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 digunapakai]

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:

i) Global stiffness matrix of element 1
ii) Global stiffness matrix of element 3
iii) Global assembly matrix of the truss structure
iv) Displacement of node 3 in vertical direction

(14 marks)

Table 1: Truss properties

Parameter		**Value**	**Unit**
Elastic modulus	**E**	**70×10^9**	**Pa**
Cross sectional area	**A**	**0.1**	**m^2**
Length	**EL1**	**1**	**m**
	EL2	**1**	
	EL3	**√2**	

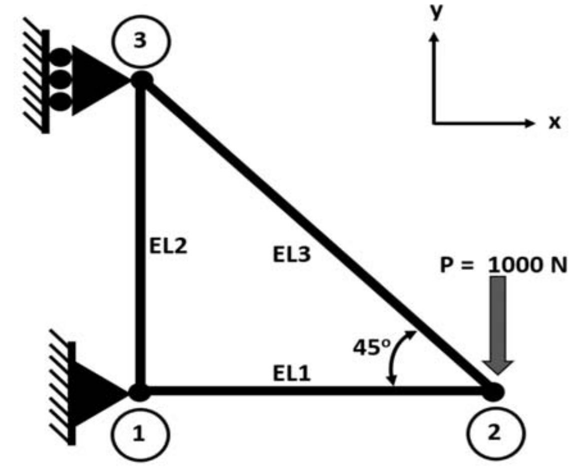


Figure 1: Truss Structure

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

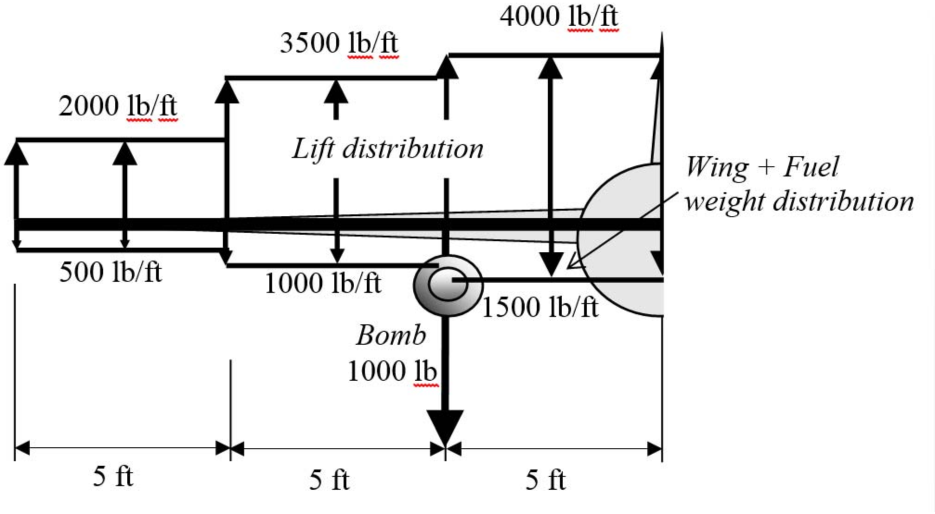
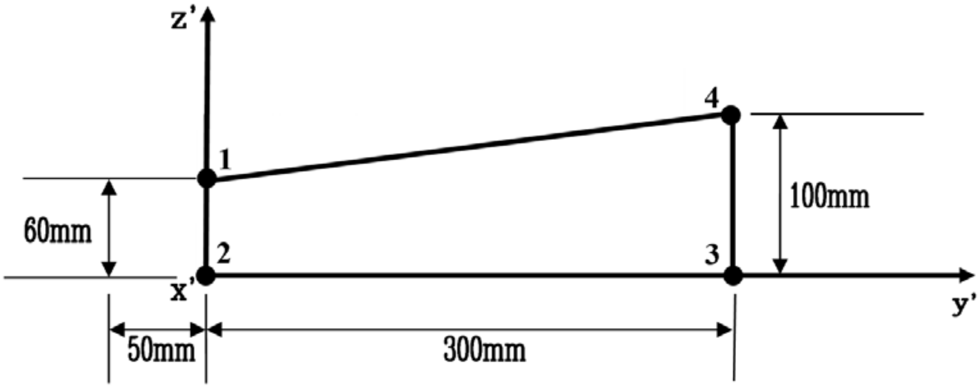


Figure 2

(20 marks)

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

Determine the axial stresses in all booms.

