2707/302
STRUCTURES III
June/July 2017
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN CIVIL ENGINEERING

MODULE III

STRUCTURES III

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination;
  Answer booklet;
  Scientific calculator.
This paper consists of EIGHT questions.
Answer FIVE questions.
All questions carry equal marks.
Maximum marks for each part of a question are as indicated.
Candidates should answer the questions in English.

This paper consists of 9 printed pages.

Candidates should check the question paper to ascertain that all the
pages are printed as indicated and that no questions are missing.

Turn over

1. Analyze the frame shown in **figure 1** using the moment distribution method and hence sketch
   the bending moment diagram. (20 marks)
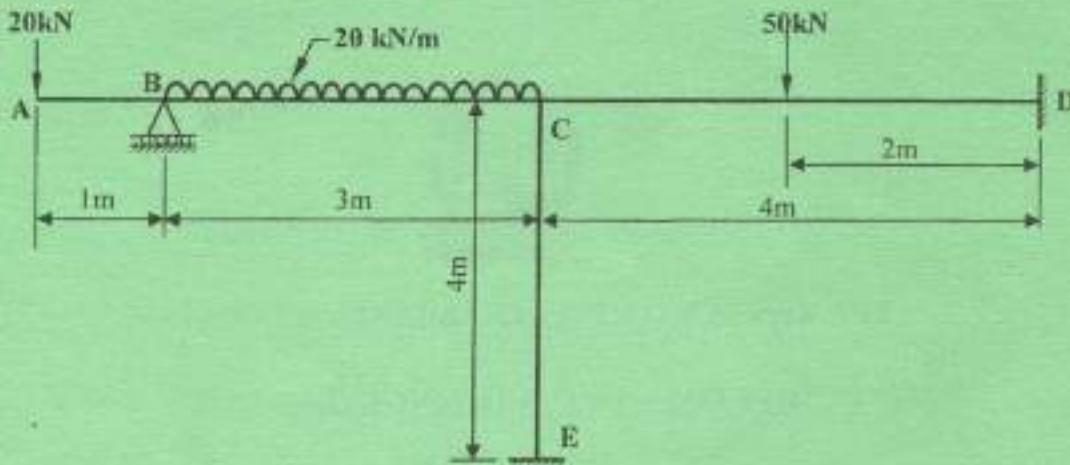
Fig. 1

