UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2015/2016 Academic Session

June 2016

EAS152 – Strength of Materials
[Kekuatan Bahan]

Duration : 3 hours
[Masa : 3 jam]

Please check that this examination paper consists of **FIFTEEN (15)** pages of printed material including **ONE (1)** appendix before you begin the examination.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **LIMA BELAS (15)** muka surat yang bercetak termasuk **SATU (1)** lampiran sebelum anda memulakan peperiksaan ini.]*

Instructions : This paper contains **SEVEN (7)** questions. Answer **FIVE (5)** questions.

*[**Arahan** : Kertas ini mengandungi **TUJUH (7)** soalan. Jawab **LIMA (5)** soalan.]*

All questions **MUST BE** answered on a new page.

*[Semua soalan **MESTILAH** dijawab pada muka surat baru.]*

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

[Sekiranya terdapat percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.]

1. [a] For the problem of a bar being compressed by a load *P* as shown in **Figure 1(a)**, compute:

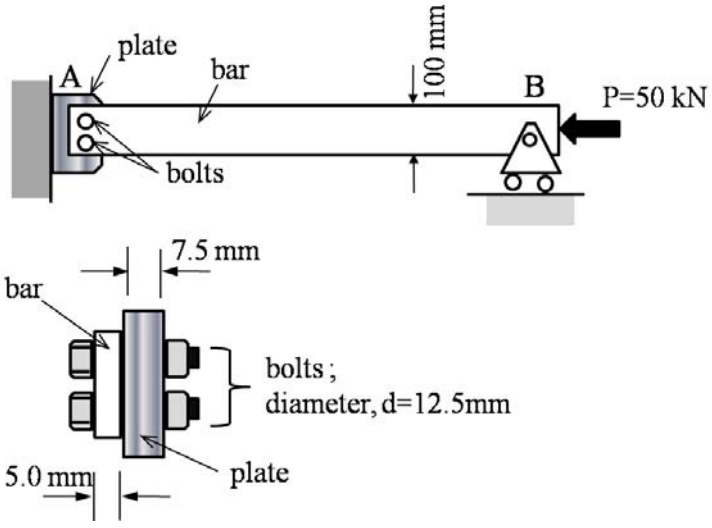
Untuk masalah bar yang dimampat oleh beban P seperti yang ditunjukkan dalam ***Rajah 1(a)****, kira:*

[i] the maximum normal stress in the bar
tegasan normal maksimum dalam bar

[ii] the shear stress in the bolt at A
tegasan ricih dalam bolt pada A

[iii] maximum bearing stress on bolt at A
tegasan galas maksimum ke atas bolt pada A

[6 marks/*markah*]



Details of connection at A

Figure 1(a)/ ***Rajah 1(a)***

[b] A rigid vertical member ADBC in **Figure 1(b)** is supported by a hinged joint at A and connected to a pair of inclined post BE by a hinged connection at B. Cross-sectional sizes of rigid vertical member ADBC and inclined post BE are 25 mm × 250 mm and 17.5 mm × 200 mm, respectively. Two concentrated loads P_1 and P_2 act on the rigid vertical member at point C and D, respectively. Details of connections at support A, joint B and support E are also shown in the figure. Diameters of bolt used at support A, connection B and support E are 15 mm, 12.5 mm and 15 mm, respectively.

*Satu anggota tegar pugak ADBC dalam **Rajah 1(b)** disokong oleh satu penyokong pin pada A dan disambung kepada satu anggota condong BE melalui satu sambungan pin pada B. Saiz keratan anggota tegar pugak ADBC dan anggota condong BE adalah masing-masing 25 mm × 250 mm and 17.5 mm × 200 mm. Dua beban tertumpu P_1 dan P_2 masing-masing bertindak ke atas anggota tegar pugak pada titik C dan D. Perincian sambungan pada penyokong A, sambungan B dan penyokong E juga ditunjuk dalam rajah. Garispusat untuk bolt yang digunakan pada penyokong A, sambungan B dan penyokong E adalah masing-masing 15 mm, 12.5 mm dan 15 mm.*

Compute:

Kira:

[i] normal stress in inclined post BE ;

tegasan normal dalam anggota condong BE;

[ii] shear stress in bolt at B;

tegasan ricih dalam bolt pada B;