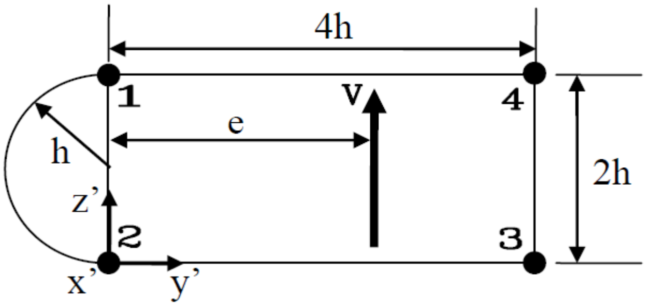


Area of booms 1 & 2 = 2000 mm^2
Area of booms 3 & 4 = 3000 mm^2

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:

$E = 10x10^6$ psi; $\upsilon = 0.3$; $\sigma_{yield} = 63$ ksi; $\sigma_{ult} = 74$ 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* >> *3*

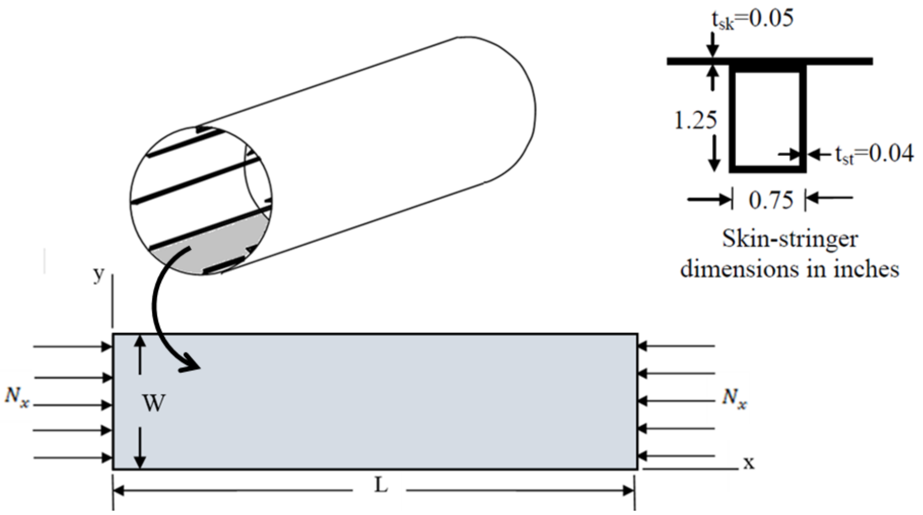


Figure 5

(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)

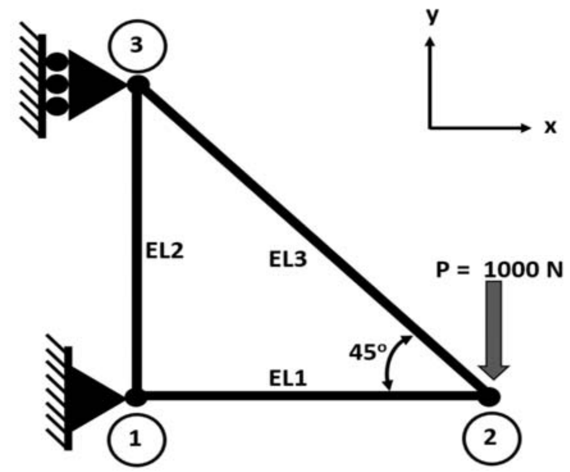
(c). *Satu struktur yang terdiri daripada 3 palang ditunjukan dalam* **Rajah 1**. *Beban P dikenakan pada nod 2 dengan magnitud daya berjumlah 1,000 Newton. Nod 1 ditambat pada penambat. Nod 3 ditambat secara mendatar manakala nod 3 bebas untuk berganjak. Sifat palang tersebut diberikan dalam* **Jadual 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)