2. A continuous beam of constant moment of inertia is simply supported at A, B and C as shown
    in **figure 2**. Analyse the beam using the three moments theorem and hence sketch the shear
   force and bending moment diagrams indicating the values at critical points. (20 marks)
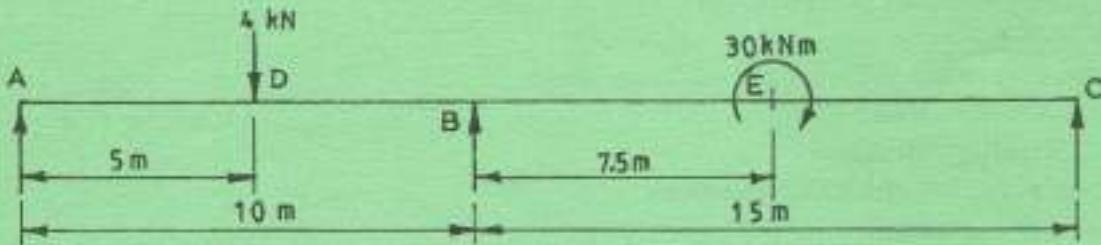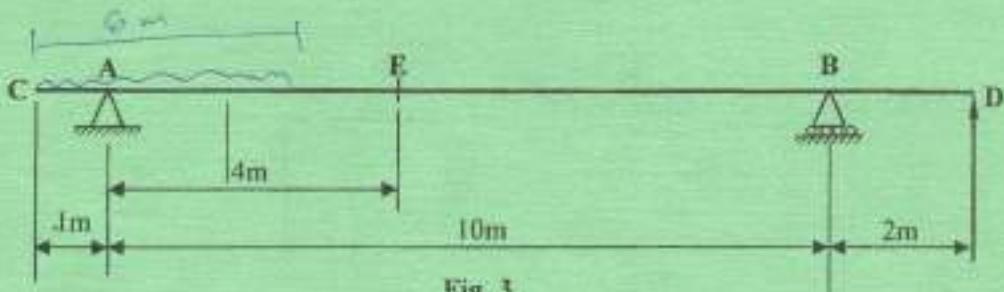
Fig. 2
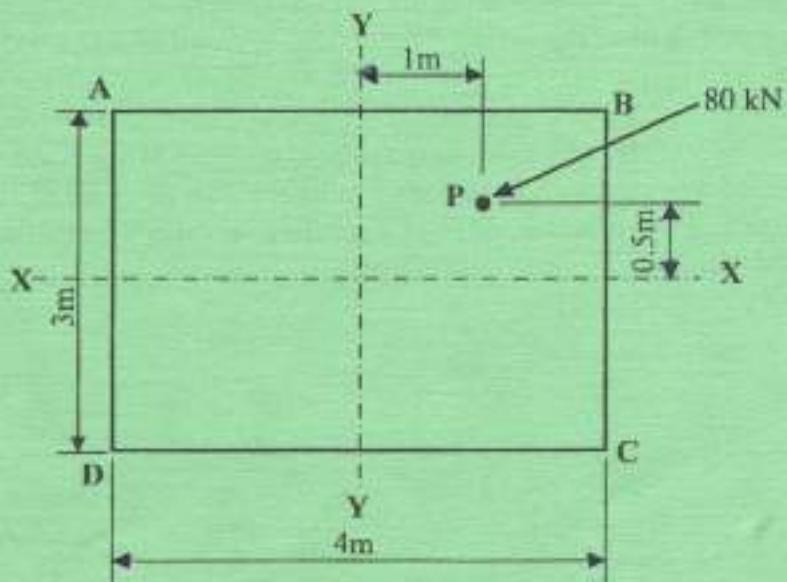
3. (a) For the beam shown in **figure 3**, sketch the influence line diagram for:

(i) the reaction at A;
(ii) the reaction at B;
(iii) the bending moment at E.

(15 marks)

(b) Determine the maximum bending moment at point E in (a) above when a uniformly distributed load of 50 kN/m and 6 m long crosses the beam from C to D. (5 marks)

Fig. 3

4. A masonry pier of 3 m by 4 m supports a vertical load of 80 kN as shown in **figure 4**. Determine:

(a) the stresses developed at each corner of the pier; (12 marks)

(b) the additional load that should be placed at the centre of the pier, so that there is no tension anywhere in the pier section; (4 marks)

(c) the stresses at the corners with the additional load in the centre. (4 marks)

Fig. 4

5. A simply supported beam shown in **figure 5** supports uniformly distributed characteristic dead and imposed loads of 5 kN/m each as well as a characteristic imposed point load of 30 kN at mid span. Assuming the beam is fully laterally restrained, select a suitable UB section in grade 43 steel to satisfy bending, shear and deflection considerations, given that

