



First Semester Examination
Academic Session 2018/2019

December 2018/January 2019

ESA321 – Aerospace Structure
[Struktur Aeroangkasa]

Duration : 3 hours
(Masa : 3 jam)

Please check that this examination paper consists of **THIRTEEN (13)** pages of printed material, included **THREE (3)** pages appendix and **FIVE (5)** questions before you begin the examination.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **TIGA BELAS (13)** mukasurat yang bercetak termasuk **TIGA (3)** mukasurat lampiran dan **LIMA (5)** soalan sebelum anda memulakan peperiksaan ini].*

Instructions : Answer **ALL** questions.

Arahan : Jawab **SEMUA** soalan].

1. **Appendix/Lampiran** **[2 pages/mukasurat]**

Student may answer the questions either in **English** or **Bahasa Malaysia**.

*[Pelajar boleh menjawab soalan dalam **Bahasa Inggeris** atau **Bahasa Malaysia**].*

Each questions must begin from a new page.

[Setiap soalan mestilah dimulakan pada mukasurat yang baru].

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

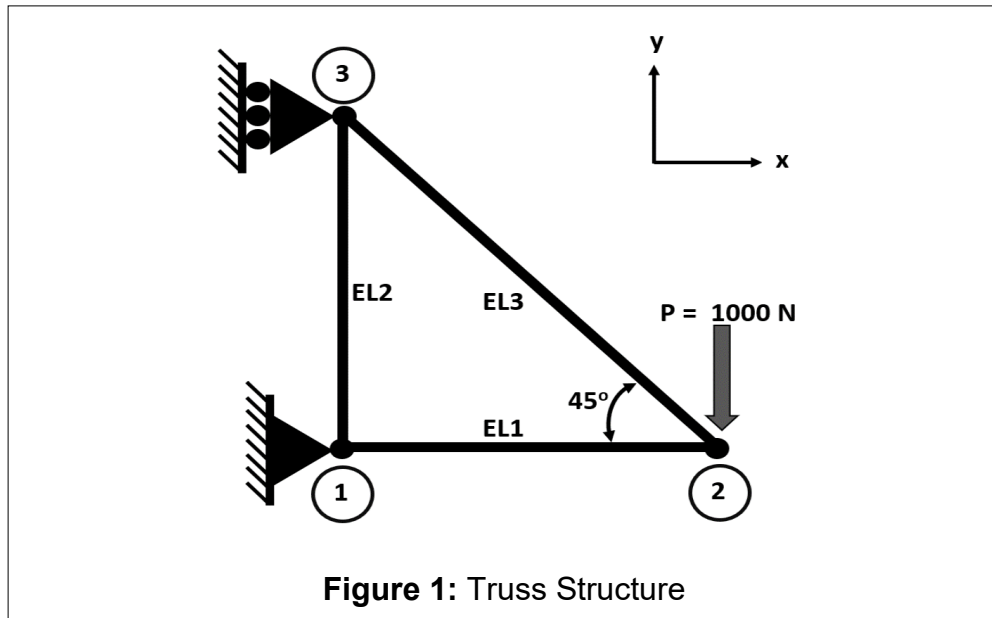
[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunakan]

1. (a). Describe the general procedure for performing structural analysis using finite element method software.
(3 marks)
- (b). List **FIVE (5)** advantages of using finite element method for solving engineering related problems.
(3 marks)
- (c). A structure made of three trusses is as shown in **Figure 1**. It is loaded vertically with force, P with a magnitude of 1,000 Newton at node 2. Node 1 is fixed at the anchor point. Node 3 is fixed in the horizontal direction while node 2 is free to displace. The properties of the trusses are given in **Table 1**. The trusses are made from the same material and have the same cross sectional area. Find the followings:
- Global stiffness matrix of element 1
 - Global stiffness matrix of element 3
 - Global assembly matrix of the truss structure
 - Displacement of node 3 in vertical direction

(14 marks)

Table 1: Truss properties

Parameter		Value	Unit
Elastic modulus	E	70 x 10⁹	Pa
Cross sectional area	A	0.1	m²
Length	EL1	1	m
	EL2	1	
	EL3	√2	



2. Using **Figure 2** shown below, draw the shear load and bending moment diagrams of the half- wing while the aircraft is in flight.

