



UNIVERSITI SAINS MALAYSIA

First Semester Examination  
2016/2017 Academic Session

December 2016/January 2017

**ESA 321/3 – Aerospace Structure**  
*[Struktur Aeroangkasa]*

Duration : 3 hours  
*Masa : 3 jam*

Please ensure that this paper contains **ELEVEN (11)** printed pages, included **TWO (2)** pages appendix and **FIVE (5)** questions before you begin examination.

*Sila pastikan bahawa kertas soalan ini mengandungi **SEBELAS (11)** mukasurat bercetak termasuk **DUA (2)** mukasurat lampiran dan **LIMA (5)** soalan sebelum anda memulakan peperiksaan.*

**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.*

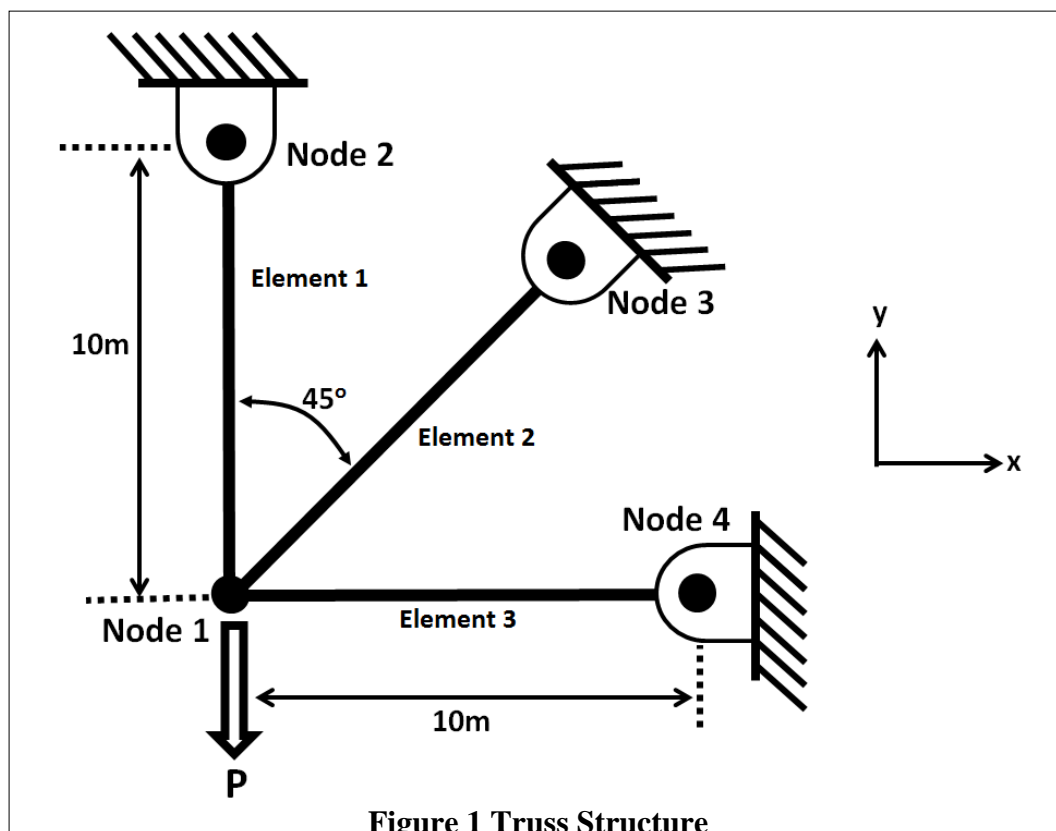
In the event of any discrepancies, the English version shall be used.

*Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.*

1. [a] Describe the general procedure for performing structural analysis using finite element method. (3 marks)
- [b] **List 5** ways that can be employed to confirm the validity of the results obtained using finite element method. (1 mark)
- [c] A structure is made of three trusses as shown in **Figure 1**. It is vertically loaded with force,  $P$  with a magnitude of 10,000 Newton at node 1. Node 2, 3 and 4 are fixed at their respective anchor points. The properties of the truss are given in **Table 1**. Find the answers of the following questions.
- (i) Global stiffness matrix of element 1
  - (ii) Global stiffness matrix of element 2
  - (iii) Global assembly matrix of the structure
  - (iv) Displacement of node 1 in vertical direction

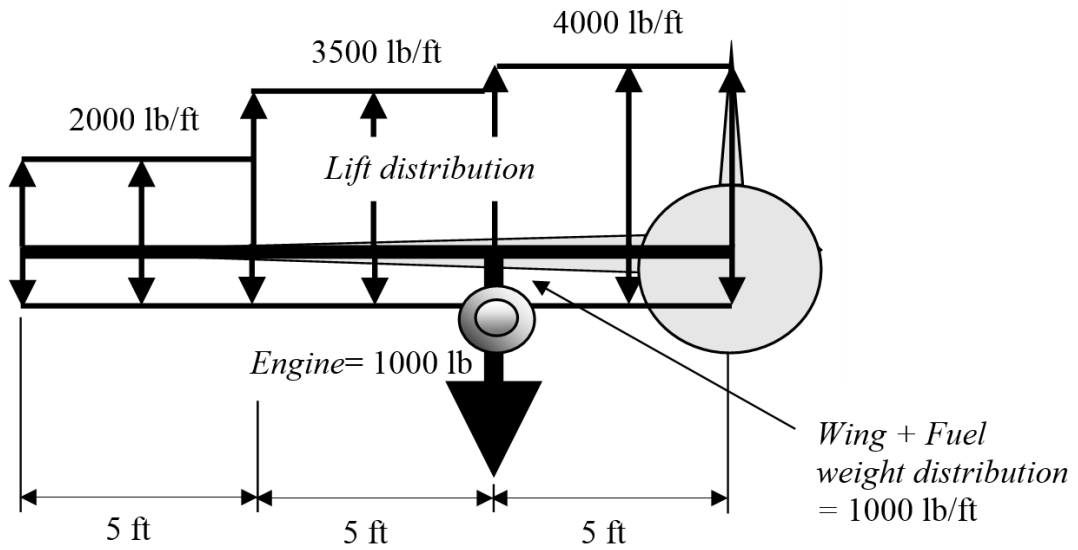
**(16 marks)****Table 1 Truss Properties**

Parameter		Value	Unit
Elastic modulus	$E$	$30 \times 10^6$	Pa
Cross sectional area	$A$	2	$m^2$
Length	$L$	10	m



...3/-

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

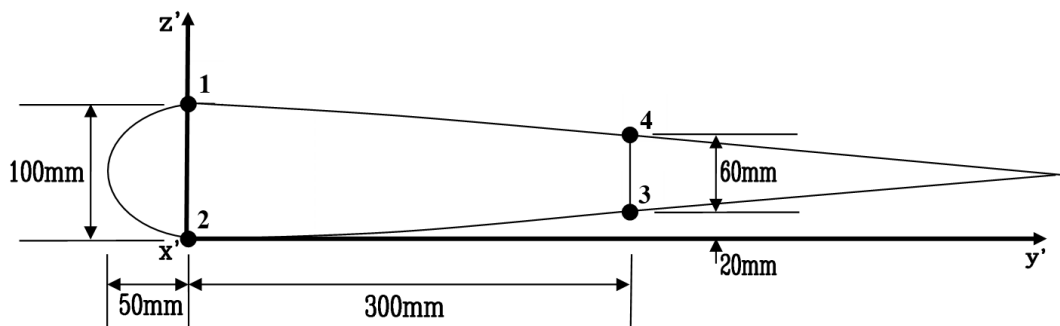


**Figure 2**

(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.

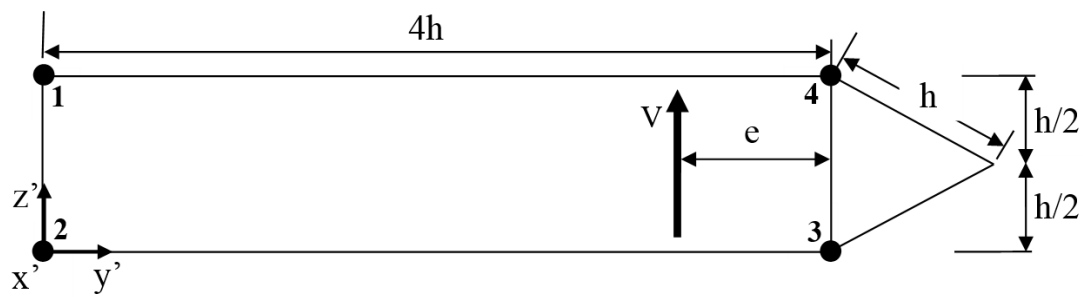


Area of booms  
 $A_1 = A_2 = A_3 = 3000 \text{ mm}^2$   
 $A_4 = 2000 \text{ mm}^2$

