[OCD007]

UNIVERSITY OF BOLTON

OFF CAMPUS DIVISION

WESTERN INTERNATIONAL COLLEGE

BENG(HONS) MECHANICAL ENGINEERING

TRIMESTER ONE EXAMINATION 2021/2022

ADVANCED MATERIALS & STRUCTURES

MODULE NO: AME6012

Date: Saturday 8th January 2022 **Time: 10:00 – 13:00**

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.

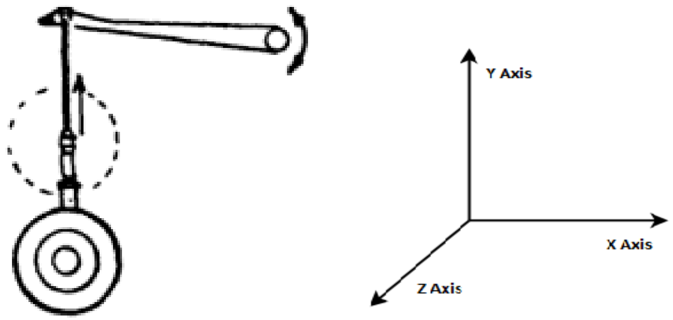
Electronic calculators may be used provided that data and program storage memory is cleaned prior to the examination.

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

University Of Bolton
Western International College
BEng(Hons) Mechanical Engineering
Trimester One Examination 2021/2022
Advanced Materials & Structures
Module No: AME6012

Q1

Part of a landing gear of an aircraft is subjected to the following direct stresses in the x, y and z directions as shown in the Figure Q1a. The stress tensor matrix for the given scenario is shown in Figure Q1b.



$$\sigma = \begin{bmatrix} 30 & 0 & 10 \\ 0 & 0 & 20 \\ 10 & 20 & 0 \end{bmatrix}$$

Figure Q1a. Aircraft landing gear **Figure Q1b**. Stress Tensor Matrix

Determine the following:

a) Draw the elemental cube showing the stresses acting on it.

(5 marks)

b) Using this information given above prove that one of the principal stress is a compressive stress of 21 MPa

(10 marks)

c) the angles relative to xyz co-ordinates and make a sketch showing the direction of these stresses.

(5 marks)

d) If the yield stress for the material is 320 MPa determine the factor of safety assuming the material follows the Von Misses criterion.

(5 marks)

Total 25 marks

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Q2

A 90 X 120mm wide pultruded section fabricated from glass reinforced polyester is shown in Figure Q2 below with the material specification. The section is used as a cantilever 3 m in length. Beams are to be used to support a mass of 500 Kg and are placed at the midpoint of the cantilever. If the beam is designed to have a maximum design strain of 0.2 %, determine the following using the data from the **Table1**.

a) Sketch the effective shape of the cross section and determine the second moment of area.

(10 Marks)

b) Determine the stress through the depth of each layer of the beam.

(10 Marks)

c) Sketch the stress distribution through the depth of each beam and indicate the salient values.

(5 Marks)

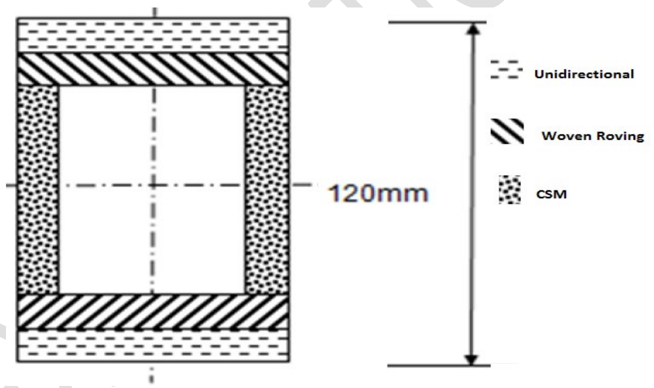

Figure Q2. Pultruded Cross section of the Beam

Table 1: Details of the composite structure

Material	Efficiency Factor, %	Modulus (GPa)	Volume Fraction, %	Thickness, mm
Unidirectional	0.9	65	60	10
Woven Roving	0.5	65	40	10
CSM	0.25	65	30	40
Polyester Resin	-	3		

Total 25 marks

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Q3

a) The values of the endurance limits at various stress amplitude levels for low-alloy constructional steel fatigue specimens are given in the **Table 2** below where σ indicates stress value and N_f for number of cycles for fatigue.