$$E = 205 \text{ kN/mm}^2$$
$$P_y = 275 \text{ N/mm}^2$$

(20 marks)
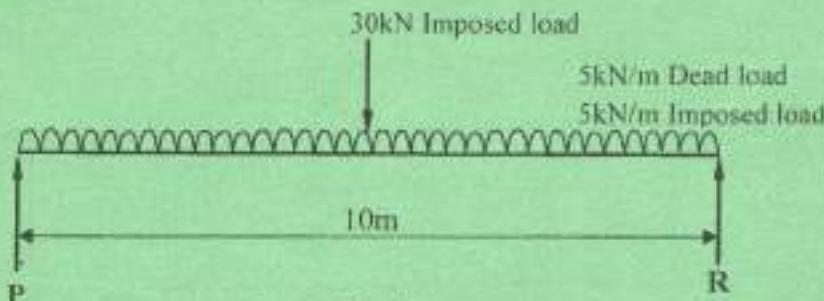
Fig. 5

6. Design the timber joists for a domestic dwelling using timber of strength class SC_2 given that:

I   the joist are spaced at 400 mm centres
II the floor has an effective span of 3.8 m
III the flooring is tongue and groove boarding with a self weight of 0.1 kN/m^2
IV the ceiling is of plasterboard with a self weight of 0.2 kN/m^2.

(20 marks)

7. (a) Determine the critical stress using the euler's formular for a pin ended steel strut 2 m long, consisting of a tube having 75 mm outside diameter and a wall thickness of 2.5 mm.   (10 marks)

(b) A short length of the tube in (a) fails at a load of 31.5 kN in a compression test and when tested as a strut with fixed ends 2 m long it fails at a load of 17.5 kN in tension respectively. Determine the value of a constant 'a' using the rankine's formular.
$$E = 210 \text{ kN/mm}^2.$$

(10 marks)

8. (a) Explain **four** types of stresses encountered in bolted connections. (8 marks)

    (b) **Figure 6** shows a bracket-to-column bolted connection. Determine its suitability to resist the design shear force of 200 kN. Assume the bolts are all M16, grade 8.8.

    (12 marks)
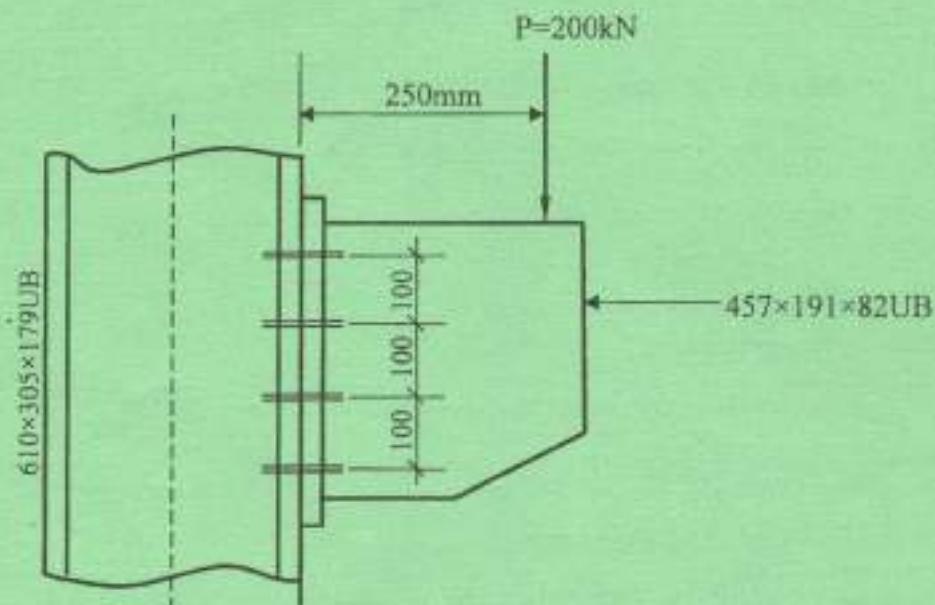
Fig. 6

Table 1: Modification factor K_3 for duration of loading

Duration of loading	Value of K_3
Long term (e.g. dead + permanent imposed)	1.00
Medium term (e.g. dead +snow, dead + temporary imposed)	1.25
Short term (e.g. dead + imposed + wind, dead + imposed + snow wind)	1.50
Very short term (e.g. dead + imposed + wind)	1.75

