2707/302
STRUCTURES III
June/July 2023
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 any ***FIVE*** *questions.*
All questions carry equal marks.
Maximum marks for each part of a question are as indicated.
Relevant design tables are attached.
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.

1. **Figure 1** shows a simply supported beam with a moving point load as shown. Draw the influence line diagrams for:

(a) reaction at A; (5 marks)

(b) shear force and bending moments at C. (15 marks)

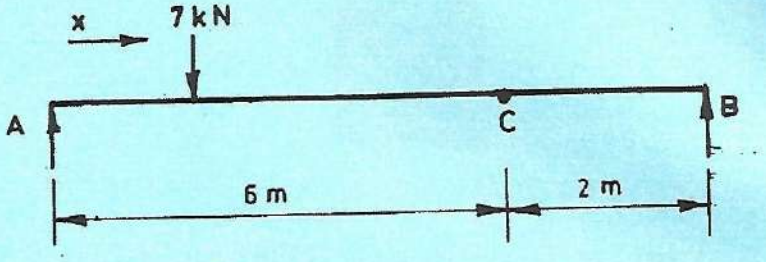

Fig. 1

2. Using moment distribution method, analyse the beam shown in **figure 2** below; by making four distribution and hence sketch the bending moments diagram, indicating values at critical points.

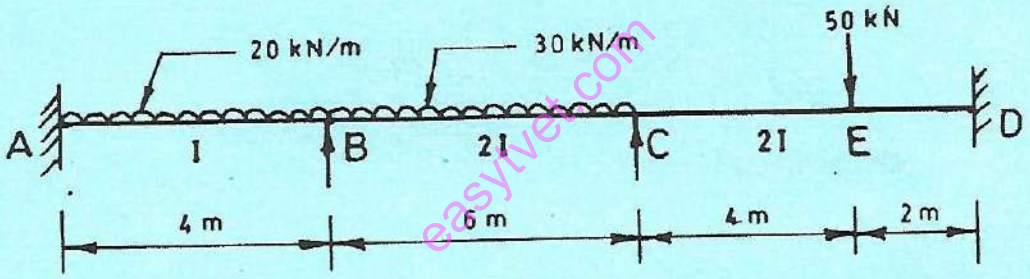

Fig. 2

(20 marks)

3. Use three moments theorem to analyse the beam in **figure 3** and hence determine the moments at B (M_B) and at C (M_C) respectively.

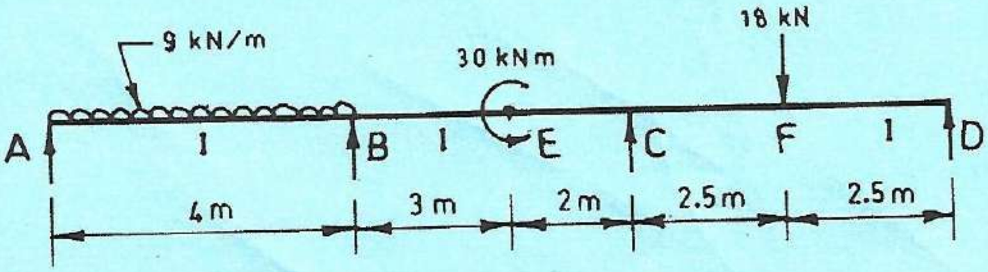

Fig. 3

(20 marks)

4. A 5.8 metre long fully laterally restrained beam is to carry unfactored uniformly distributed load of a 95 kN/M along its entire span. If loading consists of 40% imposed load and 60% dead load (inclusive of self weight), check the adequacy of a $533 \times 2.10 \times 92$ kg/m universal beam if used in accordance to BS 5950 with respect to:

(a) flexure;

(b) shear;

(c) deflection;

(d) web buckling.

Data

Assume grade 43 steel
Take Pc = 101 N/mm^2
The beam rests on 100 mm end bearings.

(20 marks)

5. (a) Determine the maximum live load to be carried by the bolted joint in **figure 4** given that the live load is 60% of the total load.