**Figure 3**

(20 marks)

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



Original thickness of all walls =  $t$

Area of booms

$$A_1 = A_2 = A$$

$$A_3 = A_4 = 2A$$

**Figure 4**

**(20 marks)**

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

- Fuselage skins between the stringers are considered flat
- Structure is made of aluminum:  
 $E = 10 \times 10^6$  psi;  $\nu = 0.3$ ;  $\sigma_{\text{yield}} = 63$  ksi;  $\sigma_{\text{ult}} = 74$  ksi
- Skin thickness,  $t_{\text{sk}}$  0.05 in
- Stringer thickness,  $t_{\text{st}}$  0.04 in

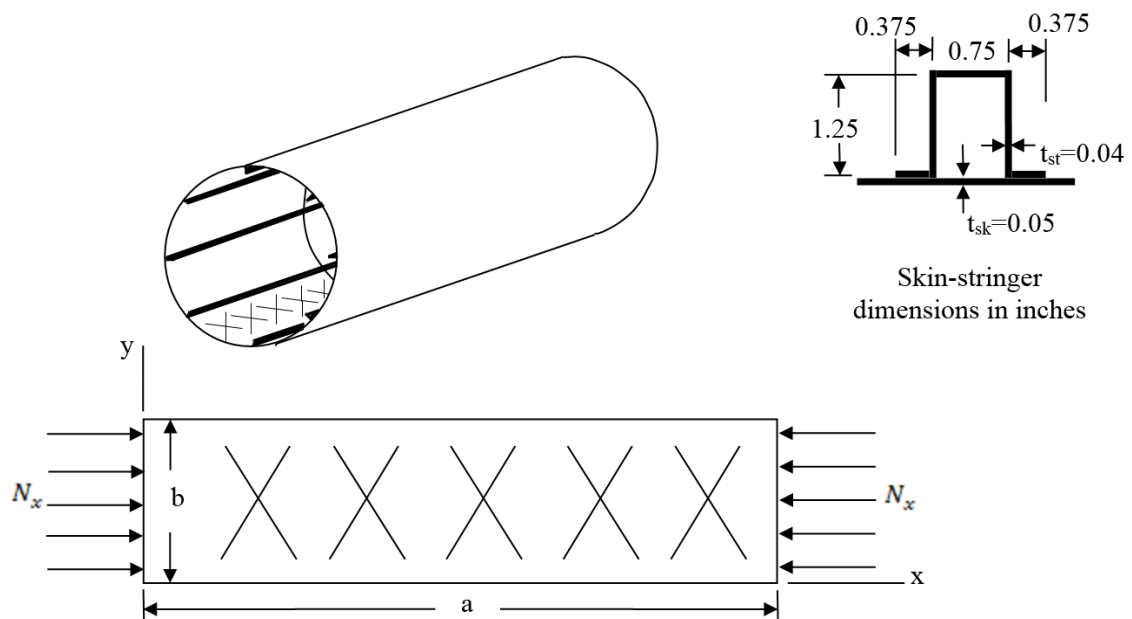
[a] Determine whether the skin and stringer can fail in buckling (including local buckling), given

- Maximum compressive load  $N_x$  1200 lb/in
- Frame/former spacing,  $a$  24 in
- Stringer spacing,  $b$  3 in

**(5 marks)**

[b] Optimize the skin-stringer (stiffened-panel/panel-strut) structure design by finding the appropriate frame and stringer spacings,  $a$  and  $b$  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).