[iii] bearing stress between bolt and rigid vertical member ADBC at B;

tegasan galas antara bolt dan anggota tegar pugak ADBC pada B;

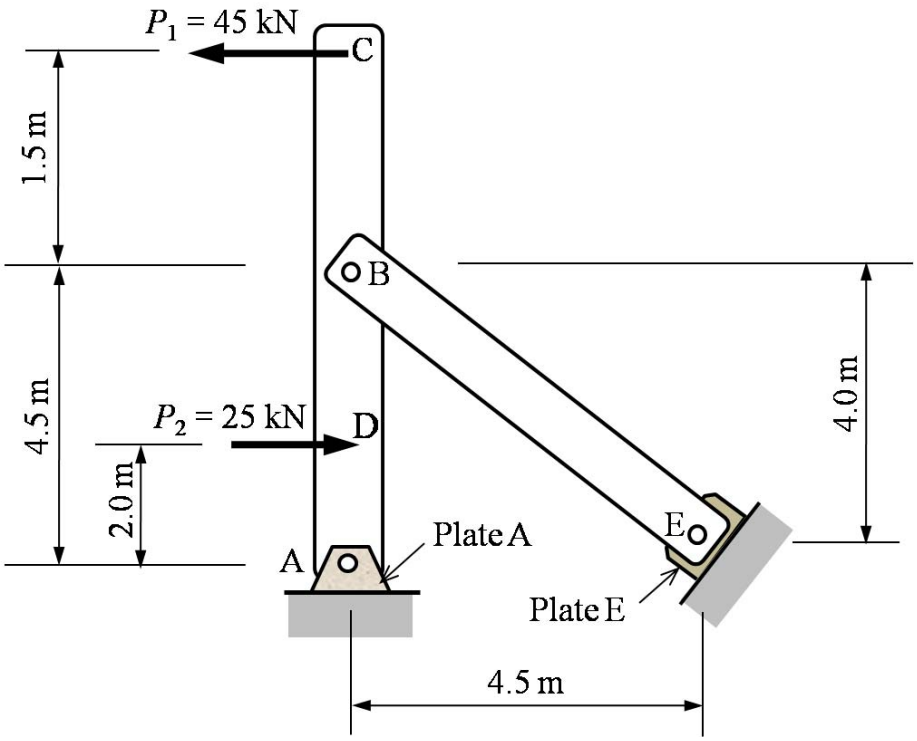
[iv] shear stress in bolt at A;

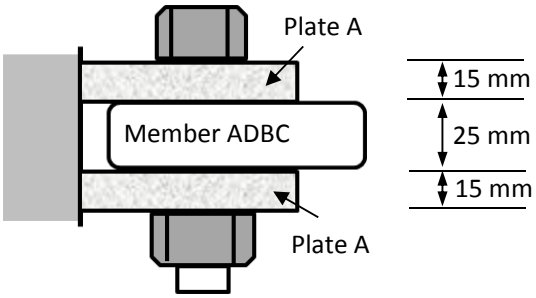
tegasan ricih dalam bolt pada A;

[v] maximum bearing stress on bolt at A

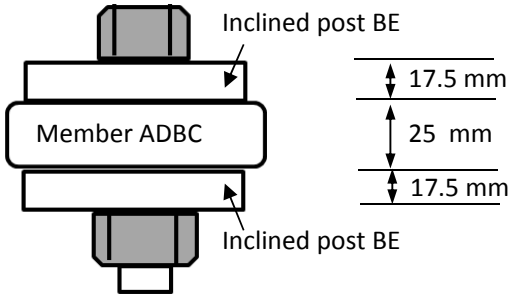
tegasan galas maksimum ke atas bolt pada A

[14 marks/*markah*]

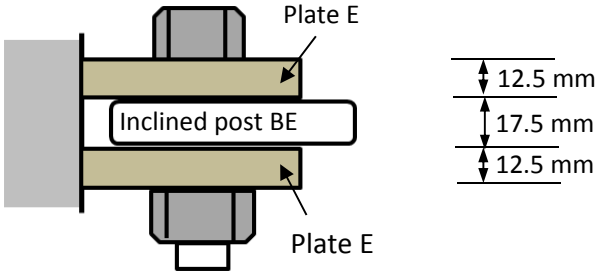




Connection detail at support A



Connection detail at joint B



Connection detail at support E

Figure 1(b)/ *Rajah 1(b)*

2. [a] For the stepped bar ABC shown in **Figure 2(a)**, determine the magnitude of load P at C so that displacement at C is zero. Cross-sectional areas of portion AB and BC are shown in the figure. Use E = 200 GPa.