Table 2, Stress & number of cycles

σ (MN/m^2)	N_f (Cycles)
550	1500
510	10050
480	20800
450	50 500
410	125000
380	275000

A similar specimen is subjected to the following program of cycles at the stress amplitudes stated; N_f =3000 at σ=510 MN/m^2, N_f =12000 at σ=450 MN/m^2 and N_f =80000 at σ= 380 MN/m^2, after which the sample remained unbroken. Determine the additional cycles the specimen need to withstand at σ=480 MN/m^2 prior to failure? Assume zero mean stress conditions.

(12 Marks)

b) The fatigue behavior of mild steel specimen under an alternating stress conditions with zero mean stress is given by the expression:

$$\sigma_r^a . N_f = K$$

Where σ_r, is the range of cyclic stress,

N_f is the number of cycles to failure and K and 'a' are material constants of mild steel.

If it is given that N_f = $I0^6$ when a= 300 MN/m^2 and N_f = $I0^8$ when a = 200 MN/m^2. Determine the constants K and 'a' and also find the life of the specimen when subjected to a stress range of 100 MN/m^2.

(13 Marks)

Total 25 marks

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Q4.

For the portal frame which supports ship's hull is shown in **figure Q4** below, yield stress is 120 MPa, determine the following.

a) Show all the possible collapse mechanism for the portal frame for **figure Q4.**

(5 Marks)

b) Find the plastic modulus (Z_p) for the portal frame.

(15 Marks)

c) For the hollow rectangular cross section of the beam find the optimum beam dimensions for the likeliest failure mode, sketch the cross section showing the dimensions.

(5 Marks)

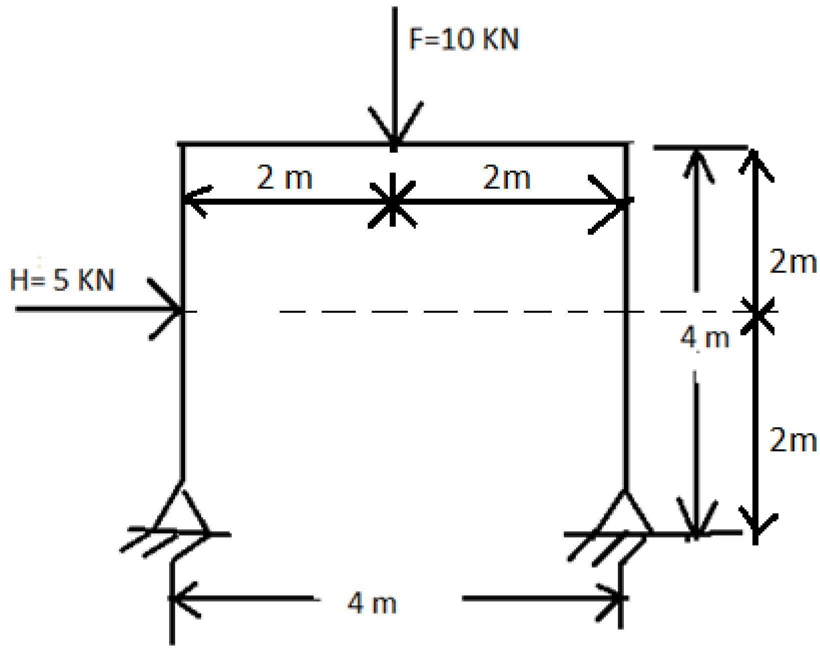

Figure Q4, Portal frame with forces.

Total 25 marks

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Q5

The cross-section of an extruded aluminium alloy member 3m long is shown schematically in figure Q5 below. The section is subjected to a torque along its longitudinal axis. For this situation:

Thickness, t_1= 0.015 m, t_2 = 0.011 m, t_3 = 0.006 m.

Lengths, AB = AG = 0.25m, BC = GF = 0.45m, BG = CF = CD = DE = EF = 0.35m.

Take Modulus of rigidity, G= 30 GPa.