- Let ratio  $a/b > 3$



**Figure 5**

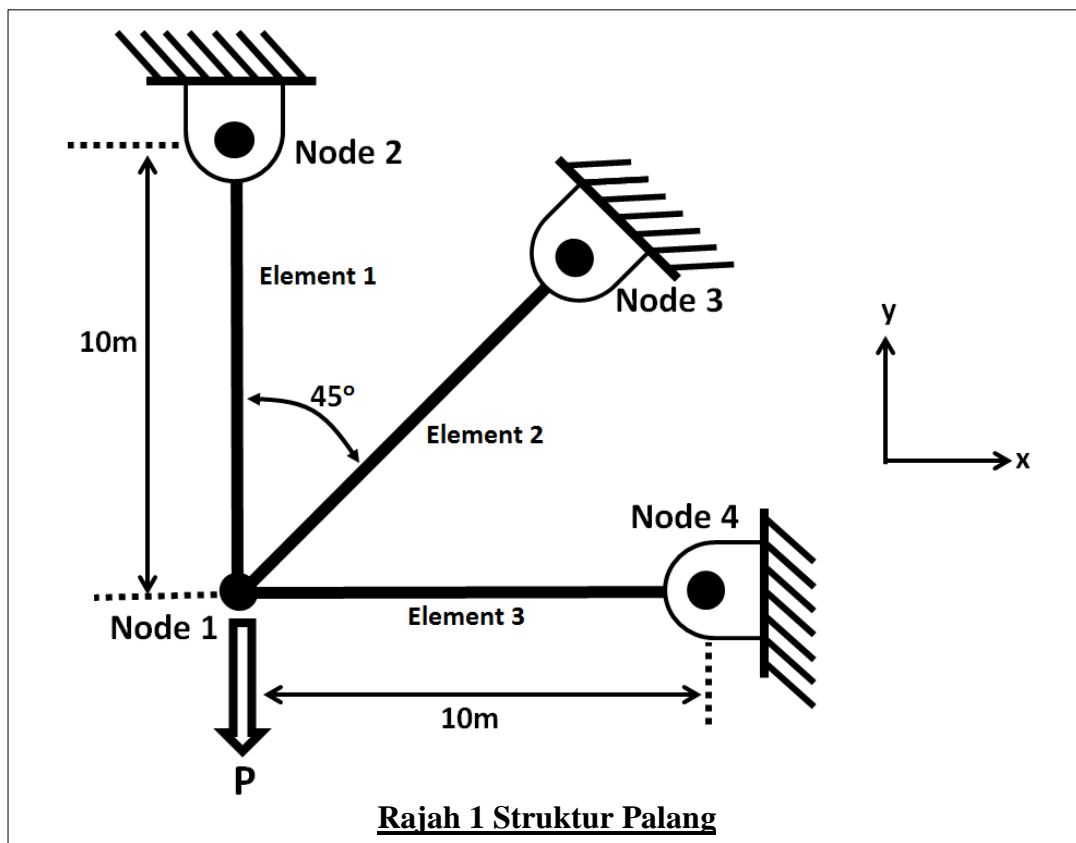
**(15 marks)**

1. [a] Perihal tatacara am untuk melakukan analisa struktur dengan menggunakan kaedah unsur terhingga. (3 markah)
- [b] Senaraikan 5 cara yang boleh digunakan untuk memastikan kesahihan keputusan yang diperolehi daripada kaedah elemen terhingga. (1 markah)
- [c] Satu struktur yang terdiri daripada 3 palang yang serupa seperti yang ditunjukkan dalam **Rajah 1**. Beban  $P$  dikenakan pada nod 1 dengan magnitud daya berjumlah 10,000 Newton. Nod 2, 3 dan 4 ditambatkan pada penambat masing-masing. Sifat palang tersebut diberikan dalam **Jadual 1**. Cari jawapan kepada soalan berikut.
- (i) Matrik kekakuan global elemen 1
- (ii) Matrik kekakuan global elemen 2
- (iii) Matrik himpunan global struktur tersebut
- (iv) Sesaran pada nod 1 dalam arah menegak