*Untuk bar pelbagai keratan ABC seperti yang ditunjukkan dalam **Rajah 2(a)**, tentukan magnitud beban P pada C supaya anjakan pada C adalah kosong. Luas keratan bahagian AB dan BC adalah seperti yang ditunjukkan dalam rajah. Guna E=200 GPa.*

[6 marks/*markah*]

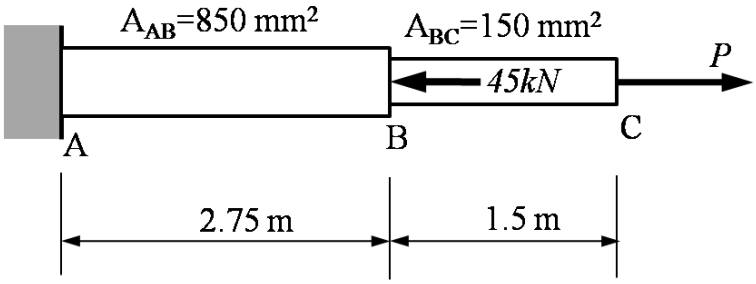


Figure 2(a)/ *Rajah 2(a)*

[b] **Figure 2(b)** shows a rigid horizontal beam ABCE which is supported by a pair of rectangular bar CD at C. The cross-sectional size of each of the rectangular bar is 37.5 mm × 12.5 mm. Modulus of elasticity of the bar is E = 125 GPa. Vertical loads of 17.5 kN and 35 kN act at points B and E, respectively.

Rajah 2(b) *menunjukkan satu rasuk tegar ufuk ABCE yang disokong oleh sepasang bar segiempat tepat CD pada C. Saiz keratan setiap bar segiempat tepat adalah 37.5 mm × 12.5 mm. Modulus keanjalan bar adalah E = 125 GPa. Beban pugak 17.5 kN dan 35 kN masing-masing bertindak pada B dan E.*

Compute:

Kira:

[i] Vertical displacement of point C

anjakan pugak titik C

[ii] Vertical displacement of point B

anjakan pugak titik B

[iii] Vertical displacement of point E

anjakan pugak titik E

If it is given that the allowable displacement of point C is 0.5 mm and that the width of rectangular bar CD should be kept unchanged, determine the minimum thickness of rectangular bar CD required.

Sekiranya diberi bahawa anjakan dibenarkan pada titik C adalah 0.5 mm dan lebar bar segiempat tepat CD harus dikekalkan, tentukan tebal minima yang diperlukan untuk bar segiempat tepat CD.

[14 marks/*markah*]

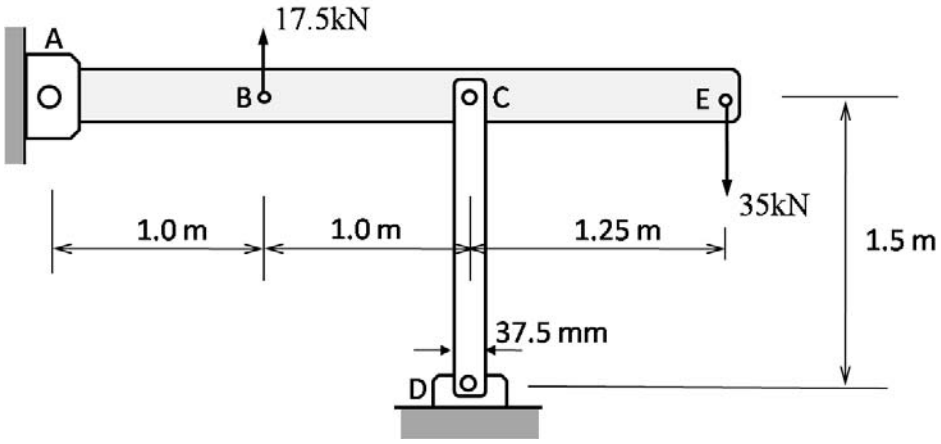


Figure 2(b)/ *Rajah 2(b)*

3. An I-beam is used to carry a concentrated load 15 kN at B, a uniformly distributed load 5kN/m along portion BC and a concentrated moment 80 kNm at A as shown in **Figure 3**.

