UNIVERSITI SAINS MALAYSIA

First Semester Examination
2004/2005 Academic Session
Peperiksaan Semester Pertama
Sidang Akademik 2004/2005

October 2004
Oktober 2004

ESA 221E/3 – Mechanics of Solids
Mekanik Pepejal

Hour : [3 hour]
Masa : [3 jam]

INSTRUCTION TO CANDIDATES:
ARAHAN KEPADA CALON :

Please ensure that this paper contains **SIXTEEN (16)** printed pages and **EIGHT (8)** questions before you begin examination.
*Sila pastikan bahawa kertas soalan ini mengandungi **ENAM BELAS (16)** mukasurat dan **LAPAN (8)** soalan sebelum anda memulakan peperiksaan.*

This paper consists of **TWO (2) parts:**
PART A: FOUR (4) questions. PART B: FOUR (4) questions
Answer **SIX (6)** questions only. **FOUR (4)** from PART A and **TWO (2)** from PART B.
*Kertas ini mengandungi **DUA (2) Bahagian**:*
BAHAGIAN A: EMPAT (4) soalan. BAHAGIAN B: EMPAT (4) soalan
*Jawab **ENAM (6)** soalan sahaja. **EMPAT (4)** daripada BAHAGIAN A dan **DUA (2)** daripada BAHAGIAN B.*

Student may answer all the questions in English. If you want to answer in Bahasa Malaysia, at least one question must be answered in English.
Calon boleh menjawab semua soalan dalam Bahasa Inggeris. Sekiranya calon ingin menjawab dalam Bahasa Malaysia, sekurang-kurangnya satu soalan perlu dijawab dalam Bahasa Inggeris.

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

...2/-

PART A: Answer FOUR (4) questions
BAHAGIAN A: Jawab EMPAT (4) soalan

1. A four-engine jet transport, which weights 230,000 Ib fully loaded, has its center of gravity at the location shown in the sketch. Before taking off for Europe the pilot must test the engines by operating them, one at a time, at a thrust of about 8,000 Ib. As he checks the left outboard engine, the other three engines idle at negligible thrust. The rear-wheel brakes are locked during the test, but the nose wheel has no brakes. In addition the nose wheel is mounted on a caster, so it cannot resist a sidewise force. **(See Figure 1).**

   (a) What forces does the ground exert on the landing wheels during the test?

   (b) What must the coefficient of friction between ground and wheels be to prevent the rear wheels from slipping?

   Sebuah kapal terbang jet berenjin empat, di mana beratnya adalah 230,00 lb muatan penuh, mempunyai pusat graviti seperti yang ditunjukkan dalam gambarajah di bawah. Sebelum berlepas ke Eropah, juruterbang mesti menguji kesemua enjin dengan membiarkannya berfungsi satu demi satu pada daya tujahan 8000 lb. Semasa menguji enjin di sebelah kiri, ketiga-tiga enjin lain berada dalam keadaan mantap dan daya tujahnya boleh diabaikan. Brek roda belakang dipasang semasa ujian tersebut tetapi roda muncung tidak mempunyai brek. Roda muncung dipasang pada cantuman bebuli supaya ia tidak boleh menahan daya dari tepi. ***(Lihat Gambarajah 1).***

   (a) Apakah daya yang dikenakan oleh lantai kepada peralatan pendaratan semasa ujian tersebut?

   (b) Apakah nilai pekali geseran yang sepatutnya antara lantai dengan roda untuk mengelakkan roda-roda belakang daripada tergelincir?

(100 marks/*markah*)