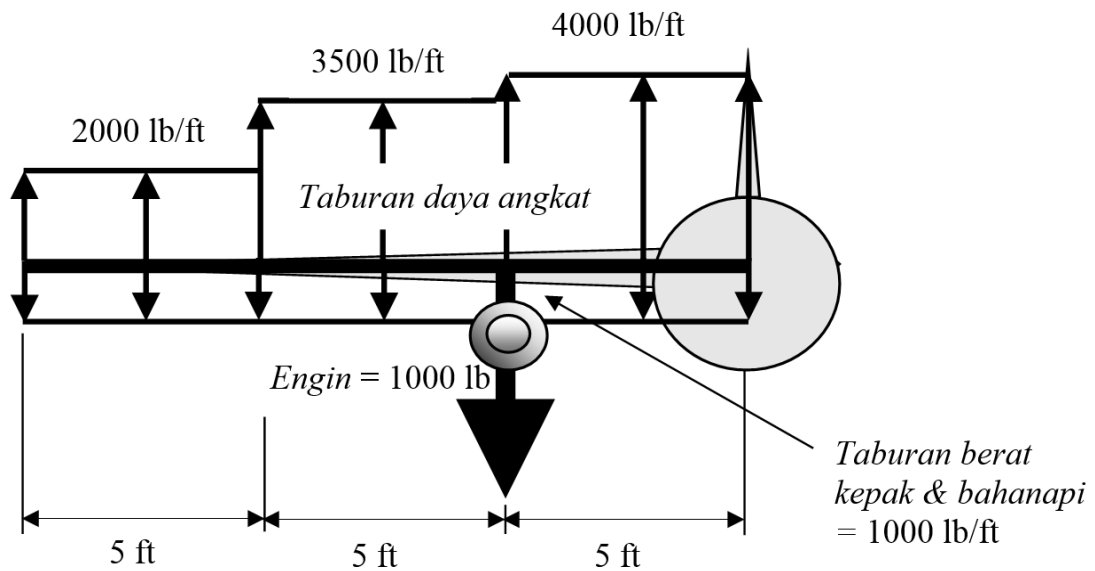
(16 markah)

**Jadual 1 Sifat Palang**

Parameter		Nilai	Unit
Modulus kenyal	E	$30 \times 10^6$	Pa
Luas keratan rentas	A	2	$m^2$
Panjang	L	10	m



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

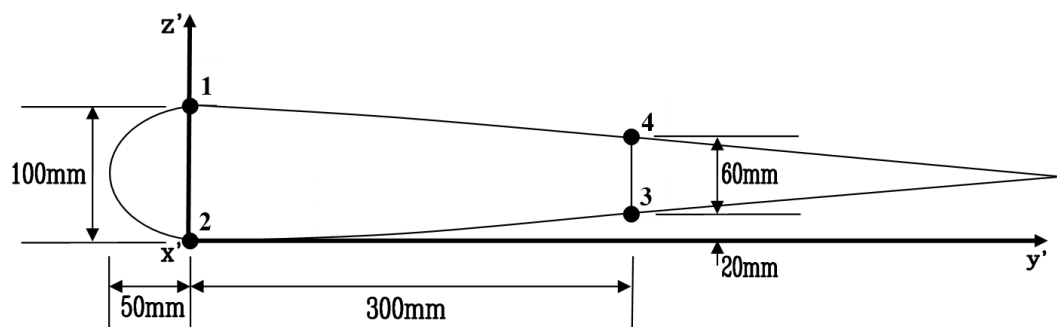


**Rajah 2**

(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.

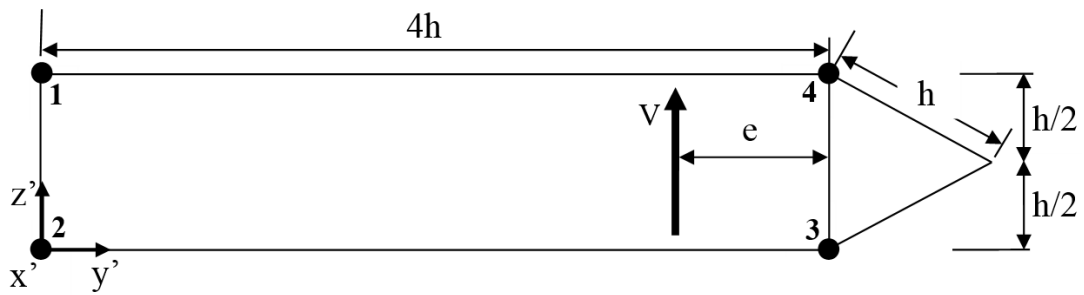


Keluasan gelegar  
 $A_1 = A_2 = A_3 = 3000 \text{ mm}^2$   
 $A_4 = 2000 \text{ mm}^2$

