OCD076

UNIVERSITY OF BOLTON

OFF CAMPUS DIVISION

SWL – SRI LANKA

BENG(HONS) MECHANICAL ENGINEERING

SEMESTER 1 EXAMINATION 2018/2019

ADVANCED MATERIALS & STRUCTURES

MODULE NO AME6002

Date:26th January 2019 **Time: 3 hrs**

INSTRUCTIONS TO CANDIDATES:

There are FIVE questions on this paper.

Answer any FOUR questions only.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

Electronic calculators may be used provided that data and program storage memory is cleaned prior to the examination.

CANDIDATES REQUIRE: **Formula Sheet (attached)**

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Off Campus Division - SWL Sri Lanka
BENG (HONS) MECHANICAL ENGINEERING
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Question 1

a) In thermal energy storage tank at working temperature measured direct tensile stresses in x, y and z directions are 120 MPa, -50 MPa and 80 MPa respectively. At measured working condition the storage part has a shear stress in the xy direction of 30 MPa and -25 Mpa in the xz direction.

(i) Draw the elemental cube showing the stresses acting.

(04 marks)

(ii) Using this information show that the maximum principal stress is 136 MPa.

(08 marks)

(iii) Determine the three angles (α, β and γ) which describe the direction of the maximum principal stress relative to xyz co-ordinate system. Produce also a sketch showing this principal stress relative the elemental cube.

(07 marks)

b) What will be the minimum yield strength needed for the material if it is to have a factor of safety of 2.5. Use von Mises yield criterion to determine this, and assume the other principal stresses are 69 MPa and -55 MPa

(06 marks)

Total 25 marks

Please turn the page

Question 2

a) A simply supported beam of dimensions 80 mm wide by 6m long is manufactured from glass- reinforced polyester with symmetrical cross-section construction is shown in Figure Q2 below. Using the material and structural properties given in the Table Q2, **Calculate the number of beams required** if the beam needs to support 12.5KN at it's mid-point. Assume that each beam supports the same load and that the Elastic Modulus of Glass is 70 GPa and that the materials design strain is 0.2%. The resin used has an Elastic Modulus of 2.7 GPa.

(15 Marks)

b) For the beam section given in the question, sketch the stress distributions through the depth of the beam indicating salient values.

(10 Marks)

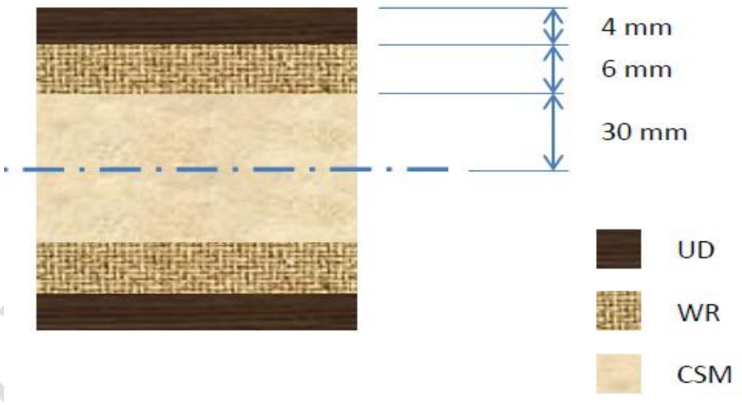

Figure Q2

Table Q2.