*Sebatang rasuk I digunakan untuk membawa satu beban tertumpu 15 kN pada B, satu beban teragih seragam 5 kN/m di sepanjang BC dan satu momen tertumpu 80 kNm pada A seperti yang ditunjukkan dalam **Rajah 3**.*

[a] Draw the shear and bending-moment diagrams,

Lukis gambarajah daya ricih dan momen lentur,

[16 marks/*markah*]

[b] State the maximum value of shear force and bending moment,

Nyatakan nilai maksimum bagi daya ricih dan momen lentur,

[2 marks/*markah*]

[c] Determine the maximum normal stress due to bending.

Tentukan nilai tegasan normal maksimum disebabkan lenturan.

[2 marks/*markah*]

Given the section modulus, S for the I-beam section is $1030 \times 10^{-6}\ m^3$.

Diberikan modulus keratan S untuk keratan rasuk I adalah $1030 \times 10^{-6}\ m^3$.

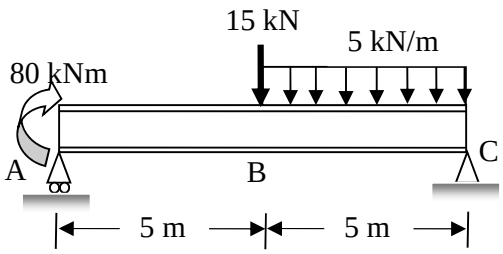


Figure 3 / *Rajah 3*

4. [a] Torsion of a shaft is produced by a couple twisting the shaft. Using a sketch, explain what are a couple, torque and angle of twist.

Kilasan aci dihasilkan oleh daya ganding yang mengilas aci berkenaan. Dengan menggunakan lakaran, jelaskan apa itu daya ganding, momen kilasan dan sudut kilasan.

[3 marks/*markah*]

[b] When an electrical motor as shown in **Figure 4** operates, it transmits 100 kW to the shaft at 15 Hz. The gears at B, C and D drive a machinery requiring power equal to 45 kW, 30 kW and 25 kW, respectively. Calculate the maximum shearing stress in the shaft and the angle of twist ϕ_{AD} between the motor at A and gear at D if:

*Apabila motor elektrik seperti yang ditunjukkan dalam **Rajah 4** beroperasi, ia menghantar kuasa sebanyak 100 kW ke aci dalam 15 Hz. Gear di B, C and D memacu mesin yang masing-masing memerlukan kuasa 45 kW, 30 kW dan 25 kW. Kirakan tegasan ricih maksimum dalam aci dan sudut kilasan ϕ_{AD} antara motor di A dan gear di D jika:*

[i] each shaft is solid
setiap aci adalah padu

[ii] each shaft is hollow with 10 mm wall thickness
setiap aci adalah geronggang dengan ketebalan dinding 10 mm

For solid shaft assembly, determine the smallest diameter of shaft AB so that the maximum shearing stress will not be increased. Use shear modulus of 80 GPa.

Untuk pemasangan aci padu, tentukan diameter terkecil untuk aci AB supaya tegasan ricih maksimum tidak bertambah. Guna modulus ricih 80 GPa.

[17 marks/*markah*]

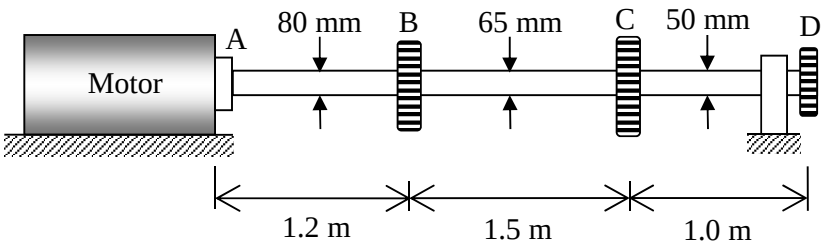


Figure 4 / *Rajah 4*

5. Using Mohr's circle determine the equivalent state of stress on an element at the same point for the following cases with respects to the element shown in **Figure 5**.