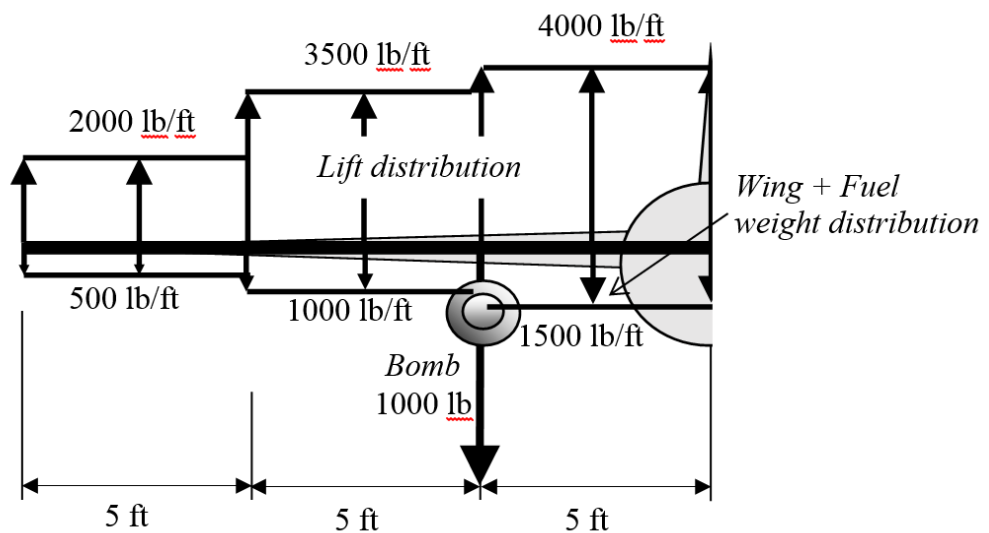
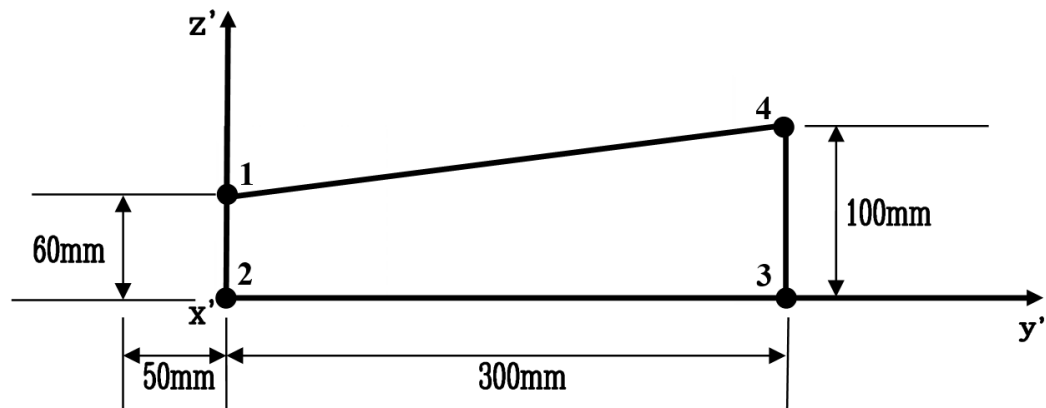


Figure 2

(20 marks)

3. Bending moments of $M_y = -50 \text{ Nm}$ and $M_z = -10 \text{ Nm}$ are applied on the idealized thin-walled 4 booms wing beam section shown in **Figure 3**.

Determine the axial stresses in all booms.



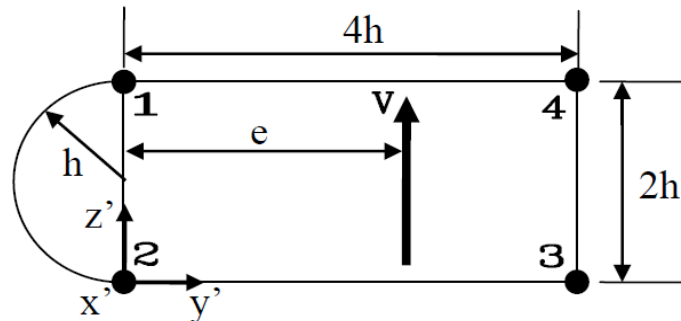
Area of booms 1 & 2 = 2000 mm^2

Area of booms 3 & 4 = 3000 mm^2

Figure 3

(20 marks)

4. Determine e , the shear center of the idealized thin-walled 2-boom beam section shown in **Figure 4**.



Original thickness of all walls = t

Area of booms 1 & 2 = $2A$

Area of booms 3 & 4 = A

Figure 4

(20 marks)

5. **Figure 5** shows a fuselage structure.