Table 2: Depth factor, K7

1.	$K_7 = 1.17$ for solid beams having a depth $< 72mm$
2.	$K_7 = (300/h)^{0.11}$ for solid beams with $72mm < h < 300mm$
3.	$K_7 = 0.81(h^2 + 92300)/(h^2 + 56800)$ for solid beams with $72mm < h < 300mm$

Table 3: Grade stresses, modulus of elasticity and density for strength class SC2 for the dry exposure condition

Strength Class	Bending Parallel to grain (Nmm^{-2})	Tension Parallel to grain (Nmm^{-2})	Compression Parallel to grain (Nmm^{-2})	Compression Perpendicular to grain* (Nmm^{-2}) (Nmm^{-2})		Shear Parallel to grain (Nmm^{-2})	Modulus of elasticity (E_{mean}) (Nmm^{-2})	($E_{minimum}$) (Nmm^{-2})	Approximate Density (kgm^{-3})
SC1	2.8	2.2	3.5	2.1	1.2	0.46	6800	4500	540
SC2	4.1	2.5	5.3	2.1	1.6	0.66	8000	5000	540
SC3	5.3	3.2	6.8	2.2	1.7	0.67	8800	5800	540
SC4	7.5	4.5	7.9	2.4	1.9	0.71	9900	6600	590
SC5	10.0	6.0	8.7	2.8	2.4	1.00	10700	7100	590/760
SC6	12.5	7.5	12.5	3.8	2.8	1.50	14100	11800	840
SC7	15.0	9.0	14.5	4.4	3.3	1.75	16200	13600	960
SC8	17.5	10.5	16.5	5.2	3.9	2.00	18700	15600	1080
SC9	20.5	12.3	19.5	6.1	4.6	2.25	21600	18000	1200

* When the specification specifically prohibits wane at bearing areas, the higher values of compression perpendicular to the grain stress may be used; otherwise the lower values apply.

Timber section sizes

Selected timber section sizes and section properties

Timber over the standard maximum length, of about 5.5 m, is more expensive and must be pre-ordered.

Basic size*		Area	Z_{xx}	Z_{yy}	I_{xx}	I_{yy}	r_{xx}	r_{yy}
D mm	B mm	10^2 mm²	10^3 mm³	10^3 mm³	10^6 mm⁴	10^6 mm⁴	mm	mm
100	38	38	63.3	24.1	3.17	0.46	28.9	11.0
100	50	50	83.3	41.7	4.17	1.04	28.9	14.4
100	63	63	105.0	66.2	5.25	2.08	28.9	18.2
100	75	75	125.0	93.8	6.25	3.52	28.9	21.7
100	100	100	166.7	166.7	8.33	9.33	28.9	28.9
150	38	57	142.5	36.1	10.69	0.69	43.3	11.0
150	50	75	187.5	62.5	14.06	1.56	43.3	14.4
150	63	94	236.3	99.2	17.72	3.13	43.3	18.2
150	75	112	281.3	140.6	21.09	5.27	43.3	21.7
150	100	150	375.0	250.0	28.13	12.50	43.3	28.9
150	150	225	562.5	562.5	42.19	42.19	43.3	43.3
175	38	66	194.0	42.1	16.97	0.80	50.5	11.0
175	50	87	255.2	72.9	22.33	1.82	50.5	14.4
175	63	110	321.6	115.8	28.14	3.65	50.5	18.2
175	75	131	382.8	164.1	33.50	6.15	50.5	21.7
200	38	76	253.3	48.1	25.33	0.91	57.7	11.0
200	50	100	333.3	83.3	33.33	2.08	57.7	14.4
200	63	126	420.0	132.3	42.00	4.17	57.7	18.2
200	75	150	500.0	187.5	50.00	7.03	57.7	21.7
200	100	200	666.7	333.3	66.67	16.67	57.7	28.9
200	150	300	1000.0	750.0	100.00	56.25	57.7	43.3
200	200	400	1333.3	1333.3	133.33	133.33	57.7	57.7
225	38	85	320.6	54.2	36.07	1.03	65.0	11.0
225	50	112	421.9	93.8	47.46	2.34	65.0	14.4
225	63	141	531.6	148.8	59.80	4.69	65.0	18.2
225	75	168	633.8	210.9	71.19	7.91	65.0	21.7
250	50	125	520.8	104.2	65.10	2.60	72.2	14.4
250	75	187	781.3	234.4	97.66	8.79	72.2	21.7
250	100	250	1041.7	416.7	130.21	20.83	72.2	28.9
250	250	625	2604.3	2604.3	325.52	325.52	72.2	72.2
300	50	150	750.0	125.0	112.50	3.13	86.6	14.4
300	75	225	1125.0	281.3	168.75	10.55	86.6	21.7
300	100	300	1500.0	500.0	225.00	25.00	86.6	28.9
300	150	450	2250.0	1125.0	337.50	84.38	86.6	43.3
300	300	900	4500.0	4500.0	675.00	675.00	86.6	86.6