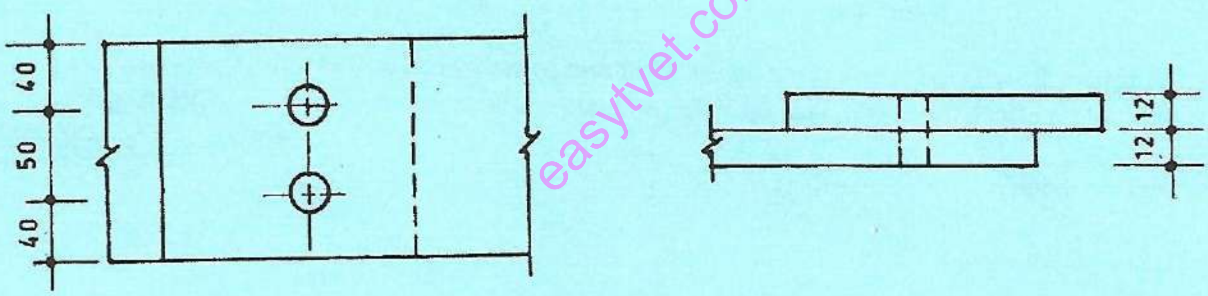

Fig.4

(16 marks)

(b) Determine the design load P that can be sustained by the 8 mm welded joint shown in **figure 5**.

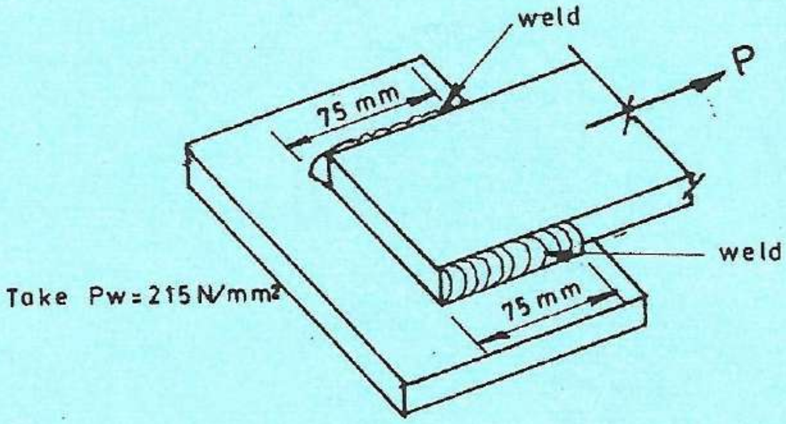

Fig. 5

Take $P_w = 215 \text{ N/mm}^2$

(4 marks)

6. A timber floor is to be supported by 50 × 50 mm joists spaced at 600 mm c/c, each of 3.2 metre effective length. Use the data provided to check the adequacy of the joists against

(a) bending;

(b) deflection;

(c) shear.

Data

Floor boarding	= 0.34 kN/m^2
Ceiling	= 0.15 kN/m^2
Imposed load	= 0.7 kN/m^2
Joist weight	= (refer to tables provided)
Load duration	= medium duartion
Modification factor K8	= 1.1

(20 marks)

7. Using moment distribution method, analyse the frame in **figure 6** by carrying out two distributions and hence sketch the bending moment diagram indicating values at critical points.

