

National Exams May 2014

04-BS-6: Mechanics of Materials

3 hours duration

Notes:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper a clear statement of any assumptions made.
2. Candidates may use one of two calculators, the Casio or Sharp approved models.

This is a Closed Book exam. However candidates are permitted to bring the following into the examination room:

- ONE aid sheet 8.5" x 11" hand-written on both sides containing notes and formulae.
Example problems and solutions to problems are not allowed!
3. Any FIVE (5) questions (out of 8 given) constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.
 4. All questions are of equal value.
 5. Information on geometric properties of wide flange or W shape sections is attached at the end of this exam.

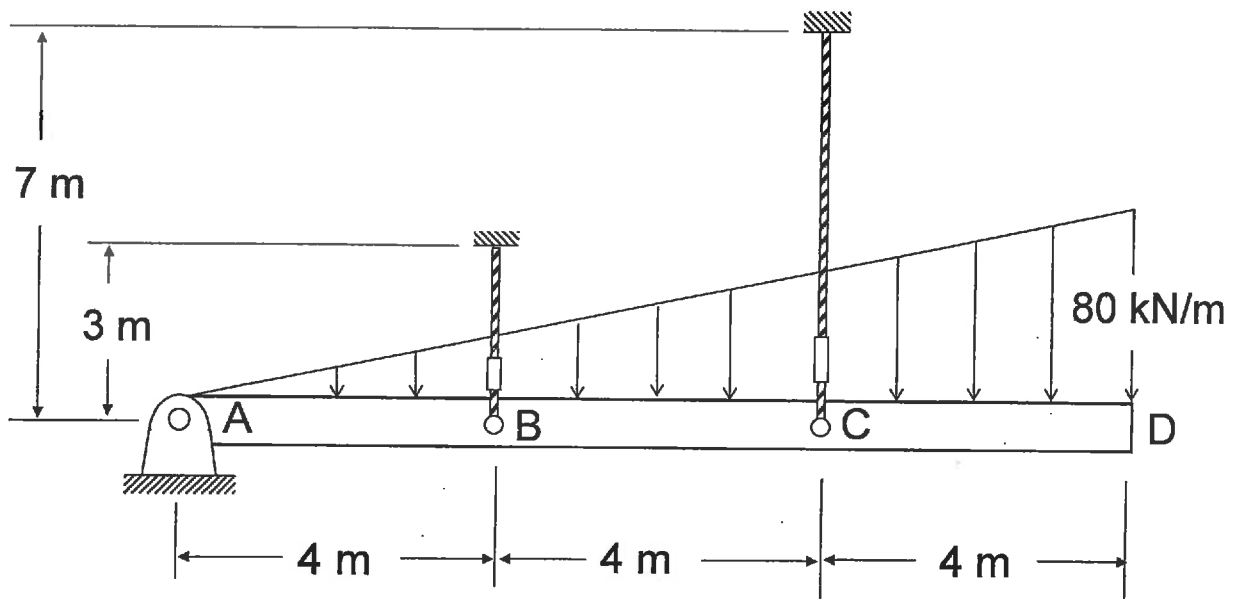
NOTE: The aid sheet must be handed in with the exam!

Your exam will not be marked if you do not hand in an aid sheet, unless there is a signed statement by the exam invigilator stating that no aid sheet was used for the exam.

Question 1: A rigid bar is supported by a 30 mm diameter pin at A and two 25 mm diameter cables at points B and C. The cable at B has a length of 3 m and the cable at C has a length of 7 m. Both cables are made of high strength steel with an elastic modulus of 200 GPa and yield stress of 800 MPa. The bar is loaded with a triangularly distributed load having a maximum intensity of 80 kN/m as shown.