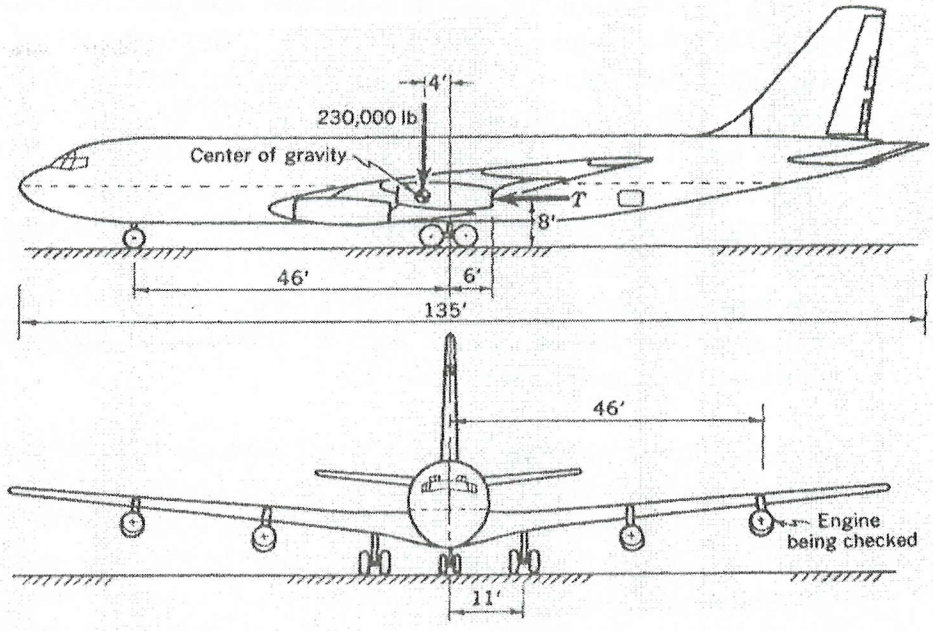


Figure 1/*Gambarajah 1*

Choose one of the questions 2(a) or 2(b)
Pilih 2(a) atau 2(b)

2. (a) Illustrated is a schematic diagram of a cable-control system for the rudder of subsonic jet trainer aircraft. The rudder lever arm is connected to the pilot's foot control by 4.5-mm-diameter extra-flexible stainless-steel cable, at 25-mm length of which has a spring constant of 60 MN/m (including the effect of untwisting). The cables have an initial tension of 1.4 kN. Cable length from rudder lever arm to the pilot's foot control is about 6 m. The pilot can push on his foot control with a force of about 700 N. In a static test of the rudder control system a force was exerted on the rudder and gradually increased until the pilot could no longer hold his foot control stationary. Through what angle had the rudder rotated when the force reached the level which just caused the pilot's foot control to move? Would this angle have been different if there had been no initial tension in the cables? **(See Figure 2).**

*Gambarajah skematik di bawah menunjukkan sistem kawalan kabel untuk kemudi sebuah pesawat jet latihan subsonic. Lengan tuil kemudi tersebut dihubungkan pada kawalan kaki juruterbang dengan kabel keluli tahan karat dengan kebolehlenturan tambahan berdiameter 4.5-mm, pada kepanjangan 25-mm, ia mempunyai pekali spring bernilai 60 MN/n (termasuk kesan tudak terpiuh) Ketegangan awalan kabel tersebut ialah 1.4 kN. Panjang kabel dari lengan tuil kemudi ke kawalan kaki juruterbang ialah 6 meter. Juruterbang boleh menolak kawalan kaki dengan daya 700 N. Semasa ujian pegun sistem kawalan kemudi tersebut, daya dikenakan kepada kemudi dan bertambah secara beransur sehingga juruterbang tidak dapat mengawal kawalan kaki. Berapakah darjah putaran kemudi apabila daya yang dikenakan menyebabkan kawalan kaki juruterbang bergerak? Adakah sudut tersebut berbeza jika ketegangan awalan tidak dikenakan pada kabel? **(Lihat Gambarajah 2).***

(100 marks/*markah*)

2. (b) A stiff beam is hinged at one end and supported by two springs of sprig constant k. Where should a force P be applied so that the spring constant of the system (P divided by the deflection under P) is 20/gk?
(See Figure 3).

Sebatang rasuk yang kukuh disambungkan dengan ensal pada satu hujung dan disokong oleh dua pegas dengan pekali pegas k. Di manakah daya patut dikenakan supaya pekali pegas (P dibahagi dengan pesongan disebabkan P) sistem tersebut ialah 20/gk? ***(Lihat Gambarajah 3).***

(100 marks/*markah*)

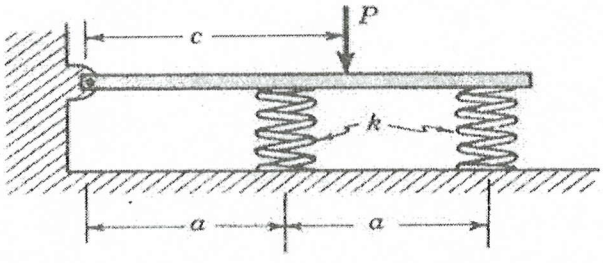


Figure 3/*Gambarajah 3*

3. The rocket shown experiences a wind gust during its vertical ascent which results in the loading shown. Rotation of the system may be prevented if the resultant moment about the center of mass of the system vanishes. This is to be achieved by varying the orientation of the thrust vector T with respect to the vertical axis. **(See Figure 4).**

(a) What relationship must exist among T, α, ρ_o, and L in order that this requirement be satisfied?