TYPE	UD	WR	CSM
Reinforcement	E-Glass	E-Glass	E-Glass
Volume fraction (%)	67	50	30
Efficiency Factor	0.9	0.6	0.2

Total 25 marks

Please turn the page

Question 3

The mean dimensions of an airplane wing can be approximated as shown in figure Q3. The figure shows cross sectional view of the leading edge and torsion box. The wing is made of an aluminum alloy which is having an allowable shear stress of τ_{max}= 150 Mpa. The wing wall thickness is 15mm and other dimensions are as shown in the figure. If aluminum alloy have shear modulus 27×10^9 determin,

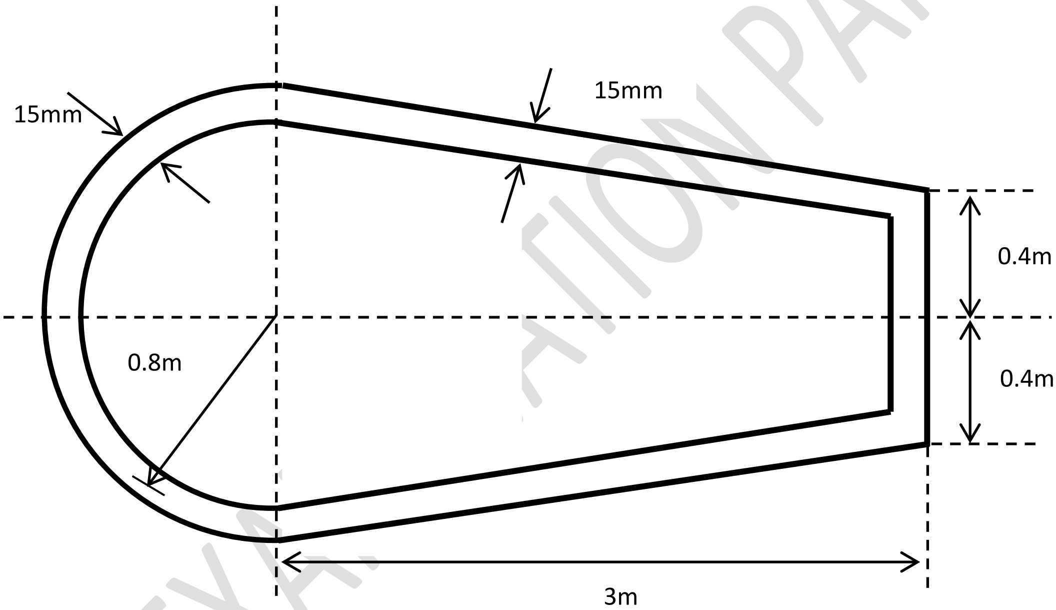

figure Q3

a) The maximum allowable torque

(15 Marks)

b) The corresponding angle of twist per meter length of the wing.

(10 Marks)

Total 25 marks

Please turn the page

Question 4

The structure in Figure Q4 consists of a rigid beam AB and five rods placed symmetrically about line CD. A load P is applied to the beam as shown. The members are made of an elastic-perfectly plastic steel (E = 210 GPa), and they each have a cross sectional area of 105 mm^2. Rods CD, FG, and HJ have a yield point stress equal to Y_1 = 550 MPa, and rods MN and RS have a yield point equal to Y_2 = 270 MPa.

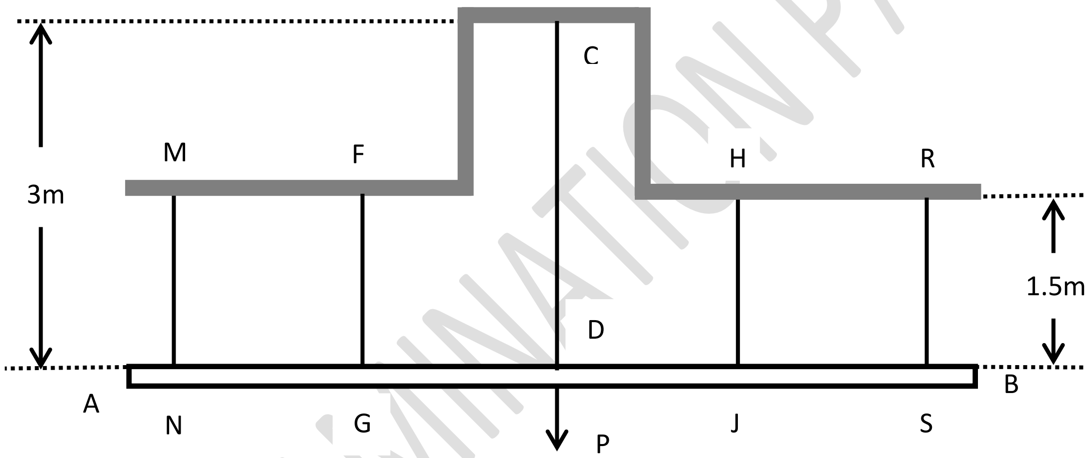

Figure Q4

a) Draw the free-body diagram for the structure show in figure Q4.