Do the following:

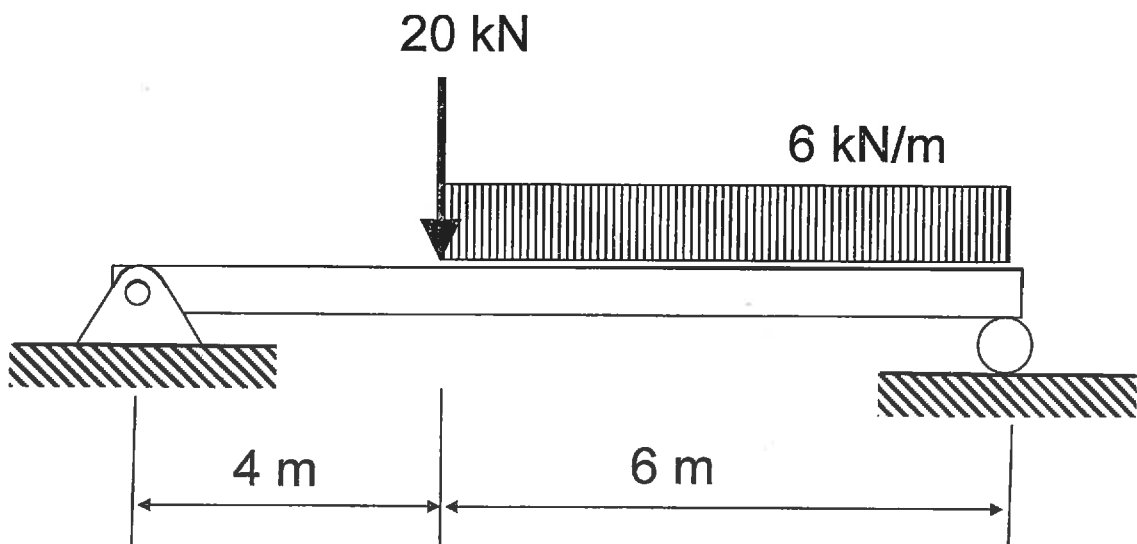
- [12 marks] (a) find the forces developed in each cable
- [4 marks] (b) determine the corresponding displacement at the end of the bar (point D)
- [4 marks] (c) find the corresponding shear stress in the pin at A given that the pin is loaded in double shear.



Question 2: A simply supported beam is subjected to a uniformly distributed load over part of the member span and a concentrated load as shown.

[20 marks] Determine the shear and moment throughout the beam as functions of x . This means that you need to give formula(s) for $V(x)$ and $M(x)$ along the length of the beam. Next construct the shear force and bending moment diagrams. Remember to label points of maximum and negative bending moment, as well as any inflection points. Show your work by indicating exactly how you obtained your answer.

Remember that it is important you set this problem up correctly by calculating the correct reaction forces at the support(s).