* Under dry exposure conditions.
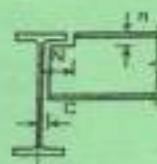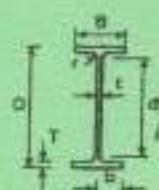
Source: BS 5268: Part 2: 1991.

Tolerances on timber cross sections

BS EN 336 sets out the customary sizes of structural timber. Class 1 timbers are 'sawn' and Class 2 timbers are 'planed'. The permitted deviations for tolerance Class 1 are −1 mm to +3 mm for dimensions up to 100 mm and −2 mm to +4 mm for dimensions greater than 100 mm. For Class 2, the tolerance for dimensions up to 100 mm is ±1 mm and ±1.5 mm for dimensions over 100 mm. Structural design to BS 5268 allows for these tolerances and therefore analysis should be carried out for a "target" section. It is the dimensions of the target section which should be included in specifications and on drawings.

Dimensions and properties

UNIVERSAL BEAMS
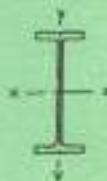
DIMENSIONS

Section Designation	Mass per Metre	Depth of Section	Width of Section	Thickness		Root Radius	Depth between Fillets	Ratios for Local Buckling		Dimensions for Detailing			Surface Area	
				Web	Flange			Flange	Web	End Clearance	Notch		Per Metre	Per Tonne
		D	B	t	T	r	d	b/T	d/t	C	N	n		
	kg/m	mm	mm	mm	mm	mm	mm			mm	mm	mm	m²	m²
457 x 191 x 98	98.3	467.2	192.8	11.4	19.6	10.2	407.6	4.92	35.8	8	102	30	1.67	16.9
457 x 191 x 89	89.3	463.4	191.9	10.5	17.7	10.2	407.6	5.42	38.8	7	102	28	1.66	18.5
457 x 191 x 82	82.0	460.0	191.3	9.9	16.0	10.2	407.6	5.96	41.2	7	102	28	1.65	20.1
457 x 191 x 74	74.3	457.0	190.4	9.0	14.5	10.2	407.6	6.57	45.3	7	102	26	1.64	22.1
457 x 191 x 67	67.1	453.4	189.9	8.5	12.7	10.2	407.6	7.48	48.0	6	102	24	1.63	24.3
457 x 152 x 82	82.1	465.8	155.3	10.5	18.9	10.2	407.6	4.11	38.8	7	84	30	1.51	18.4
457 x 152 x 74	74.2	462.0	154.4	9.6	17.0	10.2	407.6	4.54	42.5	7	84	28	1.50	20.3
457 x 152 x 67	67.2	458.0	153.8	9.0	15.0	10.2	407.6	5.13	45.3	7	84	26	1.50	22.3
457 x 152 x 60	59.8	454.6	152.9	8.1	13.3	10.2	407.6	5.75	50.3	6	84	24	1.49	24.9
457 x 152 x 52	52.3	449.8	152.4	7.6	10.9	10.2	407.6	6.99	53.6	6	84	22	1.48	28.2
406 x 178 x 74	74.2	412.8	179.5	9.5	16.0	10.2	360.4	5.61	37.9	7	96	28	1.51	20.3
406 x 178 x 67	67.1	409.4	178.8	8.8	14.3	10.2	360.4	6.25	41.0	6	96	26	1.50	22.3
406 x 178 x 60	60.1	406.4	177.9	7.9	12.8	10.2	360.4	6.95	45.6	6	96	24	1.49	24.8
406 x 178 x 54	54.1	402.6	177.7	7.7	10.9	10.2	360.4	8.15	46.8	6	96	22	1.48	27.4