(b) Determine the inertial shear force and bending moment at L/4 and 3L/4 in terms of P_o.

Roket yang ditunjukkan mengalami tiupan angina semasa terbang secara tegak yang menyebabkan bebanan seperti yang ditunjukkan. Putaran sistem tersebut boleh dielakkan sekiranya momen keseluruhan di sekitar pusat jisim sistem tersebut hilang. Ini boleh dicapai dengan variasikan penghalaan vektor tuhajan T berbanding paksi tegak. ***(Lihat Gambarajah 4).***

(a) Apakah perhubungan yang perlu ada di antara T, α, ρ_o, dan L supaya keperluan ini dipenuhi?

(b) Tentukan daya ricih inersia dan momen lenturan pada L/4 dan 3L/4 dalam sebutan P_o.

(100 marks/*markah*)

4. Consider a thin-walled cylinder of internal radius r and thickness t. If the cylinder is subjected to an internal pressure p and an axial force F, show that the r,θ,z directions are the principal stress direction. Show also that if the wall is so thin that $t/r \ll 1$, then the stresses in the pipe wall are given approximately by: **(See Figure 5).**

$$\sigma_r = 0$$

$$\sigma_\theta = \frac{pr}{t}$$

$$\sigma_z = \frac{F}{2\pi rt}$$

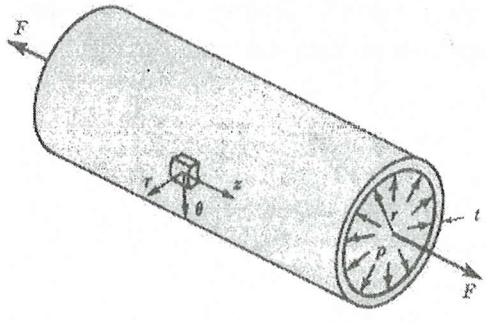
Sebuah silinder berdinding nipis mempunyai jejari dalaman r dan ketebalan t. Jika silinder tersebut dikenakan tekanan dalam p dan daya paksian F, tunjukkan arah r,θ,z adalah arah tegasan utama. Tunjukkan juga sekiranya dinding tersebut sangat nipis sehingga $t/r \ll 1$, tegasan pada dinding paip boleh didapati dengan: ***(Lihat Gambarajah 5).***

$$\sigma_r = 0$$

$$\sigma_\theta = \frac{pr}{t}$$

$$\sigma_z = \frac{F}{2\pi rt}$$

(100 marks/*markah*)



Gambarajah 5/*Figure 5*

PART B: Answer only TWO (2) questions
BAHAGIAN B: Jawab hanya DUA (2) soalan

5. (a) Define the terminologies below

(i) Proportional limit
(ii) Elastic limit
(iii) Yield strength
(iv) Yield point
(v) Upper yield point
(vi) Lower yield point
(vii) Flow strength
(viii) Strain-harderning

Berikan takrifan maksud di bawah

(i) Had berkadaran
(ii) Had elastik
(iii) Kekuatan alah
(iv) Titik atau takat alah
(v) Titik alah atas
(vi) Titik alah bawah
(vii) Kekuatan aliran
(viii) Pengerasan terikan

(40 marks/*markah*)

(b) Below is the example of a graph of a bar, which is a ductile material. Define and elaborate the three stages of the graph as the bar reaches point F (fracture point). **(See Figure 6).**

Gambarajah di bawah adalah satu contoh palang di mana palang tersebut adalah bahan mulur. Terang dan jelaskan tiga peringkat bentuk graf tersebut sebelum palang mencapai titik patah. ***(Lihat Gambarajah 6).***

(30 markah/*marks*)