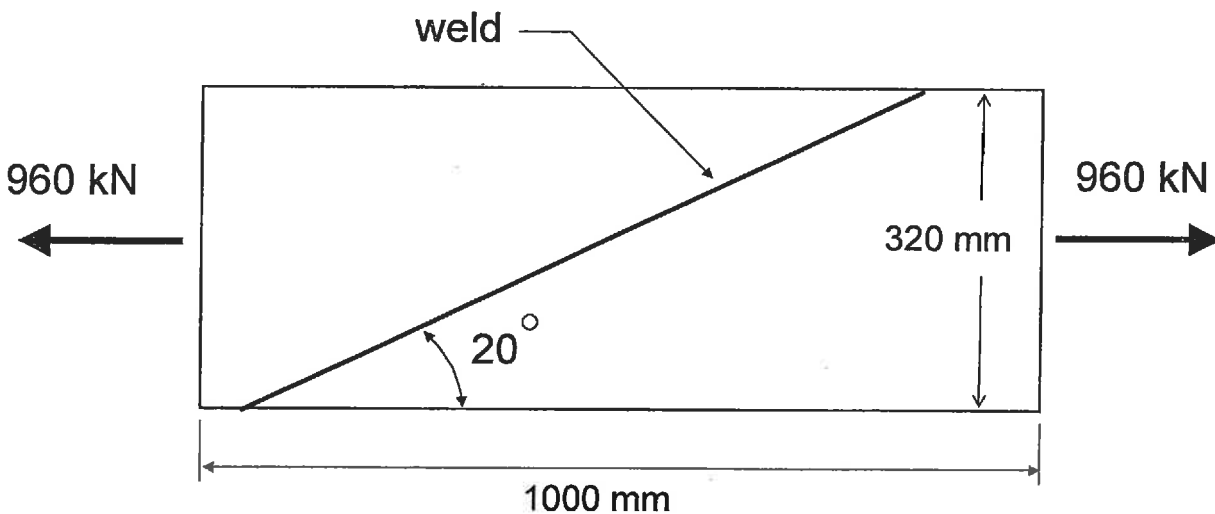


No credit will be given for a solution using the principle of superposition, when combinations of existing solutions are used to find an answer.

Question 3: Two steel plates 320 mm wide and 25 mm thick are welded together at an angle of 20 degrees to the horizontal axis as shown. The welded plate assembly resists an axial load of 960 kN.

[20 marks] Use the Mohr's circle solution (*not* the transformation equations) to determine the following:

- (a) the normal and shear stress acting on the welded joint. Make sure to show your answer on a properly oriented element.
- (b) the maximum in-plane shear stress (and associated normal stresses) acting on the steel plates. Once again, show your answer on a sketch of a properly oriented element.
- (c) briefly explain any alternative methods that you could use to solve this problem