- Fuselage skins between the stringers are considered flat
- Structure is made of aluminum:

$$E = 10 \times 10^6 \text{ psi}; \quad \nu = 0.3; \quad \sigma_{\text{yield}} = 63 \text{ ksi}; \quad \sigma_{\text{ult}} = 74 \text{ ksi}$$

- Skin thickness, t_{sk} 0.05 in
- Stringer thickness, t_{st} 0.04 in

(a). Determine whether the skin and stringer can fail in local buckling, if

- Maximum compressive load N_x 1200 lb/in
- Frame/former spacing, L 24 in
- Stringer spacing, W 3 in

(5 marks)

(b). Optimize the skin-stringer (stiffened-panel/panel-strut) structure design by finding the appropriate frame and stringer spacings, L and W such that if buckling failure occurs, the skins, stringers and stiffened-panel structure should fail simultaneously (i.e. local and general/global buckling occurs at the same critical stress).

Design requirements:

- All stringer dimensions are fixed.
- Ratio $L/W \gg 3$

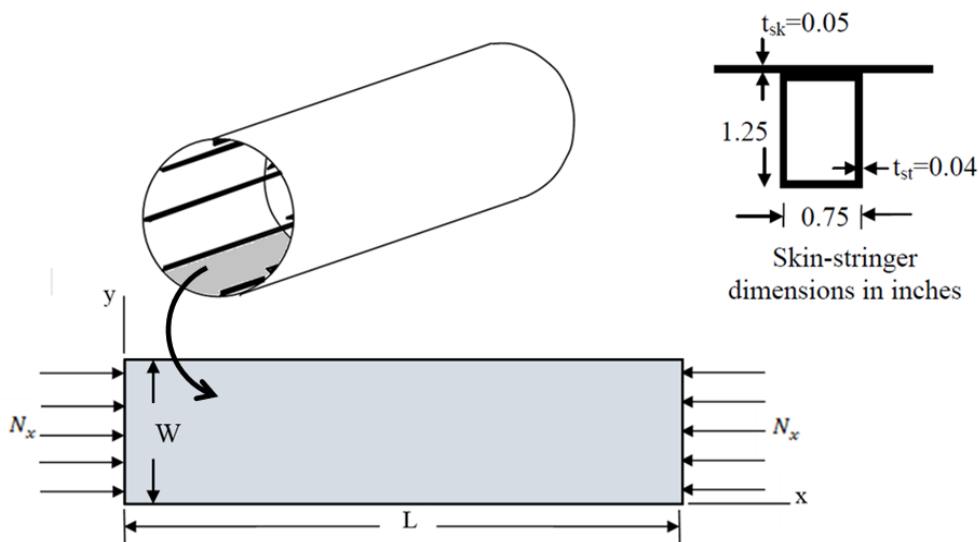


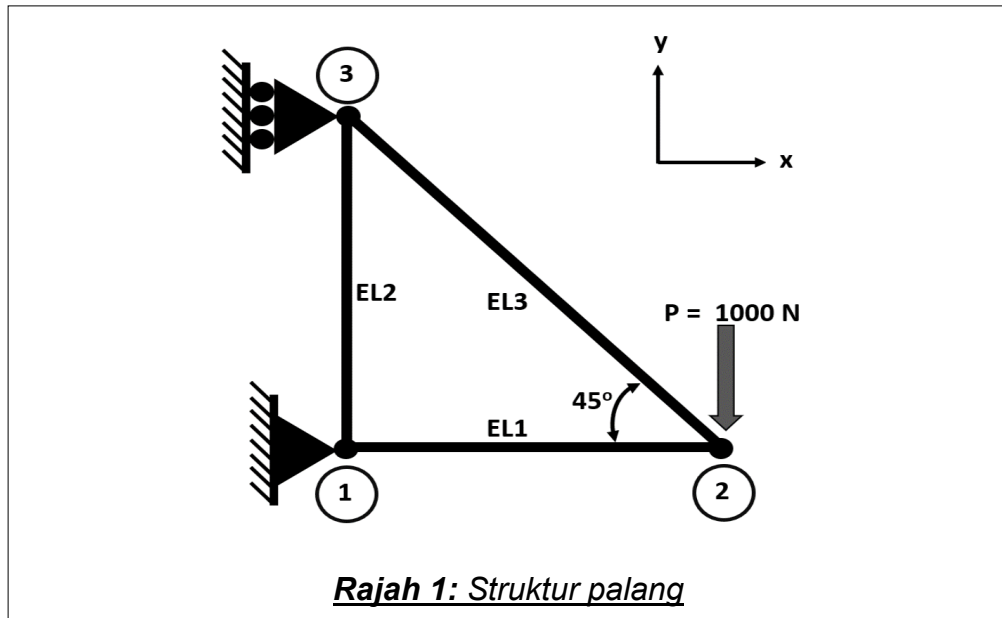