(02 Marks)

b) Assuming weight of the beam is zero, determine the magnitude of load P and the corresponding displacement of beam AB for P = P_Y, the load for which yield first occurs in the structure.

(06 Marks)

c) Repeat part (b) for P = P_P, the fully plastic load, that is, the load for which all rods have yielded.

(10 Marks)

d) The fully plastic load P_P is gradually removed. Determine the residual forces that remain in the rods of the structure.

(07 Marks)

Total 25 marks

Please turn the page

Question 5

a) The beam in Figure Q5a is made from an aluminum alloy (E = 72.0 GPa, Y=330 MPa, σ_U = 470 MPa, and σ_{am} = 170 MPa for 10^7 cycles of completely reversed load). The beam is subjected to 10^7 completely reversed cycles of load P. If h = 200 mm and p = 25.0 mm, determine the magnitude of P, based on a factor of safety of 2.

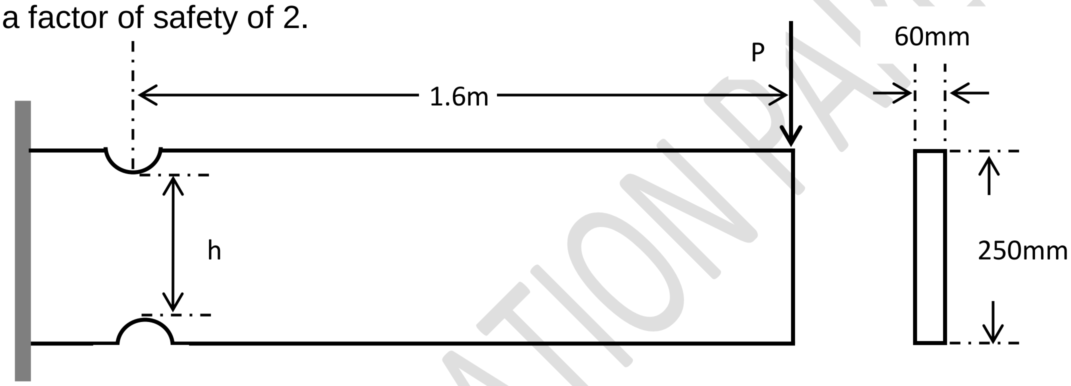

Figure Q5a

(13 marks)

b) A 2 m column with the cross section shown in Figure Q5b is constructed from two pieces of timber. The timbers are nailed together so that they act as a unit. Determine,