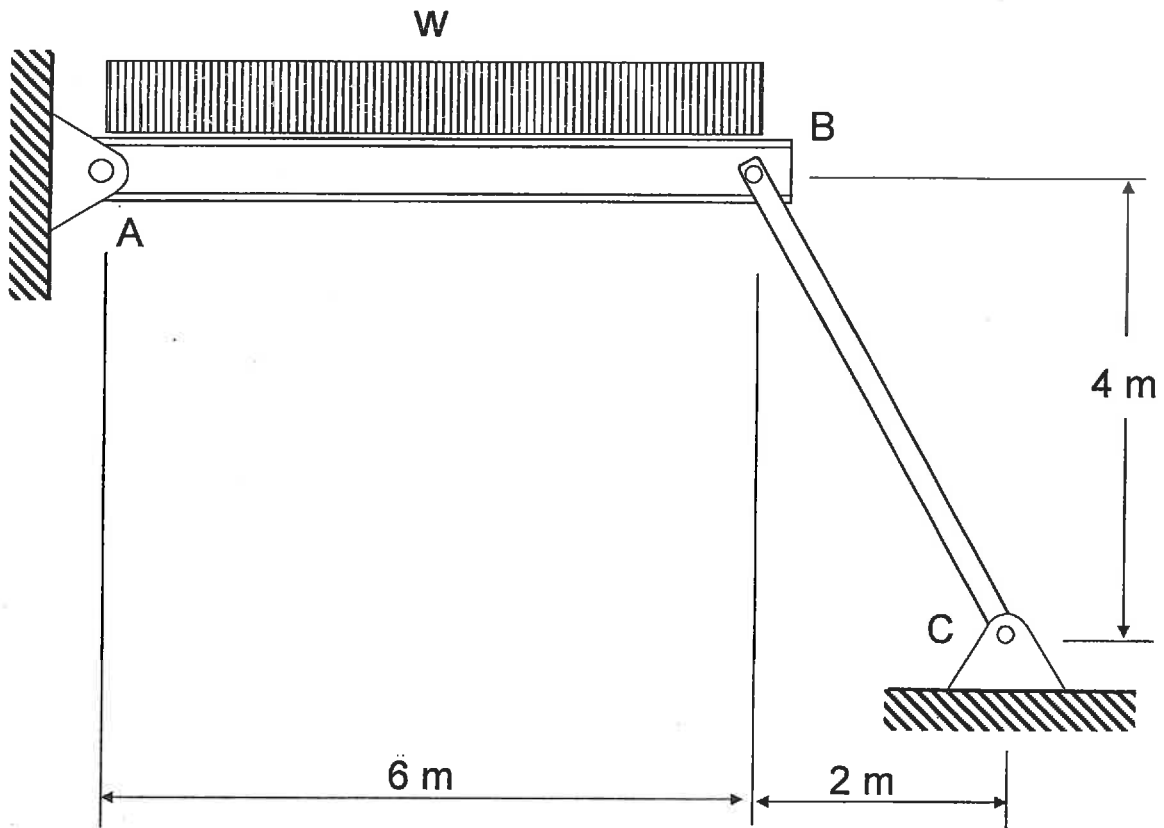


WARNING! Credit will **only** be given for a **solution using Mohr's circle**. Not the stress transformation equations. This means that you need to draw a Mohr's circle based on the stress components from this problem. Remember to show numbers on your circle. Your **calculations** must be based on the geometry of your circle. So use your calculator. In other words, you are expected to use trigonometry to construct your Mohr's circle. Do not give a graphical solution that is scaled off!

The stress transformation equations can only be used to check your answer.

Question 4: The horizontal beam AB is propped up by an inclined strut BC and supports a uniformly distributed load w . The strut is 80 mm by 80 mm in cross-section and is made of steel having a yield strength of 350 MPa and elastic modulus of 200 GPa. The strut is pinned at both ends as shown.

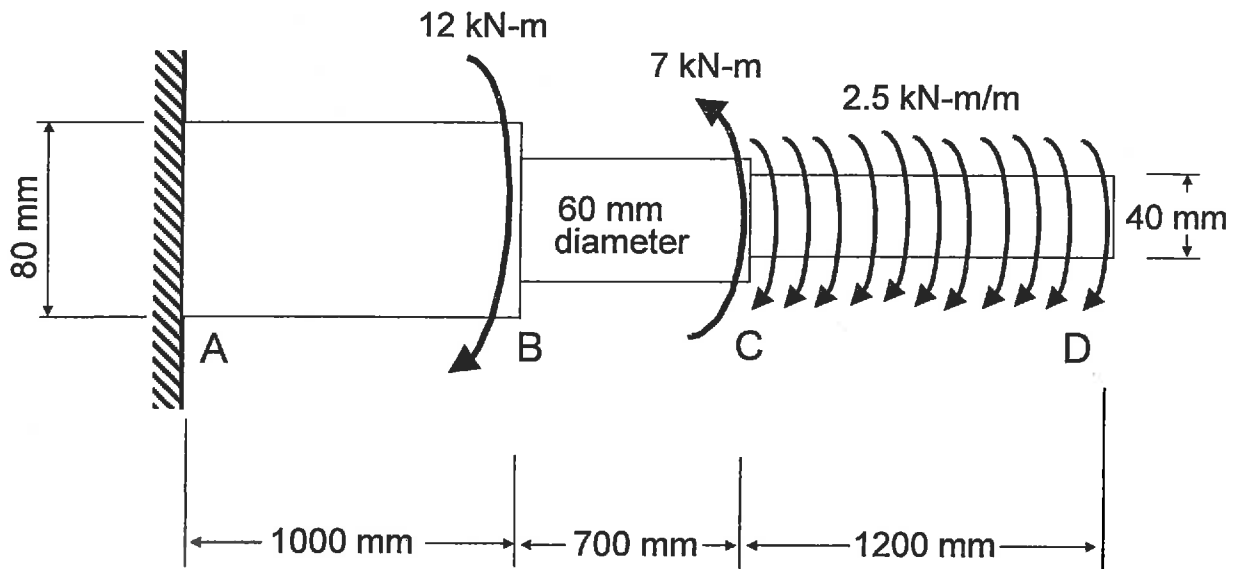
[20 marks] Determine the maximum load w the structure can carry assuming a factor of safety against buckling (of the inclined strut) set equal to 2. Consider buckling in the plane of the structure only. Do not use a safety factor for yielding of the steel.



Question 5: A stepped shaft ABCD is subjected to two concentrated torques (acting at B and C) and a uniformly distributed torque (acting along CD) as shown. The shaft is fixed at A. The entire shaft is made of steel having a shear modulus $G = 80 \text{ GPa}$ and a yield stress of 250 MPa . Dimensions (diameter and length) and magnitude of the torques are given in the diagram.