*Menggunakan bulatan Mohr tentukan tegasan setara pada elemen di titik yang sama untuk kes-kes berikut berdasarkan elemen yang ditunjukkan dalam **Rajah 5**.*

[a] the principal stress and the corresponding orientation.
Tegasan utama dan arah putarannya

[b] the maximum in-plane shear stress and the associated average normal stress and the corresponding orientation.
Tegasan ricih maksimum beserta tegasan normal purata dan arah putarannya

[c] the stresses at angles of 15° and 45°.
Tegasan pada sudut 15° dan 45°.

Sketch the corresponding element for each case.

Lakarkan elemen berkenaan untuk setiap kes.

[20 marks/*markah*]

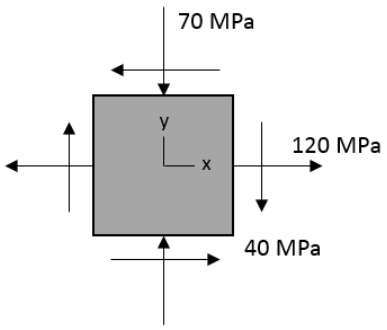


Figure 5 / *Rajah 5*

6. A 8.2 m long steel column as shown in **Figure 6** is braced about the z-z axis using struts that are assumed to be pin connected to its mid-height. Use Young's modulus and yield stress of the steel column as 200 GPa and 400 MPa, respectively.

*Sebatang tiang keluli sepanjang 8.2 m seperti ditunjukkan dalam **Rajah 6** dirembat menggunakan topang yang diandaikan sebagai sambungan pin di pertengahan tiang tersebut. Guna modulus keanjalan dan tegasan alah masing-masing sebagai 200 GPa dan 400 MPa.*

[a] Sketch the x-x and z-z axes buckling modes of the column with the following end conditions. Show the distance of contra-flexure point of the column from any end supports.

Lakarkan mod lengkokan terhadap paksi x-x dan z-z tiang tersebut berdasarkan keadaan hujung berikut. Tunjukkan jarak titik kontra-lentur tiang tersebut dari mana-mana penyokong hujung.

[i] Fixed – fixed ends
Hujung tegar – tegar

[ii] Fixed – pinned ends
Hujung tegar – pin

[4 marks/*markah*]

[b] Determine the maximum load that can be applied so that the column does not buckle or yield. The load is applied through the centroid of the column cross section. Assume *a* and *b* as 150 mm and 300 mm, respectively. Consider any one of the end conditions stated in **Question 6(a)** to calculate the maximum load.

*Tentukan beban maksimum yang boleh dikenakan supaya tiang tidak melengkok atau alah. Beban yang dikenakan adalah melalui sentroid keratan rentas tiang. Andaikan a dan b masing-masing sebagai 150 mm dan 300 mm. Pertimbangkan salah satu daripada keadaan hujung yang dinyatakan dalam **Soalan 6[a]** untuk mengira beban maksimum.*

[8 marks/*markah*]

[c] If the column has to carry an additional load of 25% of the maximum load calculated in **Question 6[b]**, determine the new cross sectional area of the column so the column does not buckle or yield. Use the same end conditions assumed in **Question 6[b].**

*Sekiranya tiang tersebut perlu menanggung beban tambahan sebanyak 25% daripada beban maksimum yang telah dikira dalam **Soalan 6[b],** tentukan keratan rentas baharu tiang supaya tiang tidak melengkok atau alah. Gunakan keadaan hujung yang sama seperti yang diandaikan dalam **Soalan 6[b].***

[8 marks/*markah*]

