of circular cross-section is subjected to a steady bending moment of 1400 Nm and simultaneously to an alternating bending moment of 1100 Nm at the same place (so that the total moment fluctuates between 2500 Nm and 300 Nm). By using Soderberg rule, calculate the diameter of the shaft if the factor of safety is to be 3.0. The yield stress of the material is 210 MPa and the fatigue limit in reversed bending is 170 MPa.

(50 markah)

-oooOOOooo-

Formula untuk Mekanik Pepejal

Theories of failures:

Tresca: $\sigma_1 - \sigma_3 = \sigma_Y$ Von-Mises: $(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 = 2\sigma^2{}_Y$

Fatigue:

$$N_f = \frac{2}{C(Y.S_R)^m \pi^{\frac{m}{2}}(2-m)}\left(a_f^{1-\frac{m}{2}} - a_0^{1-\frac{m}{2}}\right) \qquad \Delta K = Y.S_R\sqrt{\pi a} \qquad \frac{da}{dN} = \dot{C}[Y.S_R\sqrt{\pi a}]^m$$

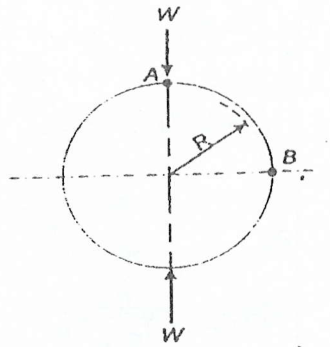
Goodman: $S_a = S_D\left(1 - \frac{S_m}{S_u}\right)$ Gerber: $S_a = S_D\left[1 - \left(\frac{S_m}{S_u}\right)^2\right]$

Soderberg: $S_a = S_D\left(1 - \frac{S_m}{S_Y}\right)$

Unsymmetrical and curved bending

Rectangular section: $n = R' - \frac{d}{\log_e[(R'+d/2)/(R'-d/2)]}$

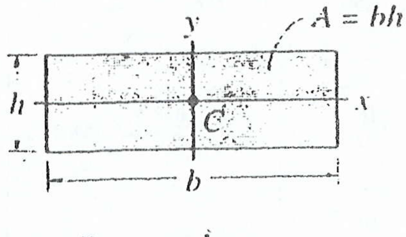
Circular section: $n = R' - \frac{d}{2\left[R' - \left(R'^2 - r^2\right)^{1/2}\right]}$



$M_o = WR\left(\frac{1}{2} - \frac{1}{\pi}\right)$

$$\frac{\sigma}{y} = \frac{M}{nA(R_1 + y)} \qquad \frac{y}{z} = \frac{I_z}{I_y}\tan\theta = \tan\phi$$

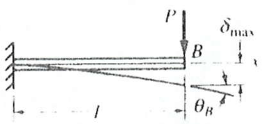
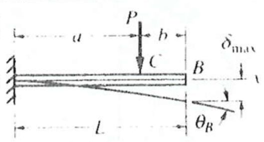
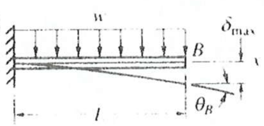
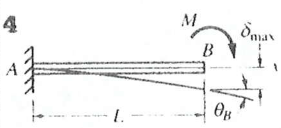
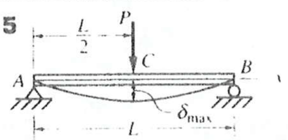
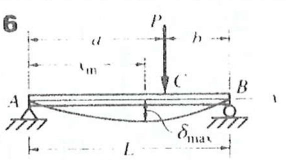
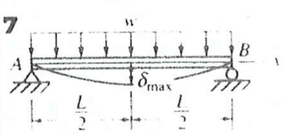
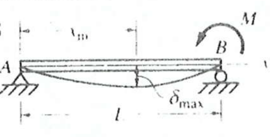
$$\sigma_x = \frac{yE}{R_y} + \frac{zE}{R_z} = \frac{y(M_z I_y - M_y I_{yz}) + z(M_y I_z - M_z I_{yz})}{I_y I_z - I_{yz}^2}$$