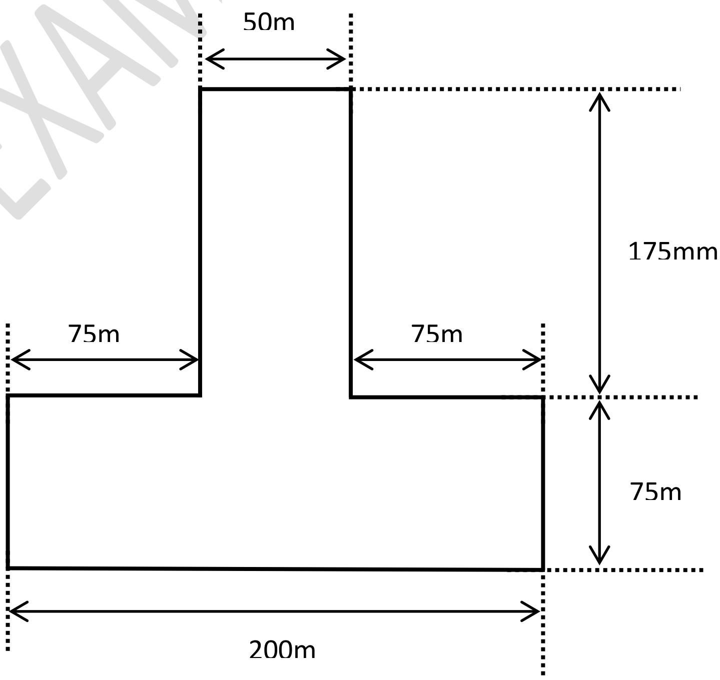

Figure Q5b

i. The slenderness ratio,
ii. The Euler buckling load (E = 18 GPa for timber)
iii. The axial stress in the column when Euler load is applied.

Total 25 marks

END OF QUESTIONS

Formula Sheet

Elasticity – finding the direction vectors

$$\begin{bmatrix} S_x \\ S_y \\ S_z \end{bmatrix} = \begin{pmatrix} \sigma_{xx} & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & \sigma_{yy} & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & \sigma_{zz} \end{pmatrix} \begin{pmatrix} l \\ m \\ n \end{pmatrix}$$

$$k = \frac{1}{\sqrt{a^2 + b^2 + c^2}}$$

Where a, b and c are the co-factors of the eigenvalue stress tensor.

$$l = ak \qquad l = \cos\alpha,$$
$$m = bk \qquad m = \cos\theta,$$
$$n = ck \qquad n = \cos\varphi.$$

Principal stresses and Mohr's Circle

$$\tau_{12} = \frac{\sigma_1 - \sigma_2}{2}$$

$$\tau_{13} = \frac{\sigma_1 - \sigma_3}{2}$$

$$\tau_{23} = \frac{\sigma_2 - \sigma_3}{2}$$

Yield Criterion

Von Mises

$$\sigma_{von\ Mises} = \frac{1}{\sqrt{2}}\left[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2\right]^{1/2}$$

Tresca

$$\sigma_{tresca} = 2 \cdot \tau_{\max}$$

$$\tau_{\max} = \max\left(\frac{|\sigma_1 - \sigma_2|}{2}; \frac{|\sigma_1 - \sigma_3|}{2}; \frac{|\sigma_3 - \sigma_2|}{2}\right)$$

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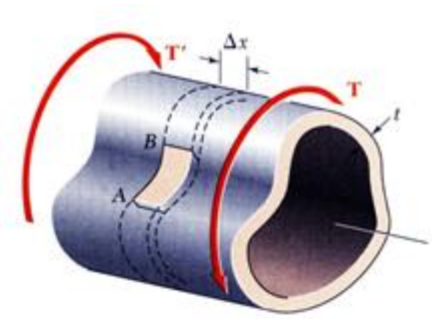
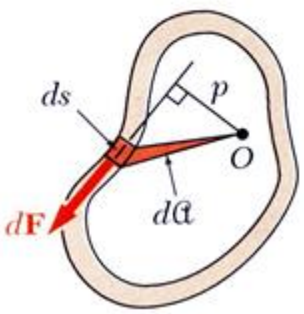
Torsion in close thin wall cross section (CTW)





- Shear stress varies inversely with thickness

$$\tau = \frac{T}{2tA}$$

- Shear flow q

$$q = \tau t$$

- Applied torque T

$$T = 2qA$$

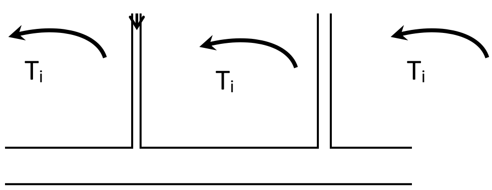
- Angle of twist φ

$$\phi = \frac{TL}{4A^2G}\oint \frac{ds}{t}$$

Torsion in multi-cells thin wall cross section

- Section considered as an assembly of N tubular sub-sections (compartments), each subjected to torque Ti as shown in the figure below:

$T =$



- Total torque

$$T = \sum_{i=1}^{n} T_i = 2\sum_{i}^{n} q_i A_i$$

- Common angle of twist for all compartments:

$$\theta = \frac{L}{4GA_i} \oint \frac{q_i - q'}{t(s)} ds$$

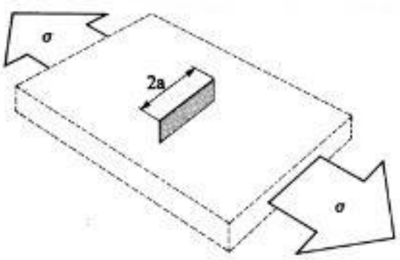
Please turn the page

$$\varphi_1 = \frac{L}{2GA_1}\left(\frac{q_1 \ell_1}{t_1} + \frac{(q_1 - q_2)\ell_3}{t_3}\right)$$
$$\varphi_2 = \frac{L}{2GA_2}\left(\frac{q_2 \ell_2}{t_2} + \frac{(q_2 - q_1)\ell_3}{t_3}\right)$$

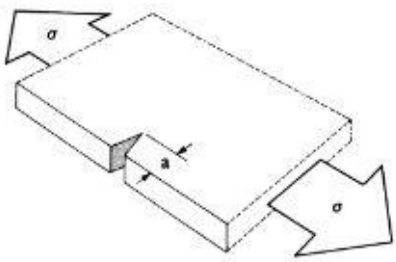
Where q is the shear flow of the main compartment, q' is the shear flow due to torque in adjacent compartments, A_i the area of cross-section i, t is the thickness of the cross-section and s is the circumference of the compartment.

Fracture mechanics

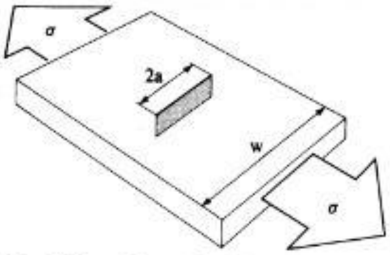
Table: Y values for plates loaded in tension



(1) Through crack of length $2a$ in an *infinite* plate
$Y = 1$

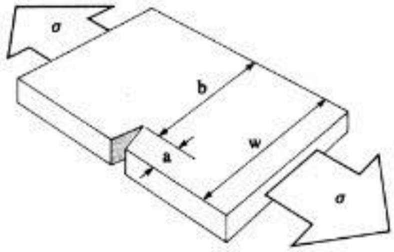


(2) Edge crack of length a in an *infinite* plate
$Y = 1.12$
Because plane strain and plane stress have identical stress fields, this calibration is also for an edge scratch of depth a on a large body carrying tensile stress σ.



(3) Through crack of length $2a$ in a plate of width w.

$$Y = \left(\sec \frac{\pi a}{w}\right)^{1/2}, \frac{2a}{w} \le 0.7$$



(4) Edge crack of length a in a plate of width w.

$$Y = 0.265\left(\frac{b}{w}\right)^4 + \frac{0.875 + 0.265a/w}{(b/w)^{3/2}}$$

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Life Calculations

$$K = Y\sigma\sqrt{\pi a}$$

$$\frac{da}{dN} = C(\Delta K)^m$$

$$N = \frac{1}{CY^m \sigma_a{}^m \pi^{\frac{m}{2}}} \left[\frac{a^{1-\frac{m}{2}}}{1-\frac{m}{2}} \right]_{a_0}^{a_1}$$

Composite materials

$$E_{composite} = E_{fibre}V_{fibre} + E_{matrix}(1 - V_{fibre})$$

Plastic Hinges.