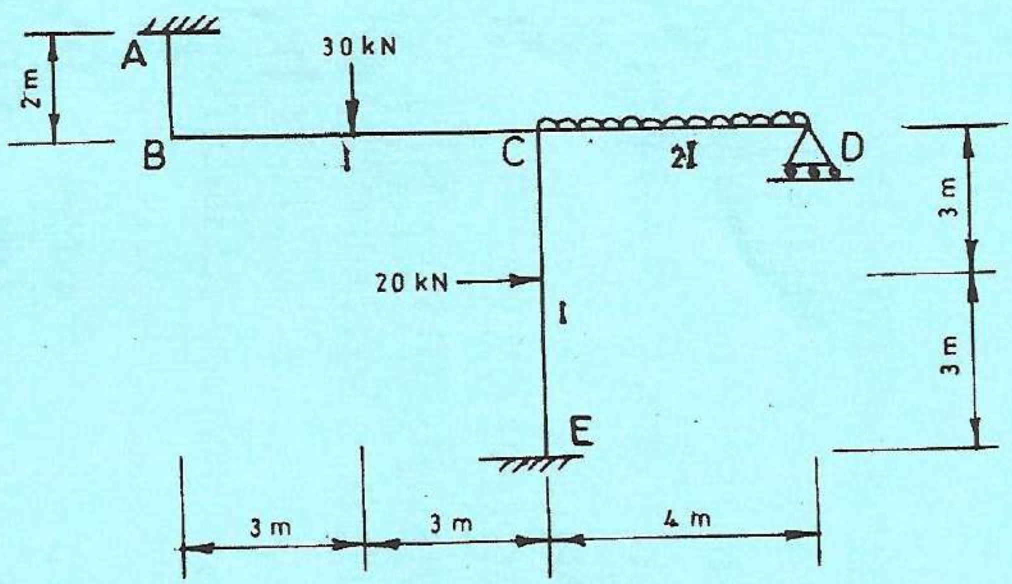

Fig.6

(20 marks)

8. A train of loads travels across a bridge while maintaining the load spacing as shown in **figure 7.**

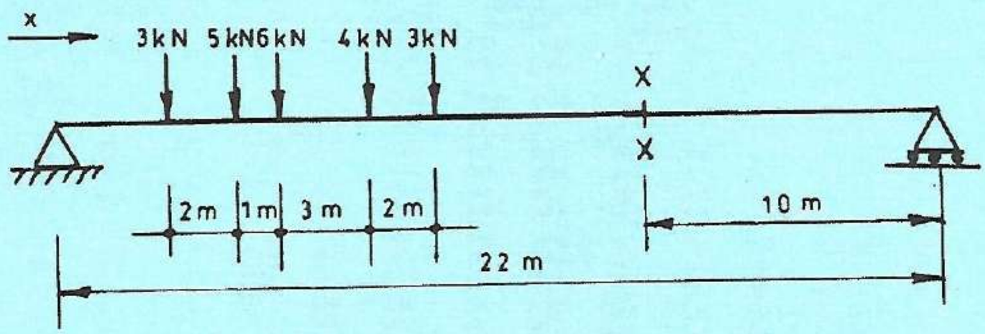

Fig.7

(a) The maximum bending moments developed at point x - x on the bridge.

(b) The maximum negative and maximum positive shearforce at the condition determined in (a) above. (20 marks)

Table 1(a) Universal beams (abstracted from the *Steelwork Design Guide to BS 5950: Part 1*, published by the Steel Construction Institute)