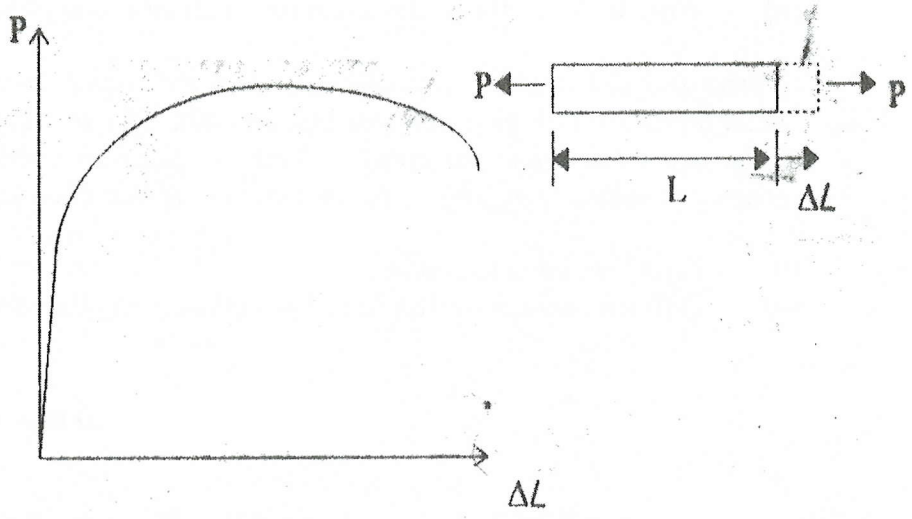


Figure 6/*Gambarajah 6*

(c) Draw the graphs of the idealized models of:

(i) Rigid material
(ii) Linearly elastic material
(iii) Perfectly plastic material
(iv) Rigid-plastic material
(v) Elastic-perfectly plastic material (non-strain-hardening)
(vi) Elastic-plastic material (strain-hardening)

Lukis graf model terunggul untuk bahan berikut:

(i) Bahan tegar
(ii) Bahan elastik yang linear
(iii) Bahan plastik yang sempurna
(iv) Bahan plastik-tegar
(v) Bahan plastik yang sempurna-elastik (tanpa pengerasan terikan)
(vi) Bahan elastik-plastik

(30 marks/*markah*)

6. (a) In figure below, the lower gage is mark as the point of zero displacement, and the displacement vectors of various points on the specimen are shown in the figure. If the displacements vary uniformly over the gage length L, **(See Figure 7).**

(i) Write the displacement equation.
(ii) Write the equation of the strain for small strains applications

Gambarajah di bawah menunjukkan satu bahan di mana, bahagian bawah bahan tersebut ditakrifkan sebagai titik anjakan sifar dan anjakan vektor adalah seperti di dalam gambarajah di bawah. Sekiranya, anjakan adalah seragam di seluruh panjang, L, bahan tersebut, ***(Lihat Gambarajah 7).***

(i) Tulis persamaan anjakan
(ii) Tulis persamaan terikan (untuk penggunaan terikan kecil)

(20 marks/*markah*)

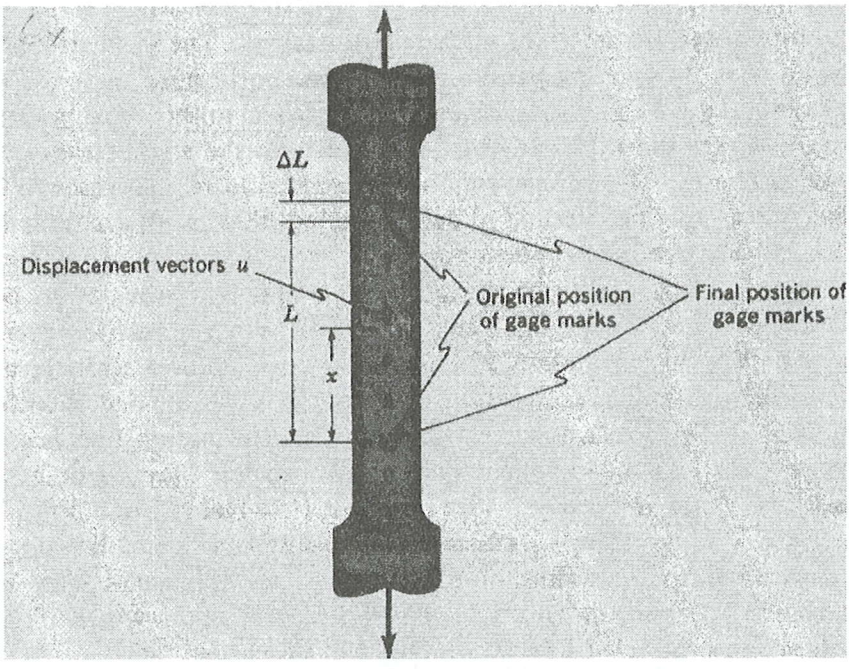


Figure 7/*Gambarajah 7*

(b) Define and elaborate the criterion between Von Mises yield criterion and Maximum shear stress criterion, and explain one difference between those two criterion.