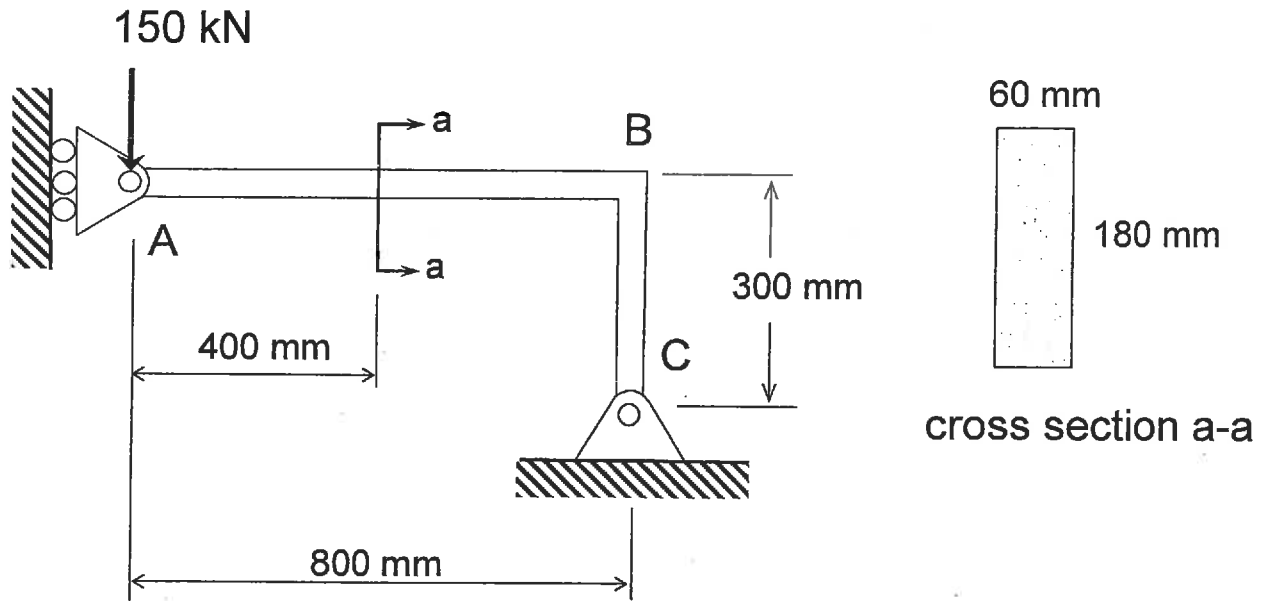
[12 marks] (a) determine the maximum shear stress in the shaft and sketch the corresponding variation of shear stress along the shaft radius at this point (where the stress is maximum).

[8 marks] (b) find the angle of twist at the end of the shaft (point D) and give your answer in degrees.



Question 6: A vertical force of 150 kN is applied to the L-shaped element with a rectangular cross-section as shown. The element is supported by a roller at A and a pin at C.