Figure 5

(15 marks)

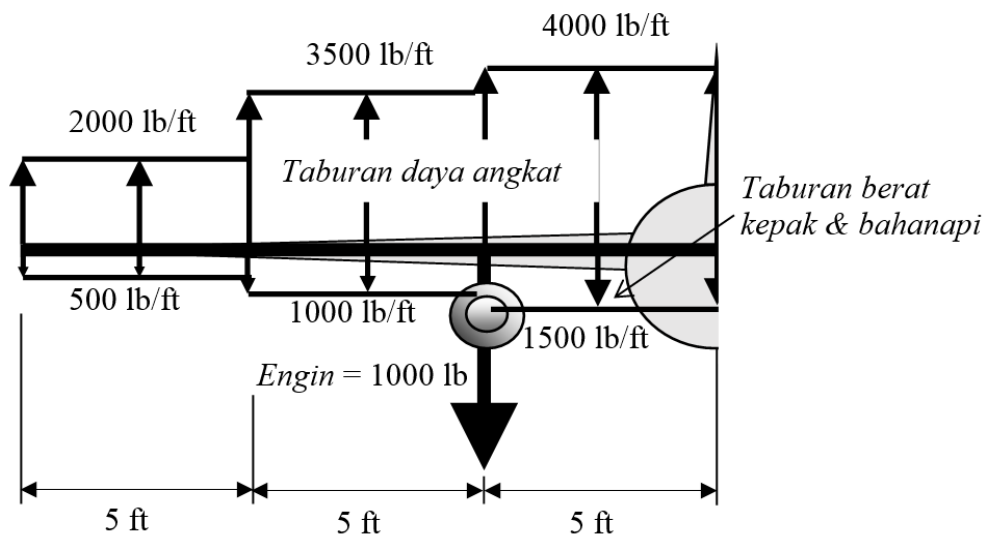
1. (a). Terangkan tatacara am untuk melakukan analisa struktur dengan menggunakan perisian kaedah unsur terhingga. (3 markah)
- (b). Senaraikan **LIMA (5)** kelebihan menggunakan kaedah elemen terhingga untuk menyelesaikan masalah berkaitan kejuruteraan. (3 markah)
- (c). Satu struktur yang terdiri daripada 3 palang ditunjukkan dalam **Rajah 1**. Beban P dikenakan pada nod 2 dengan magnitud daya berjumlah 1,000 Newton. Nod 1 ditambat pada penambat. Nod 3 ditambat secara mendatar manakala nod 3 bebas untuk berganjak. Sifat palang tersebut diberikan dalam **Jadual 1**. Palang-palang tersebut diperbuat daripada bahan yang sama dan mempunyai luas keratan rentas yang sama. Tentukan perkara-perkara berikut:
- i) Matriks kekakuan global elemen 1
 - ii) Matriks kekakuan global elemen 3
 - iii) Matriks himpunan global struktur palang
 - iv) Sesaran pada nod 3 dalam arah menegak
- (14 markah)