(a) Dimensions

Designation: Serial size (mm)	Designation: Mass per metre (kg)	Depth of section D (mm)	Width of section B (mm)	Thickness: Web t (mm)	Thickness: Flange T (mm)	Root radius r (mm)	Depth between fillets d (mm)	Ratios for local buckling: Flange b/T	Ratios for local buckling: Web d/t	Dimensions for detailing: End clearance C (mm)	Dimensions for detailing: Notch N (mm)	Dimensions for detailing: Notch n (mm)	Surface area: Per metre (m²)	Surface area: per tonne (m²)
686 × 254	170	692.9	255.8	14.5	23.7	15.2	615.1	5.40	42.4	9	132	40	2.35	13.8
	152	687.6	254.5	13.2	21.0	15.2	615.1	6.06	46.6	9	132	38	2.34	15.4
	140	683.5	253.7	12.4	19.0	15.2	615.1	6.68	49.6	8	132	36	2.33	16.6
	125	677.9	253.0	11.7	16.2	15.2	615.1	7.81	52.6	8	132	32	2.32	18.5
610 × 305	238	633.9	311.5	18.6	31.4	16.5	537.2	4.96	28.9	11	158	48	2.45	10.3
	179	617.5	307.0	14.1	23.6	16.5	537.2	6.50	38.1	9	158	42	2.41	13.4
	149	609.6	304.8	11.9	19.7	16.5	537.2	7.74	45.1	8	158	38	2.39	16.0
610 × 229	140	617.0	230.1	13.1	22.1	12.7	547.3	5.21	41.8	9	120	36	2.11	15.0
	125	611.9	229.0	11.9	19.6	12.7	547.3	5.84	46.0	8	120	34	2.09	16.8
	113	607.3	228.2	11.2	17.3	12.7	547.3	6.60	48.9	8	120	32	2.08	18.4
	101	602.2	227.6	10.6	14.8	12.7	547.3	7.69	51.6	7	120	28	2.07	20.5
533 × 210	122	544.6	211.9	12.8	21.3	12.7	476.5	4.97	37.2	8	110	36	1.89	15.5
	109	539.5	210.7	11.6	18.8	12.7	476.5	5.60	41.1	8	110	32	1.88	17.2
	101	536.7	210.1	10.9	17.4	12.7	476.5	6.04	43.7	7	110	32	1.87	18.5
	92	533.1	209.3	10.2	15.6	12.7	476.5	6.71	46.7	7	110	30	1.86	20.2
	82	528.3	208.7	9.6	13.2	12.7	476.5	7.91	49.6	7	110	26	1.85	22.6
457 × 191	98	467.4	192.8	11.4	19.6	10.2	407.9	4.92	35.8	8	102	30	1.67	17.0
	89	463.6	192.0	10.6	17.7	10.2	407.9	5.42	38.5	7	102	28	1.66	18.6
	82	460.2	191.3	9.9	16.0	10.2	407.9	5.98	41.2	7	102	28	1.65	20.1
	74	457.2	190.5	9.1	14.5	10.2	407.9	6.57	44.8	7	102	26	1.64	22.2
	67	453.6	189.9	8.5	12.7	10.2	407.9	7.48	48.0	6	102	24	1.63	24.4
457 × 152	82	465.1	153.5	10.7	18.9	10.2	407.0	4.06	38.0	7	82	30	1.51	18.4
	74	461.3	152.7	9.9	17.0	10.2	407.0	4.49	41.1	7	82	28	1.50	20.2
	67	457.3	151.9	9.1	15.0	10.2	407.0	5.06	44.7	7	82	26	1.49	22.2
	60	454.7	152.9	8.0	13.3	10.2	407.0	5.75	51.0	6	84	24	1.49	24.8
	52	449.8	152.4	7.6	10.9	10.2	407.0	6.99	53.6	6	84	22	1.48	28.4

Table 1(b) Universal beams *continued* (abstracted from the *Steelwork Design Guide to BS 5950: Part 1*, published by the Steel Construction Institute)

(b) Properties

Designation: Serial size (mm)	Designation: Mass per metre (kg)	Second moment of area: Axis x–x (cm⁴)	Second moment of area: Axis y–y (cm⁴)	Radius of gyration: Axis x–x (cm)	Radius of gyration: Axis y–y (cm)	Elastic modulus: Axis x–x (cm³)	Elastic modulus: Axis y–y (cm³)	Plastic modulus: Axis x–x (cm³)	Plastic modulus: Axis y–y (cm³)	Buckling parameter u	Torsional index x	Warping constant H (dm⁶)	Torsional constant J (cm⁴)	Area of section A (cm²)
686 × 254	170	170 000	6 620	28.0	5.53	4 910	518	5 620	810	0.872	31.8	7.41	307	217
	152	150 000	5 780	27.8	5.46	4 370	454	5 000	710	0.871	35.5	6.42	219	194
	140	136 000	5 180	27.6	5.38	3 990	408	4 560	638	0.868	38.7	5.72	169	179
	125	118 000	4 380	27.2	5.24	3 480	346	4 000	542	0.862	43.9	4.79	116	160
610 × 305	238	208 000	15 800	26.1	7.22	6 560	1020	7 460	1570	0.886	21.1	14.3	788	304
	179	152 000	11 400	25.8	7.08	4 910	743	5 520	1140	0.886	27.5	10.1	341	228
	149	125 000	9 300	25.6	6.99	4 090	610	4 570	937	0.886	32.5	8.09	200	190
610 × 229	140	112 000	4 510	25.0	5.03	3 630	392	4 150	612	0.875	30.5	3.99	217	178
	125	98 600	3 930	24.9	4.96	3 220	344	3 680	536	0.873	34.0	3.45	155	160
	113	87 400	3 440	24.6	4.88	2 880	301	3 290	470	0.87	37.9	2.99	112	144
	101	75 700	2 910	24.2	4.75	2 510	256	2 880	400	0.863	43.0	2.51	77.2	129
533 × 210	122	76 200	3 390	22.1	4.67	2 800	320	3 200	501	0.876	27.6	2.32	180	156
	109	66 700	2 940	21.9	4.60	2 470	279	2 820	435	0.875	30.9	1.99	126	139
	101	61 700	2 690	21.8	4.56	2 300	257	2 620	400	0.874	33.1	1.82	102	129
	92	55 400	2 390	21.7	4.51	2 080	229	2 370	356	0.872	36.4	1.60	76.2	118
	82	47 500	2 010	21.3	4.38	1 800	192	2 060	300	0.865	41.6	1.33	51.3	104
457 × 191	98	45 700	2 340	19.1	4.33	1 960	243	2 230	378	0.88	25.8	1.17	121	125
	89	41 000	2 090	19.0	4.28	1 770	217	2 010	338	0.879	28.3	1.04	90.5	114
	82	37 100	1 870	18.8	4.23	1 610	196	1 830	304	0.877	30.9	0.923	69.2	105
	74	33 400	1 670	18.7	4.19	1 460	175	1 660	272	0.876	33.9	0.819	52.0	95.0
	67	29 400	1 450	18.5	4.12	1 300	153	1 470	237	0.873	37.9	0.706	37.1	85.4
457 × 152	82	36 200	1 140	18.6	3.31	1 560	149	1 800	235	0.872	27.3	0.569	89.3	104
	74	32 400	1 010	18.5	3.26	1 410	133	1 620	209	0.87	30.0	0.499	66.6	95.0
	67	28 600	878	18.3	3.21	1 250	116	1 440	182	0.867	33.6	0.429	47.5	85.4
	60	25 500	794	18.3	3.23	1 120	104	1 280	163	0.869	37.5	0.387	33.6	75.9
	52	21 300	645	17.9	3.11	949	84.6	1 090	133	0.859	43.9	0.311	21.3	66.5