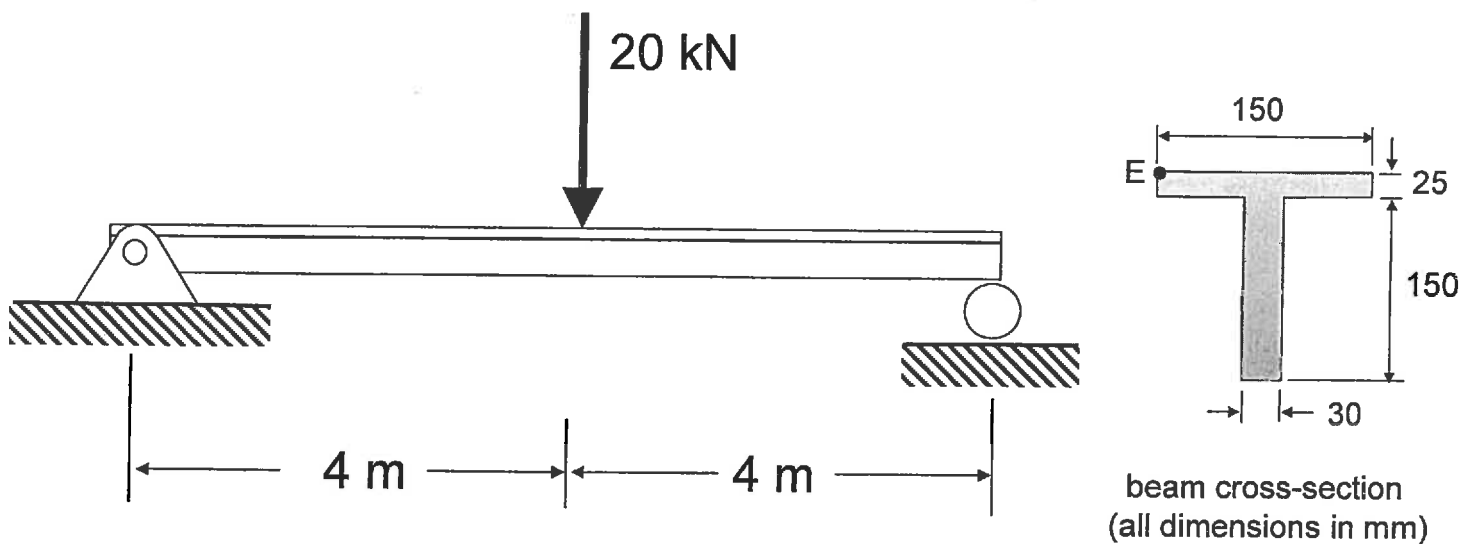
[20 marks] Compute and sketch the distribution of normal and shear stresses in the rectangular section at section a-a which is located 400 mm out from the support at A. Make sure to show your answers on a sketch. Give maximum and minimum values.



Question 7: A simply supported T-beam is subjected to a concentrated load at mid-span. The beam has the cross-section shown below and is made from steel having an allowable normal stress of 260 MPa and allowable shear stress of 60 MPa. The elastic modulus of the steel equals 200 GPa
[20 marks]

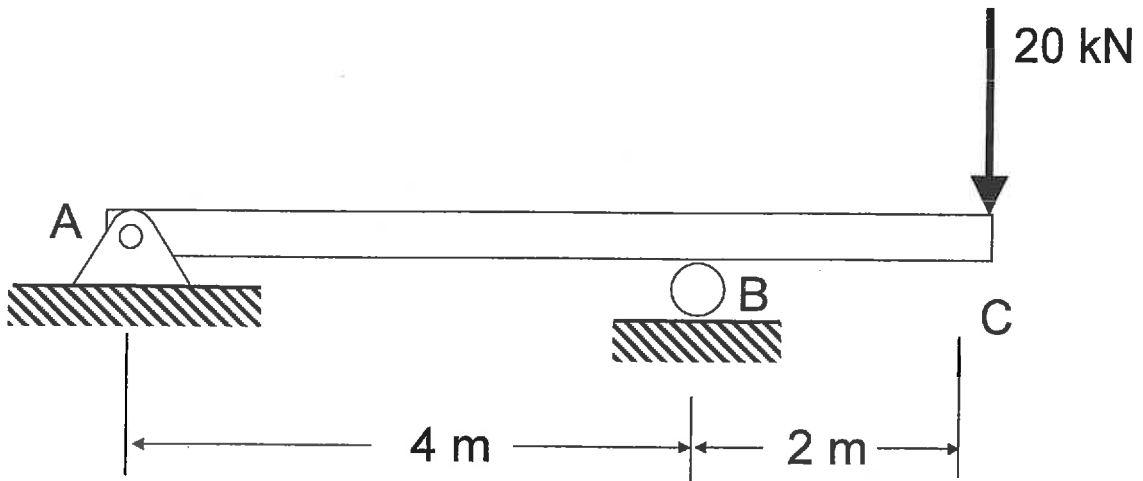
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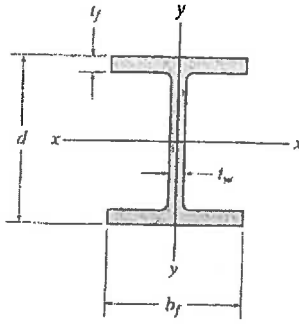
- determine the maximum (absolute) normal stress and maximum shear stress in the beam.
- determine the shear stress at the tip of the flange (point E) for the beam section located at the left support. To receive marks you must give reasons to justify your answer.