Jadual 1: Sifat palang

Parameter		Value	Unit
Modulus kenyal	E	70×10^9	Pa
Luas keratan rentas	A	0.1	m^2
Panjang	$EL1$	1	m
	$EL2$	1	
	$EL3$	$\sqrt{2}$	



2. Dengan menggunakan **Rajah 2** di bawah, lukiskan rajah beban ricih dan momen lentur kepak-separuh semasa pesawat yang sedang dalam penerbangan

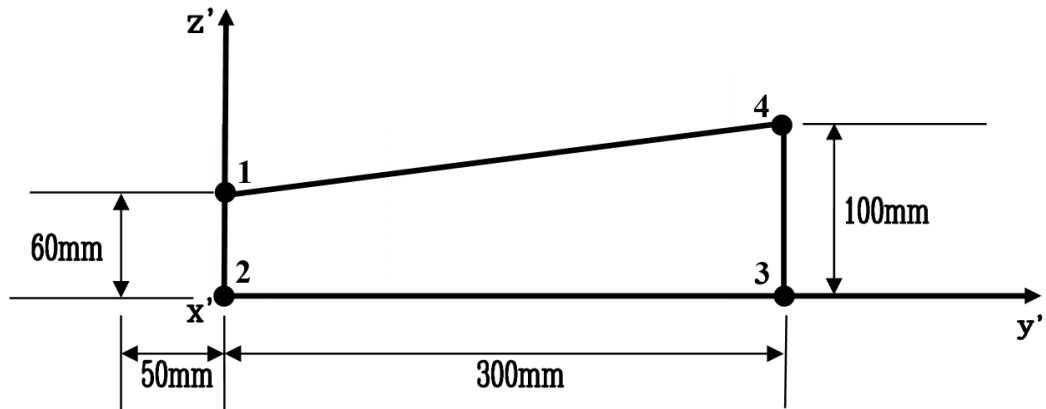


Rajah 2

(20 markah)

3. Momen lentur $M_y = -50 \text{ kNm}$ dan $M_z = 10 \text{ kNm}$ dikenakan ke atas keratan-
rentas rasuk dinding-nipis 4 gelegar yang ditunjukkan di **Rajah 3**.

Tentukan tegasan paksi pada setiap gelegar.



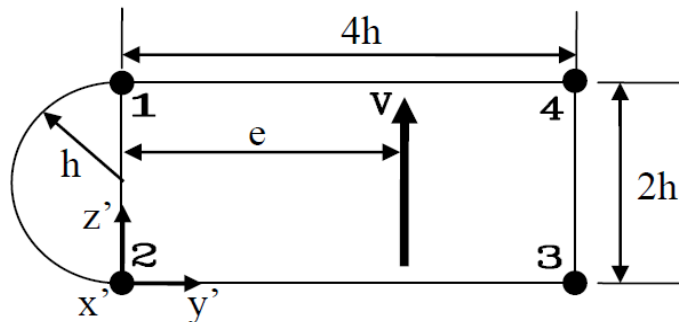
Keluasan gelegar 1 & 2 = 2000 mm^2

Keluasan gelegar 3 & 4 = 3000 mm^2

Rajah 3

(20 markah)

4. Tentukan e , pusat ricih rasuk 2-gelegar ideal yang ditunjukkan di **Rajah 4**.



Tebal asal semua dinding = t
 Keluasan gelegar 1 & 2 = $2A$
 Keluasan gelegar 3 & 4 = A

Rajah 4

(20 markah)

5. **Rajah 5** menunjukkan struktur fuselaj.

- Kulit fuselaj di antara gelegar dianggap rata.
- Struktur dibuat dari aluminum:

$$E = 10 \times 10^6 \text{ psi}; \quad \nu = 0.3; \quad \sigma_{\text{yield}} = 63 \text{ ksi}; \quad \sigma_{\text{ult}} = 74 \text{ ksi}$$

- Tebal kulit, t_{sk} 0.05 in
- Tebal gelegar, t_{st} 0.04 in

(a). Tentukan jika kulit dan gelegar boleh gagal secara lengkohan (termasuk lengkohan lokal), jika