**Rajah 3**

(20 markah)

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



Tebal asal semua dinding =  $t$

Keluasan gelegar

$$A_1 = A_2 = A$$

$$A_3 = A_4 = 2A$$

**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 lengkokan (termasuk lengkokan loal), jika

- Beban mampat maksimum,  $N_x$  1200 lb/in

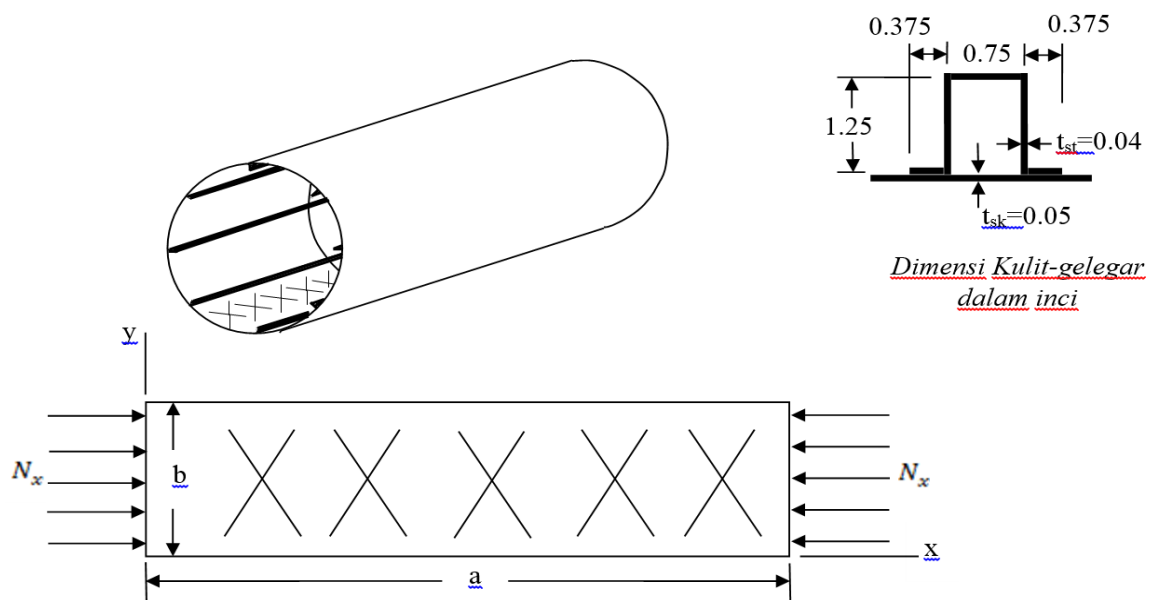
- Jarak antara rusuk/bingkai,  $a$  24 in

- Jarak antara gelegar,  $b$  3 in

(5 markah)

[b] Optimumkan rekabentuk struktur kulit-gelegar dengan mencari jarak sesuai,  $a$  dan  $b$ ; antara rusuk ke rusuk dan gelegar ke gelegar, andai jika berlaku kegagalan secara lengkokan kulit, gelegar dan struktur kulit-gelegar, hendaklah gagal serentak (iaitu kegagalan lokal dan global berlaku pada tegasan kritikal yang sama).