Table 2 — Compressive strength p_c (N/mm²)

4) Values of p_c (N/mm²) with $\lambda \geq 110$ for strut curve b															
λ	Steel grade and design strength p_y (N/mm²)														
	S 275					S 355					S 460				
	235	245	255	265	275	315	325	335	345	355	400	410	430	440	460
110	115	118	120	121	123	129	130	131	133	134	138	139	140	141	142
112	113	115	117	118	120	125	127	128	129	130	134	134	136	136	138
114	110	112	114	115	117	122	123	124	125	126	130	130	132	132	133
116	107	109	111	112	114	119	120	121	122	122	126	126	128	128	129
118	105	106	108	109	111	115	116	117	118	119	122	123	124	124	125
120	102	104	105	107	108	112	113	114	115	116	119	119	120	121	122
122	100	101	103	104	105	109	110	111	112	112	115	116	117	117	118
124	97	98	100	101	102	106	107	108	109	109	112	112	113	114	115
126	95	96	98	99	100	103	104	105	106	106	109	109	110	111	111
128	93	94	95	96	97	101	101	102	103	103	106	106	107	107	108
130	90	92	93	94	95	98	99	99	100	101	103	103	104	105	105
135	85	86	87	88	89	92	93	93	94	94	96	97	97	98	98
140	80	81	82	83	84	86	87	87	88	88	90	90	91	91	92
145	76	77	78	78	79	81	82	82	83	83	84	85	85	86	86
150	72	72	73	74	74	76	77	77	78	78	79	80	80	80	81
155	68	69	69	70	70	72	72	73	73	73	75	75	75	76	76
160	64	65	65	66	66	68	68	69	69	69	70	71	71	71	72
165	61	62	62	62	63	64	65	65	65	65	66	67	67	67	68
170	58	58	59	59	60	61	61	61	62	62	63	63	63	64	64
175	55	55	56	56	57	58	58	58	59	59	60	60	60	60	60
180	52	53	53	53	54	55	56	55	56	56	56	57	57	57	57
185	50	50	51	51	51	52	52	53	53	53	54	54	54	54	54
190	48	48	48	48	49	50	50	50	50	50	51	51	51	51	52
195	45	46	46	46	46	47	47	48	48	48	49	49	49	49	49
200	43	44	44	44	44	45	45	45	46	46	46	46	47	47	47
210	40	40	40	40	41	41	41	41	42	42	42	42	42	43	43
220	36	37	37	37	37	38	38	38	38	38	39	39	39	39	39
230	34	34	34	34	34	35	35	35	35	35	35	36	36	36	36
240	31	31	31	31	32	32	32	32	32	32	33	33	33	33	33
250	29	29	29	29	29	30	30	30	30	30	30	30	30	30	30
260	27	27	27	27	27	27	28	28	28	28	28	28	28	28	28
270	25	25	25	25	25	26	26	26	26	26	26	26	26	26	26
280	23	23	23	23	24	24	24	24	24	24	24	24	24	24	24
290	22	22	22	22	22	22	22	22	22	22	23	23	23	23	23
300	20	20	21	21	21	21	21	21	21	21	21	21	21	21	21
310	19	19	19	19	19	20	20	20	20	20	20	20	20	20	20
320	18	18	18	18	18	18	18	19	19	19	19	19	19	19	19
330	17	17	17	17	17	17	17	17	17	18	18	18	18	18	18
340	16	16	16	16	16	16	16	16	17	17	17	17	17	17	17
350	15	15	15	15	15	16	16	16	16	16	16	16	16	16	16