406 x 140 x 46	46.0	403.2	142.2	6.8	11.2	10.2	360.4	6.35	53.0	5	78	22	1.34	29.2
406 x 140 x 39	39.0	398.0	141.8	6.4	8.6	10.2	360.4	8.24	56.3	5	78	20	1.33	34.2
356 x 171 x 67	67.1	363.4	173.2	9.1	15.7	10.2	311.6	5.52	34.2	7	94	26	1.38	20.6
356 x 171 x 57	57.0	358.0	172.2	8.1	13.0	10.2	311.6	6.62	38.5	6	94	24	1.37	24.1
356 x 171 x 51	51.0	355.0	171.5	7.4	11.5	10.2	311.6	7.46	42.1	6	94	22	1.36	26.7
356 x 171 x 45	45.0	351.4	171.1	7.0	9.7	10.2	311.6	8.82	44.5	6	94	20	1.36	30.1
356 x 127 x 39	39.1	353.4	126.0	6.6	10.7	10.2	311.6	5.89	47.2	5	70	22	1.18	30.2
356 x 127 x 33	33.1	349.0	125.4	6.0	8.5	10.2	311.6	7.38	51.9	5	70	20	1.17	35.4
305 x 165 x 54	54.0	310.4	166.9	7.9	13.7	8.9	265.2	6.09	33.6	6	90	24	1.26	23.3
305 x 165 x 46	46.1	306.6	165.7	6.7	11.8	8.9	265.2	7.02	39.6	5	90	22	1.25	27.1
305 x 165 x 40	40.3	303.4	165.0	6.0	10.2	8.9	265.2	8.09	44.2	5	90	20	1.24	30.8
305 x 127 x 48	48.1	311.0	125.3	9.0	14.0	8.9	265.2	4.47	29.5	7	70	24	1.09	22.7
305 x 127 x 42	41.9	307.2	124.3	8.0	12.1	8.9	265.2	5.14	33.1	6	70	22	1.08	25.8
305 x 127 x 37	37.0	304.4	123.4	7.1	10.7	8.9	265.2	5.77	37.4	6	70	20	1.07	29.0
305 x 102 x 33	32.8	312.7	102.4	6.6	10.8	7.6	275.9	4.74	41.8	5	58	20	1.01	30.8
305 x 102 x 28	28.2	308.7	101.8	6.0	8.8	7.6	275.9	5.78	46.0	5	58	18	1.00	35.4
305 x 102 x 25	24.8	305.1	101.6	5.8	7.0	7.6	275.9	7.26	47.6	5	58	16	0.992	40.0
254 x 146 x 43	43.0	259.6	147.3	7.2	12.7	7.6	219.0	5.80	30.4	6	82	22	1.08	25.1
254 x 146 x 37	37.0	256.0	146.4	6.3	10.9	7.6	219.0	6.72	34.8	5	82	20	1.07	29.0
254 x 146 x 31	31.1	251.4	146.1	6.0	8.6	7.6	219.0	8.49	36.5	5	82	18	1.06	34.2
254 x 102 x 28	28.3	260.4	102.2	6.3	10.0	7.6	225.2	5.11	35.7	5	58	18	0.904	31.9
254 x 102 x 25	25.2	257.2	101.9	6.0	8.4	7.6	225.2	6.07	37.5	5	58	16	0.897	35.6
254 x 102 x 22	22.0	254.0	101.6	5.7	6.8	7.6	225.2	7.47	39.5	5	58	16	0.890	40.5
203 x 133 x 30	30.0	206.8	133.9	6.4	9.6	7.6	172.4	6.97	26.9	5	74	16	0.923	30.8
203 x 133 x 25	25.1	203.2	133.2	5.7	7.8	7.6	172.4	8.54	30.2	5	74	16	0.915	36.4
203 x 102 x 23	23.1	203.2	101.8	5.4	9.3	7.6	169.4	5.47	31.4	5	60	16	0.790	34.2
178 x 102 x 19	19.0	177.8	101.2	4.8	7.9	7.6	146.8	6.41	30.6	4	60	16	0.738	38.8
152 x 89 x 16	16.0	152.4	88.7	4.5	7.7	7.6	121.8	5.76	27.1	4	54	16	0.638	39.8
127 x 76 x 13	13.0	127.0	76.0	4.0	7.6	7.6	96.6	5.00	24.1	4	48	16	0.537	41.3