Hollow Rectangular cross section

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DIMENSIONS AND PROPERTIES

Designation		Mass per Metre	Area of Section	Ratios for Local Buckling		Second Moment of Area		Radius of Gyration		Elastic Modulus		Plastic Modulus		Torsional Constants		Surface Area per Metre
Size D B mm	Thickness t mm	kg	A cm^2	(1) d/t	(1) b/t	Axis x-x cm^4	Axis y-y cm^4	Axis x-x cm	Axis y-y cm	Axis x-x cm^3	Axis y-y cm^3	Axis x-x cm^3	Axis y-y cm^3	J cm^4	C cm^3	m^2
50x30	2.5	2.89	3.68	17.0	9.00	11.8	5.22	1.79	1.19	4.73	3.48	5.92	4.11	11.7	5.73	0.154
	3.0	3.41	4.34	13.7	7.00	13.6	5.94	1.77	1.17	5.43	3.96	6.88	4.76	13.5	6.51	0.152
	3.2	3.61	4.60	12.6	6.38	14.2	6.20	1.76	1.16	5.68	4.13	7.25	5.00	14.2	6.80	0.152
	4.0	4.39	5.59	9.50	4.50	16.5	7.08	1.72	1.13	6.60	4.72	8.59	5.88	16.6	7.77	0.150
	5.0	5.28	6.73	7.00	3.00	18.7	7.89	1.67	1.08	7.49	5.26	10.0	6.80	19.0	8.67	0.147
60x40	2.5	3.68	4.68	21.0	13.0	22.8	12.1	2.21	1.60	7.61	6.03	9.32	7.02	25.1	9.73	0.194
	3.0	4.35	5.54	17.0	10.3	26.5	13.9	2.18	1.58	8.82	6.95	10.9	8.19	29.2	11.2	0.192
	3.2	4.62	5.88	15.8	9.50	27.8	14.6	2.18	1.57	9.27	7.29	11.5	8.64	30.8	11.7	0.192
	4.0	5.64	7.19	12.0	7.00	32.8	17.0	2.14	1.54	10.9	8.52	13.8	10.3	36.7	13.7	0.190
	5.0	6.85	8.73	9.00	5.00	38.1	19.5	2.09	1.50	12.7	9.77	16.4	12.2	43.0	15.7	0.187
	6.3	8.31	10.6	6.52	3.35	43.4	21.9	2.02	1.44	14.5	11.0	19.2	14.2	49.5	17.6	0.184
80x40	3.0	5.29	6.74	23.7	10.3	54.2	18.0	2.84	1.63	13.6	9.00	17.1	10.4	43.8	15.3	0.232
	3.2	5.62	7.16	22.0	9.50	57.2	18.9	2.83	1.63	14.3	9.46	18.0	11.0	46.2	16.1	0.232
	4.0	6.90	8.79	17.0	7.00	68.2	22.2	2.79	1.59	17.1	11.1	21.8	13.2	55.2	18.9	0.230
	5.0	8.42	10.7	13.0	5.00	80.3	25.7	2.74	1.55	20.1	12.9	26.1	15.7	65.1	21.9	0.227
	6.3	10.3	13.1	9.70	3.35	93.3	29.2	2.67	1.49	23.3	14.6	31.1	18.4	75.6	24.8	0.224
	8.0	12.5	16.0	7.00	2.00	106	32.1	2.58	1.42	26.5	16.1	36.5	21.2	85.8	27.4	0.219
90x50	3.0	6.24	7.94	27.0	13.7	84.4	33.5	3.26	2.05	18.8	13.4	23.2	15.3	76.5	22.4	0.272
	3.6	7.40	9.42	22.0	10.9	98.3	38.7	3.23	2.03	21.8	15.5	27.2	18.0	89.4	25.9	0.271
	5.0	9.99	12.7	15.0	7.00	127	49.2	3.16	1.97	28.3	19.7	36.0	23.5	116	32.9	0.267