Question 8: A simply supported beam with an overhang is subjected to a concentrated load acting at the end of the overhang as shown. The beam is a W150x30 section made from steel having an allowable normal stress of 240 MPa and allowable shear stress of 60 MPa. The elastic modulus of the steel used in the beam equals 200 GPa.

[20 marks] Determine the deflection and slope at the end of the overhang (point C) using the method of integration.





Wide-Flange Sections or W Shapes SI Units											
Designation	Area A	Depth d	Web thickness t_w	Flange		x-x axis			y-y axis		
				width b_f	thickness t_f	I	S	r	I	S	r
W310 × 129	16 500	318	13.10	308.0	20.6	308	1940	137	100	649	77.8
W310 × 74	9 480	310	9.40	205.0	16.3	165	1060	132	23.4	228	49.7
W310 × 67	8 530	306	8.51	204.0	14.6	145	948	130	20.7	203	49.3
W310 × 39	4 930	310	5.84	165.0	9.7	84.8	547	131	7.23	87.6	38.3
W310 × 33	4 180	313	6.60	102.0	10.8	65.0	415	125	1.92	37.6	21.4
W310 × 24	3 040	305	5.59	101.0	6.7	42.8	281	119	1.16	23.0	19.5
W310 × 21	2 680	303	5.08	101.0	5.7	37.0	244	117	0.986	19.5	19.2
W250 × 149	19 000	282	17.30	263.0	28.4	259	1840	117	86.2	656	67.4
W250 × 80	10 200	256	9.40	255.0	15.6	126	984	111	43.1	338	65.0
W250 × 67	8 560	257	8.89	204.0	15.7	104	809	110	22.2	218	50.9
W250 × 58	7 400	252	8.00	203.0	13.5	87.3	693	109	18.8	185	50.4
W250 × 45	5 700	266	7.62	148.0	13.0	71.1	535	112	7.03	95	35.1
W250 × 28	3 620	260	6.35	102.0	10.0	39.9	307	105	1.78	34.9	22.2
W250 × 22	2 850	254	5.84	102.0	6.9	28.8	227	101	1.22	23.9	20.7
W250 × 18	2 280	251	4.83	101.0	5.3	22.5	179	99.3	0.919	18.2	20.1
W200 × 100	12 700	229	14.50	210.0	23.7	113	987	94.3	36.6	349	53.7
W200 × 86	11 000	222	13.00	209.0	20.6	94.7	853	92.8	31.4	300	53.4
W200 × 71	9 100	216	10.20	206.0	17.4	76.6	709	91.7	25.4	247	52.8
W200 × 59	7 580	210	9.14	205.0	14.2	61.2	583	89.9	20.4	199	51.9
W200 × 46	5 890	203	7.24	203.0	11.0	45.5	448	87.9	15.3	151	51.0
W200 × 36	4 570	201	6.22	165.0	10.2	34.4	342	86.8	7.64	92.6	40.9
W200 × 22	2 860	206	6.22	102.0	8.0	20.0	194	83.6	1.42	27.8	22.3
W150 × 37	4 730	162	8.13	154.0	11.6	22.2	274	68.5	7.07	91.8	38.7
W150 × 30	3 790	157	6.60	153.0	9.3	17.1	218	67.2	5.54	72.4	38.2
W150 × 22	2 860	152	5.84	152.0	6.6	12.1	159	65.0	3.87	50.9	36.8
W150 × 24	3 060	160	6.60	102.0	10.3	13.4	168	66.2	1.83	35.9	24.5
W150 × 18	2 290	153	5.84	102.0	7.1	9.19	120	63.3	1.26	24.7	23.5
W150 × 14	1 730	150	4.32	100.0	5.5	6.84	91.2	62.9	0.912	18.2	23.0