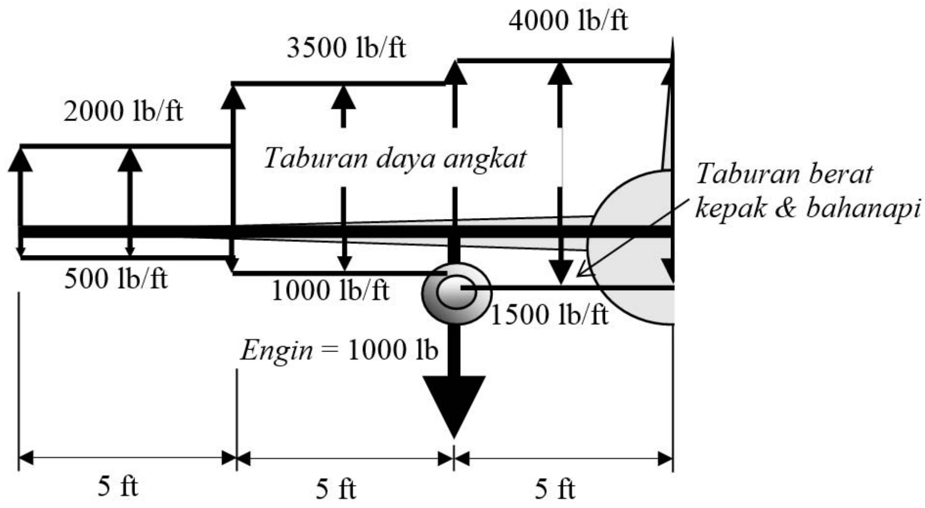
Jadual 1: *Sifat palang*

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	**$\sqrt{2}$**	



Rajah 1: *Struktur palang*

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

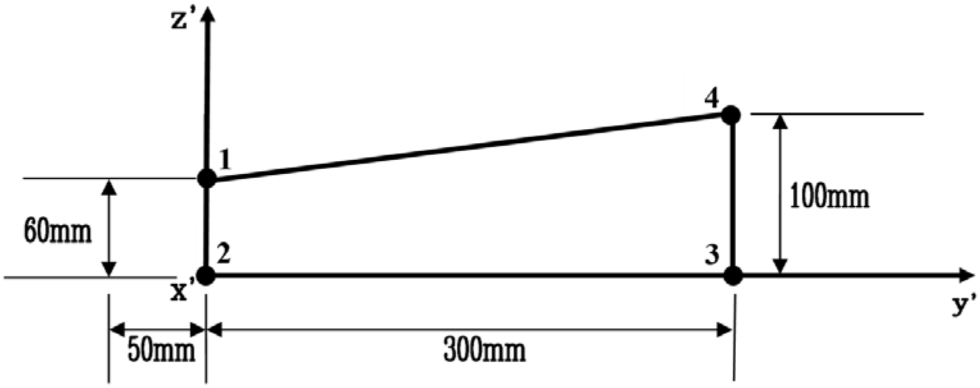


Rajah 2

(20 markah)

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

Tentukan tegasan paksi pada setiap gelegar.

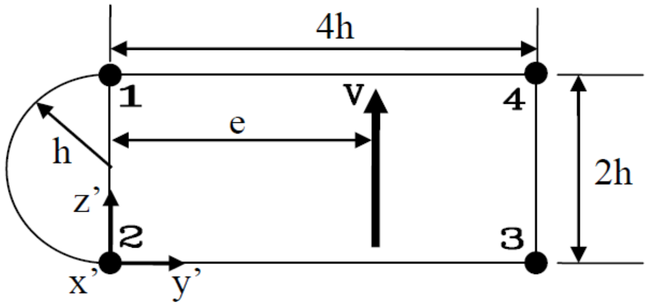


Keluasan gelegar 1 & 2 = 2000 mm^2
Keluasan gelegar 3 & 4 = 3000 mm^2

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:*

$E = 10x10^6$ *psi;* $\upsilon = 0.3$; σ_{yield} =63 *ksi;* σ_{ult} =74 *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 lokal), jika*

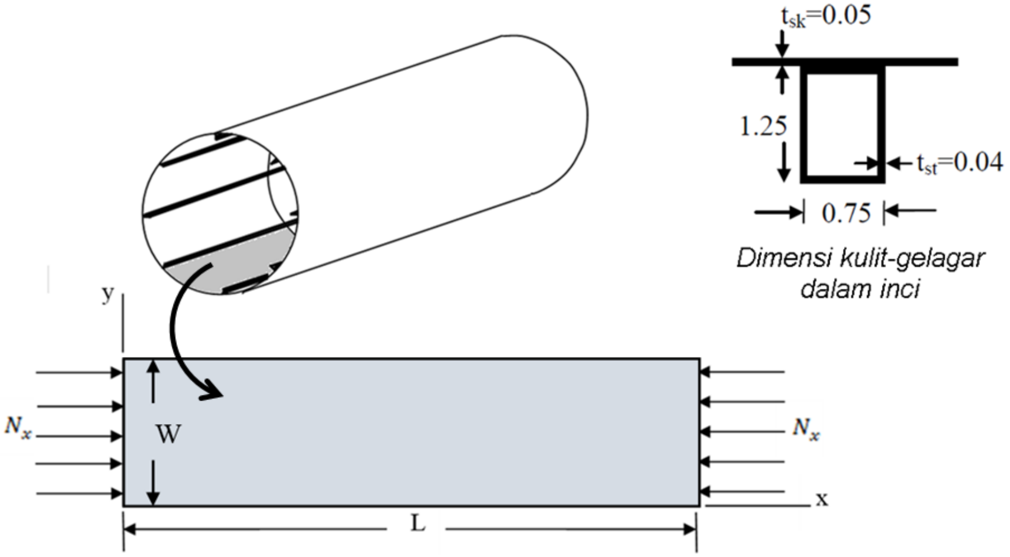
- *Beban mampat maksimum, N_x* *1200 lb/in*
- *Jarak antara rusuk/bingkai,* L *24 in*
- *Jarak antara gelegar,* W *3 in*