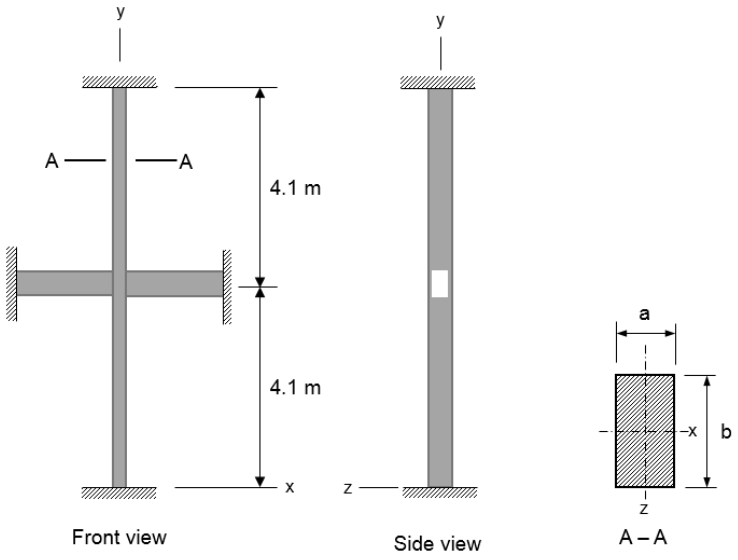
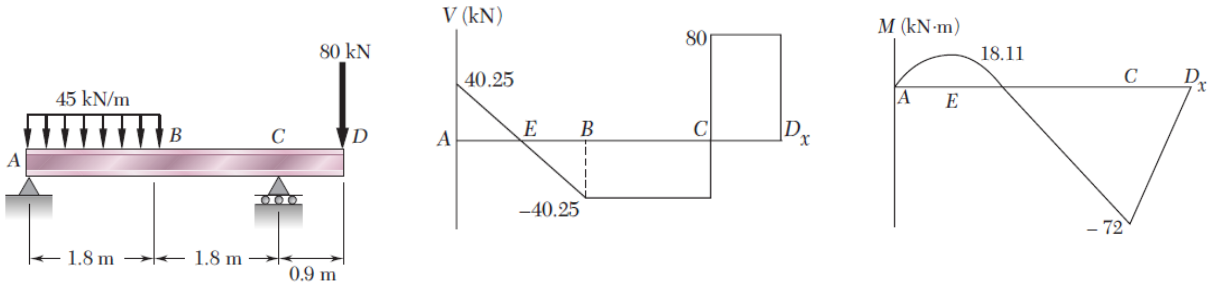


Figure 6 / *Rajah 6*

7. [a] A 4.5 m long steel beam with overhang CD is to carry the distributed and concentrated loads shown in **Figure 7(a)**. Knowing that the allowable normal stress in bending for the grade of steel to be used is 165 MPa, select the most suitable W-Shape universal beam section in terms of section modulus that should be used **(refer to Appendix)**.

*Sebatang rasuk keluli dengan bahagian terjulur CD dengan panjang 4.5 m diperlukan untuk menanggung beban teragih seragam dan tumpu seperti dalam **Rajah 7(a)**. Diketahui tegasan normal akibat lenturan yang dibenarkan untuk gred keluli yang akan digunakan adalah 165 MPa, pilih keratan rasuk universal bentuk W yang paling sesuai digunakan dari segi modulus keratan **(rujuk Lampiran).***

[10 marks/*markah*]



(a) A beam (b) Shear force (c) Bending moment

Figure 7(a) / *Rajah 7(a)*

[b] [i] **Figure 7(b)** shows a cantilever beam AC subjected to a uniformly distributed load of 5 kN/m along portion BC. Calculate the vertical deflection at joint B of the beam in terms of EI which is constant for the beam.

***Rajah 7(b)** menunjukkan satu rasuk julur AC dikenakan beban teragih seragam 5 kN/m sepanjang rentang BC. Kira pesongan tegak rasuk di titik B dalam sebutan EI yang malar sepanjang rasuk.*

[8 marks/*markah*]

[ii] Calculate the required value of *I* if the vertical deflection at joint B is 5 cm. Given *E* is 200 GPa.

Kirakan nilai I yang diperlukan sekiranya pesongan tegak di titik B ialah 5 cm. Diberikan E ialah 200 GPa.

[2 marks/*markah*]

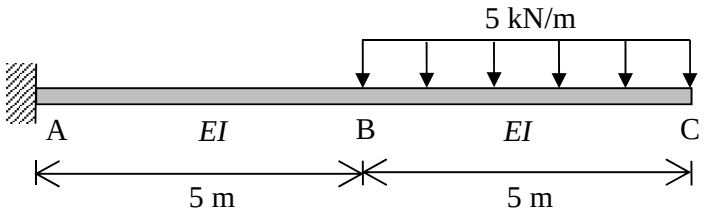
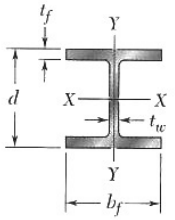


Figure 7(b) / *Rajah 7(b)*

APPENDIX / *LAMPIRAN*



Properties of Rolled-Steel Shapes
(SI Units)