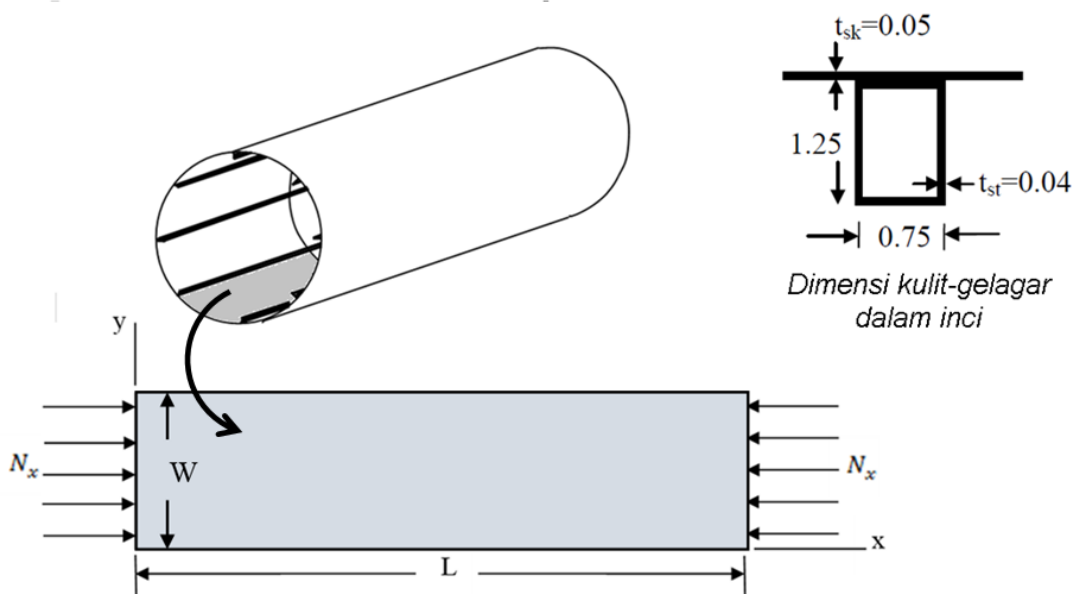
- Beban mampat maksimum, N_x 1200 lb/in
- Jarak antara rusuk/bingkai, L 24 in
- Jarak antara gelegar, W 3 in

(5 markah)

(b). Optimumkan rekabentuk struktur kulit-gelegar dengan mencari jarak sesuai, L (antara rusuk ke rusuk) dan W (antara gelegar ke gelegar) di mana andai jika berlaku kegagalan secara lengkohan kulit, gelegar dan struktur kulit-gelegar, hendaklah gagal serentak (iaitu kegagalan lokal dan global berlaku pada tegasan kritikal yang sama).

Keperluan rekabentuk :

- Semua dimensi gelegar tidak berubah
- Nisbah $L/W \gg 3$



Rajah 5

(15 markah)

Equation for truss element stiffness in global coordinate system

$$k = \frac{EA}{L} \begin{matrix} & \begin{matrix} u_i & v_i & u_j & v_j \end{matrix} \\ \begin{bmatrix} l^2 & lm & -l^2 & -lm \\ lm & m^2 & -lm & -m^2 \\ -l^2 & -lm & l^2 & lm \\ -lm & -m^2 & lm & m^2 \end{bmatrix} \end{matrix}$$

Where

$$l = \cos\theta = \frac{X_j - X_i}{L}$$

and

$$m = \sin\theta = \frac{Y_j - Y_i}{L}$$

$$\sigma_x = \frac{P}{A} + \frac{-(M_z I_y + M_y I_{yz})y + (M_y I_z + M_z I_{yz})z}{I_y I_z - I_{yz}^2}$$