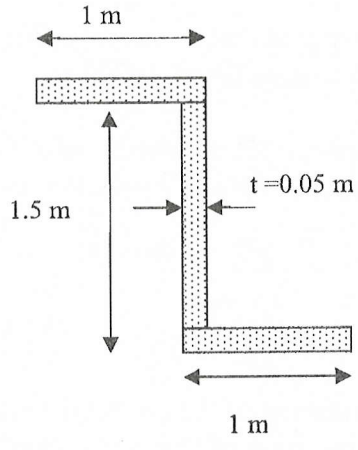
Takrif dan jelaskan kriterium di antara kriterium alah Von Mises dengan kriterium tegasan ricik maksimum, dan jelaskan satu perbezaan di antara dua kriterium tersebut.

(30 marks/*markah*)

(c) Calculate the Polar Moment of Inertia (moment of Inertia) I_z of the diagrams below. $\beta = 1/3$

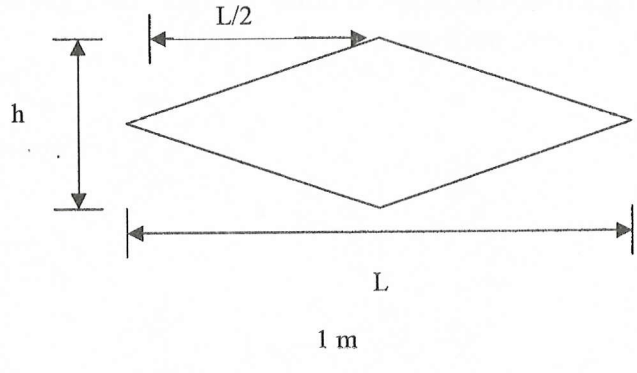
Hitungkan momen inersia kutub, I_z, untuk diagram di bawah: $\beta = 1/3$

(i)



$\beta = 1/3$

(ii) (L>>h).



$\beta = 1/3$

(50 marks/*markah*)

7. (a) Define the meaning of Residual Stress. Elaborate the residual stress in terms of graphs and diagrams.

Takrifkan maksud tegasan baki. Jelaskan maksud tegasan baki bentuk graf dan diagram.

(40 marks/*markah*)

(b) A Solid Circular Shaft has a 3 inch radius. If the maximum shear stress in the shaft is 10000 psi,

(i) What is the maximum of the torsional moment?
(ii) What is the value of the twist angle (in radian)?

Sebuah aci bulat yang padu mempunyai radius 3 inch. Sekiranya, tegasan ricih maksimum dalam aci adalah 10000 psi,

(i) Hitungkan momen kilasan maksimum?
(ii) Hitungkan nilai sudut piuhan (dalam nilai radian)?

(30 marks/*markah*)

(c) (i) Define the meaning of the isotropic material?
(ii) Explain the meaning of Poisson's ratio? (in terms of Young's Modulus and shear-strain formula)

(i) Takrihkan maksud bahan isotropi?
(ii) Jelaskan maksud kadar Poisson? (dengan menggunakan Modulus Young, E, dan persamaan terikan ricih)

(30 marks/*markah*)

8. (a) If the stresses are due to bending

(i) Define the meaning of Pure bending.
(ii) Draw the radius of curvature
(iii) Draw the plane of symmetry
(iv) Define the stresses obtained from the stress-strain relations. (restricted to linear isotropic elastic materials, and to materials which follow Hooke's Law)

Di dalam tegasan yang disebabkan oleh lenturan,

(i) Takrifkan maksud lenturan tulen.
(ii) Lukiskan jejari kelengkungan.
(iii) Lukiskan satah simetri.
(iv) Takrifkan tegasan yang dihasilkan dari hubungkait tegasan-terikan. (Di dalam aplikasi bahan elastik isotropi yang linear dan bahan yang menuruti Hukum Hooke)

(50 marks/*markah*)