W Shapes
(Wide-Flange Shapes)

Designation†	Area A, mm²	Depth d, mm	Flange: Width b_f, mm	Flange: Thickness t_f, mm	Web Thickness t_w, mm	Axis X-X: I_x 10⁶ mm⁴	Axis X-X: S_x 10³ mm³	Axis X-X: r_x mm	Axis Y-Y: I_y 10⁶ mm⁴	Axis Y-Y: S_y 10³ mm³	Axis Y-Y: r_y mm
W310 × 143	18200	323	309	22.9	14.0	348	2150	138	113	731	78.8
107	13600	311	306	17.0	10.9	248	1590	135	81.2	531	77.3
74	9480	310	205	16.3	9.4	165	1060	132	23.4	228	49.7
60	7590	303	203	13.1	7.5	129	851	130	18.3	180	49.1
52	6670	318	167	13.2	7.6	119	748	134	10.3	123	39.3
44.5	5690	313	166	11.2	6.6	99.2	634	132	8.55	103	38.8
38.7	4940	310	165	9.7	5.8	85.1	549	131	7.27	88.1	38.4
32.7	4180	313	102	10.8	6.6	65.0	415	125	1.92	37.6	21.4
23.8	3040	305	101	6.7	5.6	42.7	280	119	1.16	23.0	19.5
W250 × 167	21300	289	265	31.8	19.2	300	2080	119	98.8	746	68.1
101	12900	264	257	19.6	11.9	164	1240	113	55.5	432	65.6
80	10200	256	255	15.6	9.4	126	984	111	43.1	338	65.0
67	8580	257	204	15.7	8.9	104	809	110	22.2	218	51.0
58	7420	252	203	13.5	8.0	87.3	693	108	18.8	185	50.3
49.1	6250	247	202	11.0	7.4	70.6	572	106	15.1	150	49.2
44.8	5720	266	148	13.0	7.6	71.1	535	111	7.03	95.0	35.1
32.7	4180	258	146	9.1	6.1	48.9	379	108	4.73	64.8	33.7
28.4	3630	260	102	10.0	6.4	40.0	308	105	1.78	34.9	22.1
22.3	2850	254	102	6.9	5.8	28.9	228	101	1.23	24.1	20.8
W200 × 86	11000	222	209	20.6	13.0	94.7	853	92.4	31.4	300	53.2
71	9100	216	206	17.4	10.2	76.6	709	91.7	25.4	247	52.8
59	7560	210	205	14.2	9.1	61.1	582	89.9	20.4	199	51.9
52	6660	206	204	12.6	7.9	52.7	512	89.0	17.8	175	51.7
46.1	5860	203	203	11.0	7.2	45.5	448	87.9	15.3	151	51.1
41.7	5310	205	166	11.8	7.2	40.9	399	87.8	9.01	109	41.2
35.9	4580	201	165	10.2	6.2	34.4	342	86.7	7.64	92.6	40.8
31.3	4000	210	134	10.2	6.4	31.4	299	88.6	4.1	61.2	32.0
26.6	3390	207	133	8.4	5.8	25.8	249	87.2	3.3	49.6	31.2
22.5	2860	206	102	8.0	6.2	20.0	194	83.6	1.42	27.8	22.3
19.3	2480	203	102	6.5	5.8	16.6	164	81.8	1.15	22.5	21.5
W150 × 37.1	4730	162	154	11.6	8.1	22.2	274	68.5	7.07	91.8	38.7
29.8	3790	157	153	9.3	6.6	17.2	219	67.4	5.56	72.7	38.3
24.0	3060	160	102	10.3	6.6	13.4	168	66.2	1.83	35.9	24.5
18.0	2290	153	102	7.1	5.8	9.17	120	63.3	1.26	24.7	23.5
13.5	1730	150	100	5.5	4.3	6.87	91.6	63.0	0.918	18.4	23.0
W130 × 28.1	3580	131	128	10.9	6.9	10.9	166	55.2	3.81	59.5	32.6
23.8	3010	127	127	9.1	6.1	8.80	139	54.1	3.11	49.0	32.1
W100 × 19.3	2480	106	103	8.8	7.1	4.77	90.0	43.9	1.61	31.3	25.5

†A wide-flange shape is designated by the letter W followed by the nominal depth in millimeters and the mass in kilograms per meter.

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