Dimensions and properties

UNIVERSAL BEAMS

PROPERTIES

Section Designation	Second Moment of Area		Radius of Gyration		Elastic Modulus		Plastic Modulus		Buckling Parameter	Torsional Index	Warping Constant	Torsional Constant	Area of Section
	Axis x-x cm⁴	Axis y-y cm⁴	Axis x-x cm	Axis y-y cm	Axis x-x cm³	Axis y-y cm³	Axis x-x cm³	Axis y-y cm³	u	x	H dm⁶	J cm⁴	A cm²
457 × 191 × 98	45700	2350	19.1	4.33	1960	240	2230	379	0.882	25.7	1.18	121	125
457 × 191 × 89	41000	2090	19.0	4.29	1770	218	2010	338	0.879	28.3	1.04	90.7	114
457 × 191 × 82	37100	1870	18.8	4.23	1610	196	1830	304	0.879	30.8	0.922	69.2	104
457 × 191 × 74	33300	1670	18.8	4.20	1460	176	1650	272	0.877	33.8	0.818	51.8	94.6
457 × 191 × 67	29400	1450	18.5	4.12	1300	153	1470	237	0.872	37.9	0.705	37.1	85.5
457 × 152 × 82	36600	1190	18.7	3.37	1570	153	1810	240	0.871	27.4	0.591	89.2	105
457 × 152 × 74	32700	1050	18.6	3.33	1410	136	1630	213	0.873	30.2	0.518	65.9	94.5
457 × 152 × 67	28900	913	18.4	3.27	1260	119	1450	187	0.868	33.6	0.448	47.7	85.6
457 × 152 × 60	25500	795	18.3	3.23	1120	104	1290	163	0.868	37.5	0.387	33.6	76.2
457 × 152 × 52	21400	645	17.9	3.11	950	84.6	1100	133	0.858	43.8	0.311	21.4	66.6
406 × 178 × 74	27300	1550	17.0	4.04	1320	172	1500	267	0.882	27.6	0.608	62.8	94.5
406 × 178 × 67	24300	1370	16.9	3.90	1190	153	1350	237	0.880	30.5	0.533	46.1	85.5
406 × 178 × 60	21600	1200	16.8	3.97	1060	135	1200	209	0.880	33.8	0.466	33.3	76.5
406 × 178 × 54	18700	1020	16.5	3.85	930	115	1060	178	0.871	38.3	0.392	23.1	69.0
406 × 140 × 46	15700	538	16.4	3.03	778	75.7	888	118	0.872	39.0	0.207	19.0	58.6
406 × 140 × 39	12500	410	15.9	2.87	629	57.8	724	90.8	0.858	47.5	0.155	10.7	49.7
356 × 171 × 67	19500	1360	15.1	3.99	1070	157	1210	243	0.886	24.4	0.412	55.7	85.5
356 × 171 × 57	16000	1110	14.9	3.91	896	129	1010	199	0.882	28.8	0.330	33.4	72.6
356 × 171 × 51	14100	968	14.8	3.86	796	113	896	174	0.881	32.1	0.286	23.8	64.9