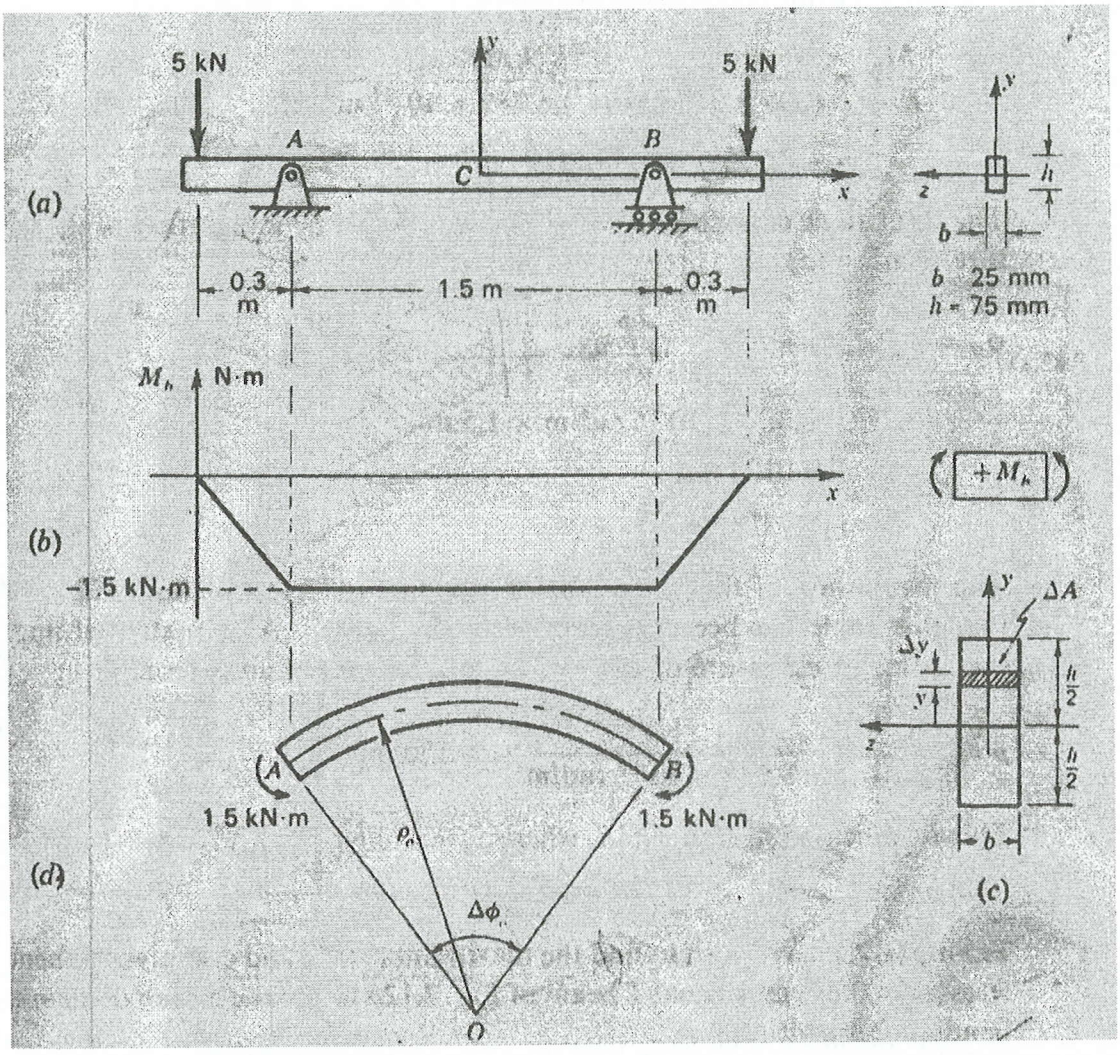
(b) A steel beam 25 mm wide and 75 mm deep is pinned to support at points A and B, as shown in Figure below, where the support B is on rollers and free to move horizontally. When the ends of the beam are loaded with 5-kN loads, find

(i) The maximum bending stress at the mid-span of the beam.
(ii) The angle $\Delta\Phi_0$ subtended by the cross sections at A and B in the deformed beam.

Satu keluli alur mempunyai lebar 25 mm dan tinggi 75 mm, dipinkan di bahagian A dan B, seperti di dalam gambarah di bawah, di mana sokongan di titik B adalah pengguling dan adalah bebas bergerak secara mendatar. Apabila beban 5 kN diletakkan di kedua-dua hujung alur, hitungkan

(i) Tegasan lentur maksimum di rentang tengah alur
(ii) Sudut $\Delta\Phi_0$ yang terletak di antara keratan rentas A dan B di dalam proses pengubah bentukan alur.

(50 marks/*markah*)


5 kN
5 kN
A
B
C
y
x
(a)
0.3 m
1.5 m
0.3 m
z
h
b
b 25 mm
h = 75 mm
M_b N·m
(b)
−1.5 kN·m
$+M_b$
y
ΔA
Δy
y
z
h/2
h/2
b
(c)
A
B
1.5 kN·m
1.5 kN·m
ρ_n
$\Delta\phi_n$
O
(d)

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