Rectangular area

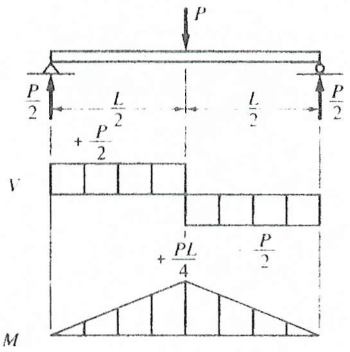
$$I_x = \frac{1}{12}bh^3 \qquad I_y = \frac{1}{12}hb^3$$

Beam Deflection Formulas

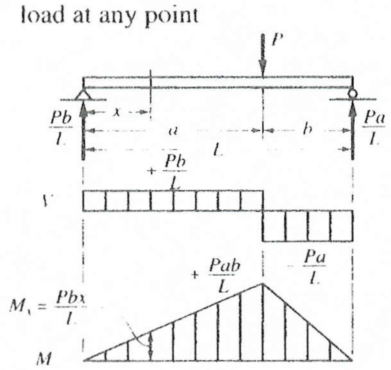
Beam Loading and Deflection	Maximum Deflection	Slope at End(s)	Deflection Equations
1 	$\delta_{max} = \frac{PL^3}{3EI}$	$\theta_B = \frac{PL^2}{2EI}$	$\delta = \frac{Px^2}{6EI}(3L - x)$
2 	$\delta_{max} = \frac{Pa^2}{6EI}(3L - a)$	$\theta_B = \frac{Pa^2}{2EI}$	$\delta_{AC} = \frac{Px^2}{6EI}(3a - x)$ $\delta_{CB} = \frac{Pa^2}{6EI}(3x - a)$
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 $x_m = \frac{L}{\sqrt{3}}$	$\theta_A = \frac{ML}{6EI}$ $\theta_B = \frac{ML}{3EI}$	$\delta = \frac{Mx}{6EIL}(L^2 - x^2)$

Shear and Moment Formulas for Some Simple Loadings

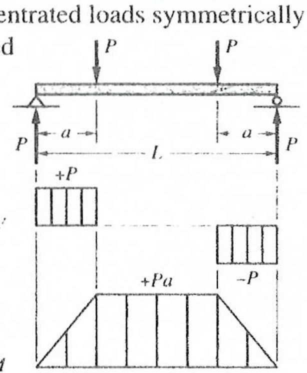
1. Simple beam with a concentrated load at the center



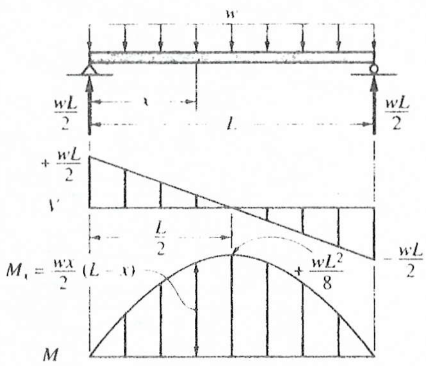
2. Simple beam with a concentrated load at any point



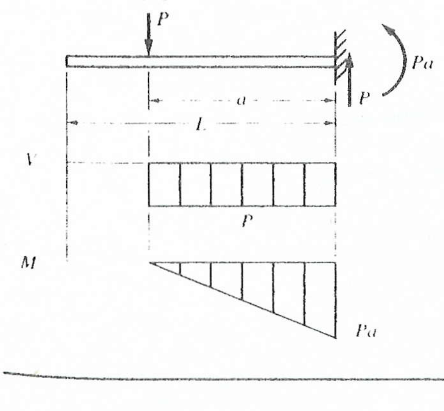
3. Simple beam with two equal concentrated loads symmetrically placed



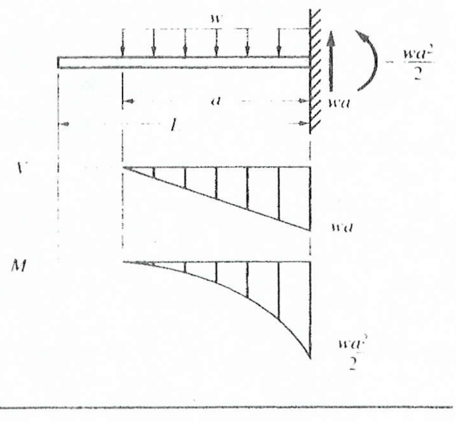
4. Simple beam with a uniform load



5. Cantilever beam with a concentrated load at any point



6. Cantilever beam with a uniform load



Stress concentration factors for grooves, holes and fillets