356 × 171 × 45	12100	811	14.5	3.76	687	94.8	775	147	0.874	36.8	0.237	15.8	57.3
356 × 127 × 39	10200	358	14.3	2.68	576	56.8	658	89.1	0.871	35.2	0.105	15.1	49.8
356 × 127 × 33	8250	280	14.0	2.58	473	44.7	543	70.3	0.863	42.2	0.081	8.79	42.1
305 × 165 × 54	11700	1060	13.0	3.93	754	127	846	196	0.889	23.6	0.234	34.8	68.8
305 × 165 × 46	9900	896	13.0	3.90	646	108	720	166	0.891	27.1	0.195	22.2	58.7
305 × 165 × 40	8500	764	12.9	3.86	560	92.6	623	142	0.889	31.0	0.164	14.7	51.3
305 × 127 × 48	9580	461	12.5	2.74	616	73.6	711	116	0.874	23.3	0.102	31.8	61.2
305 × 127 × 42	8200	389	12.4	2.70	534	62.6	614	98.4	0.872	26.6	0.0846	21.1	53.4
305 × 127 × 37	7170	336	12.3	2.67	471	54.5	539	85.4	0.871	29.7	0.0725	14.8	47.2
305 × 102 × 33	6500	194	12.5	2.15	416	37.9	481	60.0	0.867	31.6	0.0442	12.2	41.8
305 × 102 × 28	5370	155	12.2	2.08	348	30.5	403	48.5	0.859	37.4	0.0349	7.40	35.9
305 × 102 × 25	4460	123	11.9	1.97	292	24.2	342	38.8	0.846	43.4	0.0273	4.77	31.6
254 × 146 × 43	6540	677	10.9	3.52	504	92.0	566	141	0.890	21.2	0.103	23.9	54.8
254 × 146 × 37	5540	571	10.8	3.48	433	78.0	483	119	0.889	24.4	0.0857	15.3	47.2
254 × 146 × 31	4410	448	10.5	3.36	351	61.3	393	94.1	0.879	29.6	0.0660	8.55	39.7
254 × 102 × 28	4010	179	10.5	2.22	308	34.9	353	54.8	0.874	27.5	0.0280	9.57	36.1
254 × 102 × 25	3420	149	10.3	2.15	266	29.2	306	46.0	0.867	31.4	0.0230	6.42	32.0
254 × 102 × 22	2840	119	10.1	2.06	224	23.5	259	37.3	0.856	36.3	0.0182	4.15	28.0
203 × 133 × 30	2900	385	8.71	3.17	280	57.5	314	88.2	0.881	21.5	0.0374	10.3	38.2
203 × 133 × 25	2340	308	8.56	3.10	230	46.2	258	70.9	0.877	25.6	0.0294	5.96	32.0
203 × 102 × 23	2110	164	8.46	2.36	207	32.2	234	49.8	0.888	22.5	0.0154	7.02	29.4
178 × 102 × 19	1360	137	7.48	2.37	153	27.0	171	41.6	0.886	22.6	0.00987	4.41	24.3
152 × 89 × 16	834	89.8	6.41	2.10	109	20.2	123	31.2	0.889	19.6	0.00470	3.56	20.3
127 × 76 × 13	473	55.7	5.35	1.84	74.6	14.7	84.2	22.6	0.896	16.3	0.00199	2.85	16.5

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