(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 lengkokan 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 >> 3*



Dimensi kulit-gelagar dalam inci

Rajah 5

(15 markah)

Appendix/*Lampiran*

Equation for truss element stiffness in global coordinate system

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

Where

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

and

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

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

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

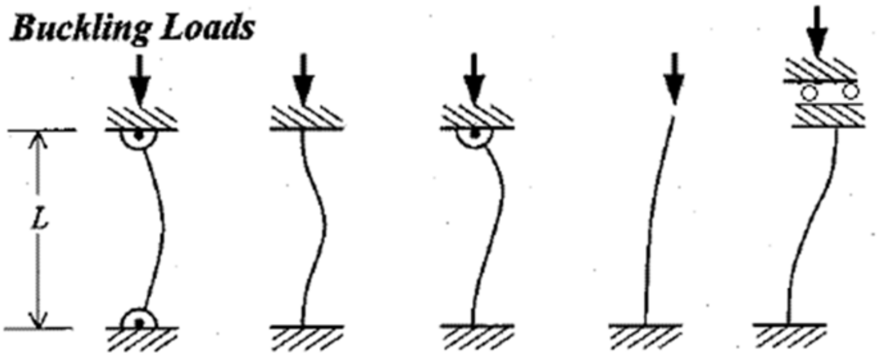
$$\theta = \frac{q}{2AG}\oint\frac{ds}{t}$$

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

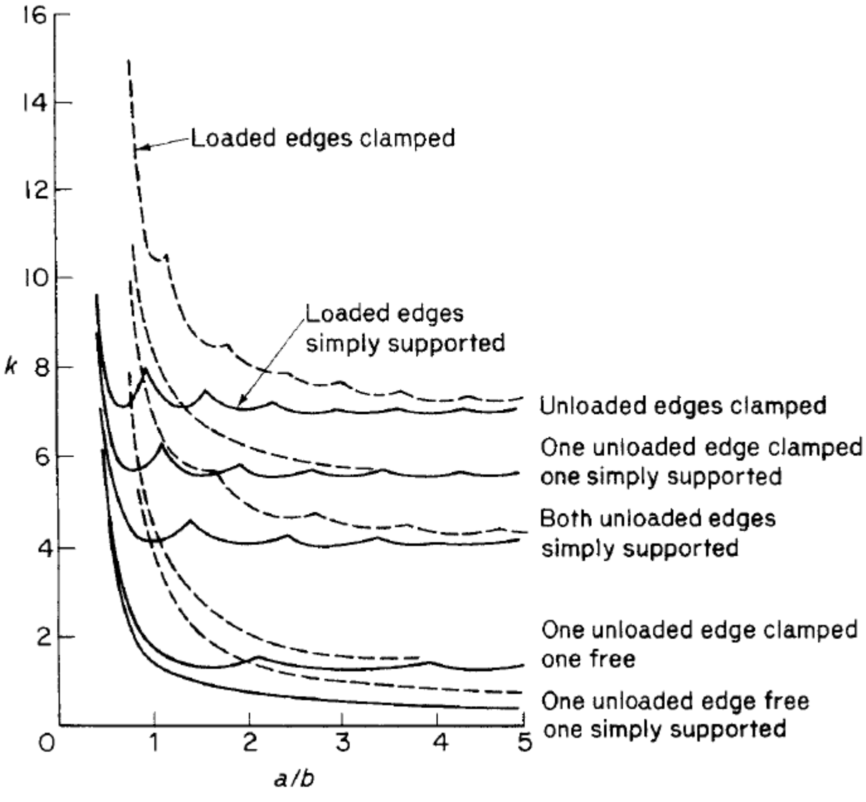
$$\sigma_{cr} = \frac{\pi^2 E}{\left(L_e / r\right)^2}$$

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

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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