Table 3 Design strength p_y of grade 43 steel

Thickness less than or equal to (mm)	p_y for rolled sections, plates and hollow sections (N/mm^2)
16	275
40	265
63	255
100	245

The modulus of elasticity *E*, for deflection purposes, may be taken as 205 kN/mm^2 for all grades of steel.

Table 4 Ordinary bolts in clearance holes

Strength of bolts and bearing strength of bolts and connected ply (N/mm^2)

Strength of bolts	Bolt grade 4.6	Bolt grade 8.8
Shear strength p_s	160	375
Bearing strength p_{bb}	460	1035

Bearing strength of connected parts	Steel grade 43	Steel grade 50	Steel grade 55
Bearing strength p_{bs}	460	550	650

Table : 5 Load capacity (Grade 4.6 bolts and Grade of 43 steel)

Nominal diameter (mm)	Shank area A (mm^2)	Tensile stress Area A_t, A_T (mm^2)
16	201	157
20	314	245
22	380	303
24	452	353

Table 6 Grade stresses and moduli of elasticity for strength classes: for the dry exposure condition (BS 5268 Part 2 1988 Table 9)

Strength class	Bending parallel to grain (N/mm²)	Tension parallel to grain (N/mm²)	Compression parallel to grain (N/mm²)	Compression perpendicular to grain* (N/mm²)	(N/mm²)	Shear parallel to grain (N/mm²)	Modulus of elasticity Mean (N/mm²)	Modulus of elasticity Minimum (N/mm²)	Approximate density† (kg/m³)
SC1	2.8	2.2‡	3.5	2.1	1.2	0.46	6 800	4 500	540
SC2	4.1	2.5‡	5.3	2.1	1.6	0.66	8 000	5 000	540
SC3	5.3	3.2‡	6.8	2.2	1.7	0.67	8 800	5 800	540
SC4	7.5	4.5‡	7.9	2.4	1.9	0.71	9 900	6 600	590
SC5	10.0	6.0‡	8.7	2.8	2.4	1.00	10 700	7 100	590/760
SC6§	12.5	7.5	12.5	3.8	2.8	1.50	14 100	11 800	840
SC7§	15.0	9.0	14.5	4.4	3.3	1.75	16 200	13 600	960
SC8§	17.5	10.5	16.5	5.2	3.9	2.00	18 700	15 600	1080
SC9§	20.5	12.3	19.5	6.1	4.6	2.25	21 600	18 000	1200

Table 7 Modification factor K_3 for duration of loading (BS 5268 Part 2 1988 Table 17)

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 8 Modification factor K_7 for depth

h	$K_7 = (300/h)^{0.11}$
72	1.170
75	1.165
97	1.132
100	1.128
120	1.106
122	1.104
125	1.101
145	1.083
147	1.082
150	1.079
169	1.065
170	1.064
175	1.061
194	1.049
195	1.049
200	1.046
219	1.035
220	1.034
225	1.032
244	1.023
245	1.023
250	1.020
294	1.002
295	1.002
300	1.000

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