- Gunakan nisbah  $a/b > 3$



**Rajah 5**

(15 markah)

**Equation for truss element stiffness in global coordinate system**

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

Where

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

and

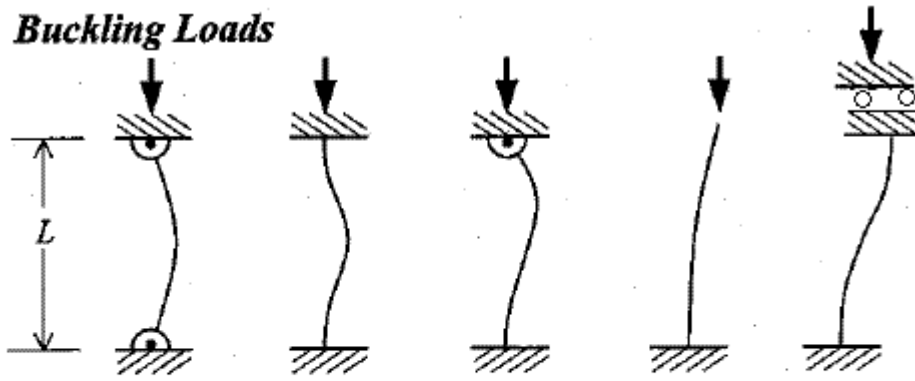
$$m = \sin\theta = \frac{Y_j - Y_i}{L}$$

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

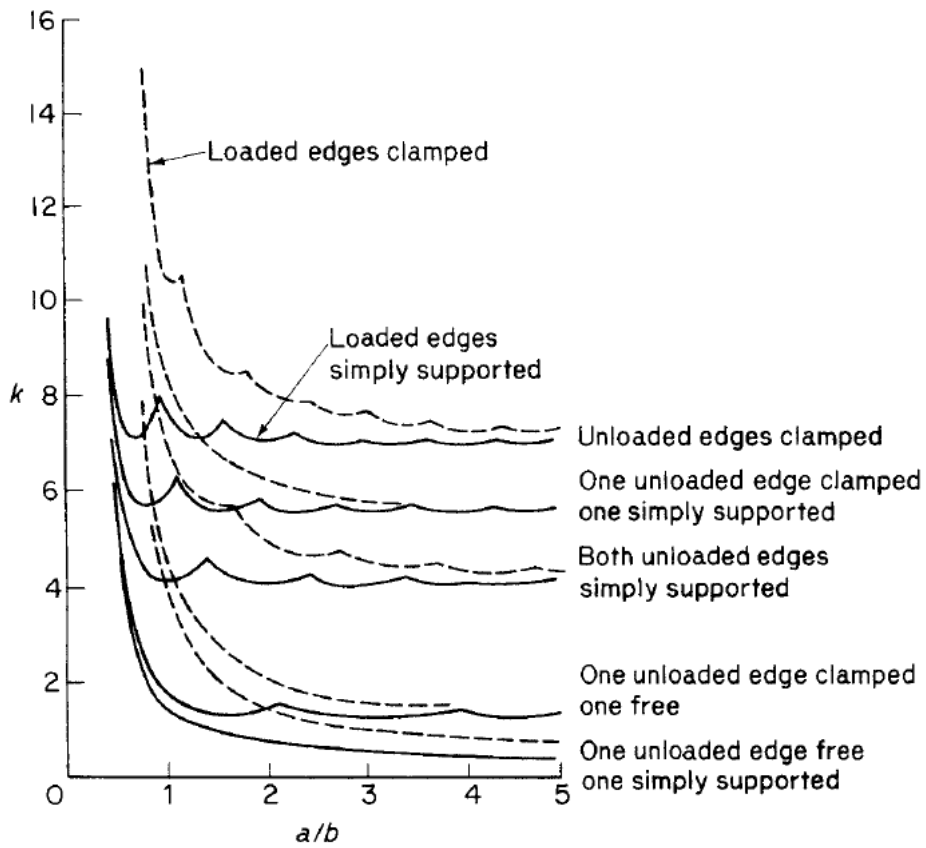
$$\Delta q = - \left[ \frac{(V_y I_y - V_z I_{yz})Q_z + (V_z I_z - V_y I_{yz})Q_y}{I_y I_z - I_{yz}^2} \right] \quad \theta = \frac{q}{2AG} \oint \frac{ds}{t}$$

$$P_{cr} = \frac{\pi^2 EI}{L_e^2} \quad \sigma_{cr} = \frac{\pi^2 E}{(L_e/r)^2} \quad \sigma_{cr} = k \frac{\pi^2 E}{12(1-\nu^2)} \left( \frac{t}{b} \right)^2$$

**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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