	6.3	12.3	15.6	11.3	4.94	150	57.0	3.10	1.91	33.3	22.6	43.2	28.0	138	38.1	0.264
	8.0	15.0	19.2	8.25	3.25	174	64.6	3.01	1.84	38.6	25.8	51.4	32.9	160	43.2	0.259
100x50	3.0	6.71	8.54	30.3	13.7	110	36.8	3.58	2.08	21.9	14.7	27.3	16.8	88.4	25.0	0.292
	3.2	7.13	9.08	28.3	12.6	116	38.8	3.57	2.07	23.2	15.5	28.9	17.7	93.4	26.4	0.292
	4.0	8.78	11.2	22.0	9.50	140	46.2	3.53	2.03	27.9	18.5	35.2	21.5	113	31.4	0.290
	5.0	10.8	13.7	17.0	7.00	167	54.3	3.48	1.99	33.3	21.7	42.6	25.8	135	36.9	0.287
	6.3	13.3	16.9	12.9	4.94	197	63.0	3.42	1.93	39.4	25.2	51.3	30.8	160	42.9	0.284
	8.0	16.3	20.8	9.50	3.25	230	71.7	3.33	1.86	46.0	28.7	61.4	36.3	186	48.9	0.279
100x60	3.0	7.18	9.14	30.3	17.0	124	55.7	3.68	2.47	24.7	18.6	30.2	21.2	121	30.7	0.312
	3.6	8.53	10.9	24.8	13.7	145	64.8	3.65	2.44	28.9	21.6	35.6	24.9	142	35.6	0.311
	5.0	11.6	14.7	17.0	9.00	189	83.6	3.58	2.38	37.8	27.9	47.4	32.9	188	45.9	0.307
	6.3	14.2	18.1	12.9	6.52	225	98.1	3.52	2.33	45.0	32.7	57.3	39.5	224	53.8	0.304
	8.0	17.5	22.4	9.50	4.50	264	113	3.44	2.25	52.8	37.8	68.7	47.1	265	62.2	0.299
120x60	3.6	9.66	12.3	30.3	13.7	227	76.3	4.30	2.49	37.9	25.4	47.2	28.9	183	43.3	0.351
	5.0	13.1	16.7	21.0	9.00	299	98.8	4.23	2.43	49.9	32.9	63.1	38.4	242	56.0	0.347
	6.3	16.2	20.7	16.0	6.52	358	116	4.16	2.37	59.7	38.8	76.7	46.3	290	65.9	0.344
	8.0	20.1	25.6	12.0	4.50	425	135	4.08	2.30	70.8	45.0	92.7	55.4	344	76.6	0.339
120x80	5.0	14.7	18.7	21.0	13.0	365	193	4.42	3.21	60.9	48.2	74.6	56.1	401	77.9	0.387
	6.3	18.2	23.2	16.0	9.70	440	230	4.36	3.15	73.3	57.6	91.0	68.2	487	92.9	0.384
	8.0	22.6	28.8	12.0	7.00	525	273	4.27	3.08	87.5	68.1	111	82.6	587	110	0.379
	10.0	27.4	34.9	9.00	5.00	609	313	4.18	2.99	102	78.1	131	97.3	688	126	0.374
150x100	4.0	15.1	19.2	34.5	22.0	607	324	5.63	4.11	81.0	64.8	97.4	73.6	660	105	0.490
	5.0	18.6	23.7	27.0	17.0	739	392	5.58	4.07	98.5	78.5	119	90.1	807	127	0.487
	6.3	23.1	29.5	20.8	12.9	898	474	5.52	4.01	120	94.8	147	110	986	153	0.484
	8.0	28.9	36.8	15.8	9.50	1087	569	5.44	3.94	145	114	180	135	1203	183	0.479
	10.0	35.3	44.9	12.0	7.00	1282	665	5.34	3.85	171	133	216	161	1432	214	0.474
	12.5	42.8	54.6	9.00	5.00	1488	763	5.22	3.74	198	153	256	190	1679	246	0.468

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