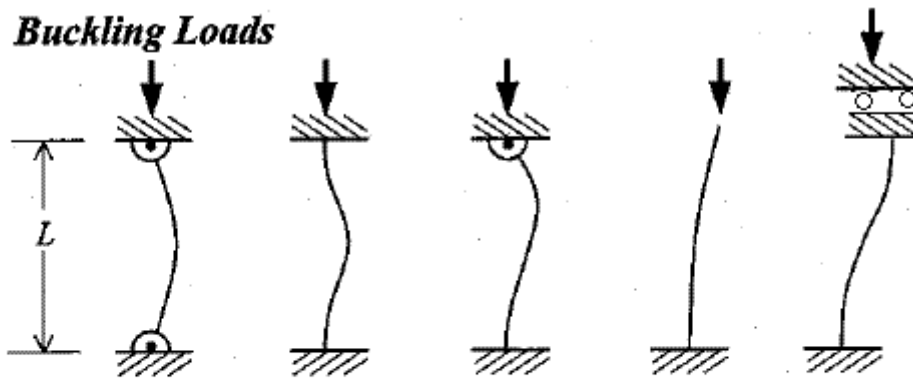
$$\Delta q = - \left[\frac{(V_y I_y - V_z I_{yz})Q_z + (V_z I_z - V_y I_{yz})Q_y}{I_y I_z - I_{yz}^2} \right] \quad \theta = \frac{q}{2AG} \oint \frac{ds}{t}$$

$$P_{cr} = \frac{\pi^2 EI}{L_e^2}$$

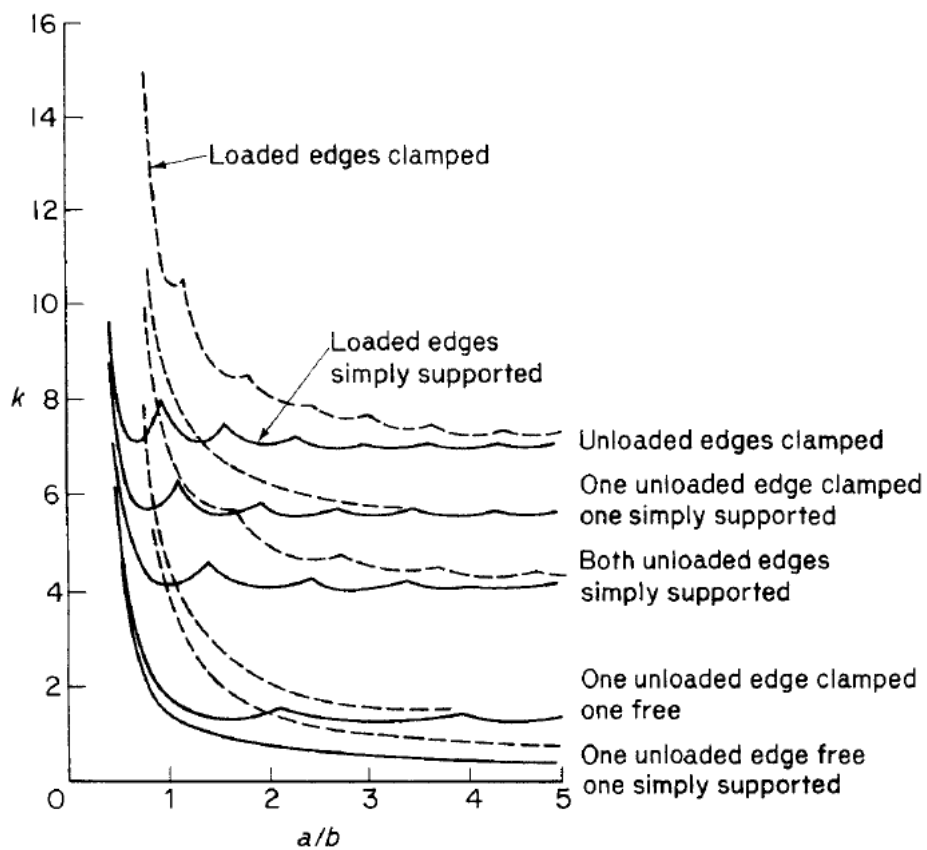
$$\sigma_{cr} = \frac{\pi^2 E}{(L_e/r)^2}$$

$$\sigma_{cr} = k \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{b} \right)^2$$

Buckling Loads



Buckling Load	$\frac{\pi^2 EI}{L^2}$	$\frac{4\pi^2 EI}{L^2}$	$\frac{2.045\pi^2 EI}{L^2}$	$\frac{\pi^2 EI}{4L^2}$	$\frac{\pi^2 EI}{L^2}$
Effective Length L_e	L	$0.5L$	$0.699L$	$2L$	L



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