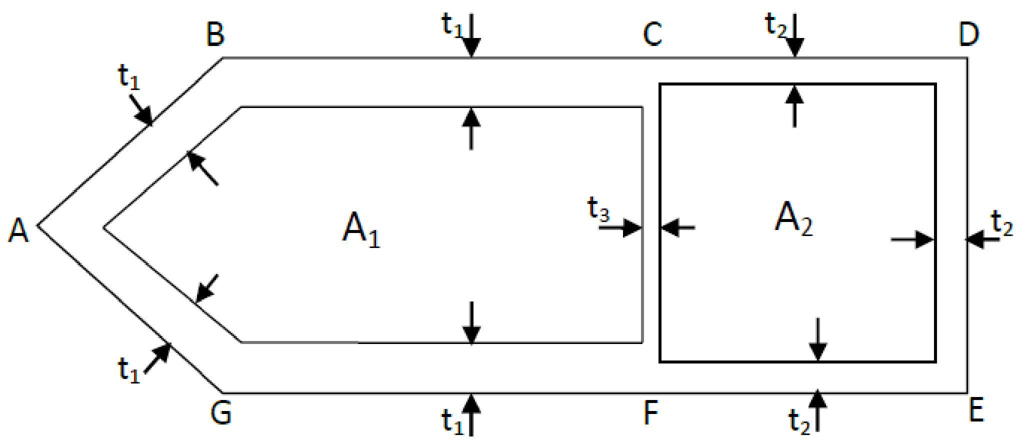

Figure Q5, Cross section of aluminium alloy

a) Determine maximum torque for an allowable shear stress of 50 MPa.

(8 marks)

b) For each wall thickness evaluate shear stresses in each part of the section and show the positions by a simple sketch

(4 marks)

c) Under the calculated torque determine the angle of twist

(3 marks)

d) After field trials a redesign has been suggested. This involves removing section DE from the cross section shown. For this new section determine the maximum shear stress and the percentage increase in the angle of twist.

(10 marks)

Total 25 marks

END OF QUESTIONS
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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

Yield Criterion

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

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

Von Mises

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

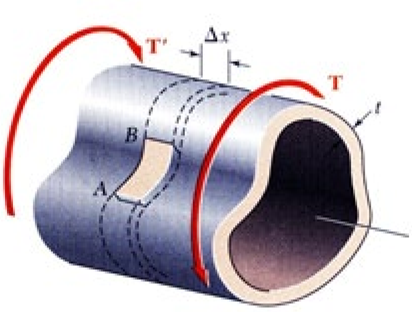
$$\sigma_{von\ Mises} = \frac{1}{\sqrt{2}}\left[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2\right]^{1/2}$$

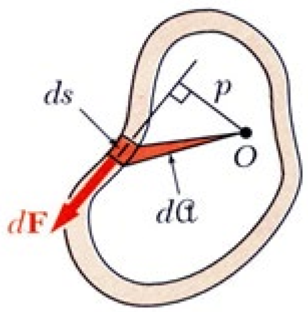
Tresca

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

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

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

$$T = 2qA$$

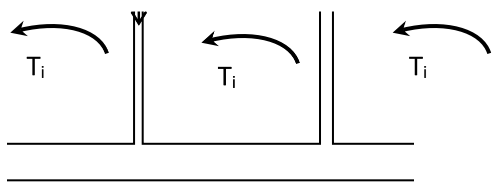
- Angle of twist φ

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

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:

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

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

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

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.

Torsion in open thin wall cross section (OTW)

$$If\ \frac{b}{t} \geq 10\ \ then\ \ \alpha = \beta = \frac{1}{3}$$

$$and\quad J_\alpha = J_\beta = J = \sum_{i=1}^{n} \frac{1}{3} b_i t_i^3$$

Shear stress

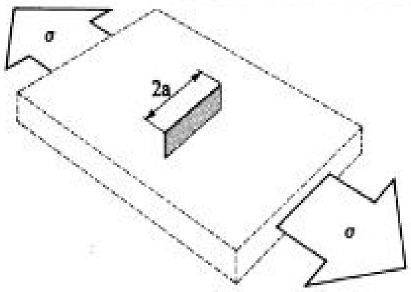
$$\tau_{\max} = \frac{T t_{\max}}{J}$$

Twist angle

$$\varphi = \frac{LT}{GJ}$$

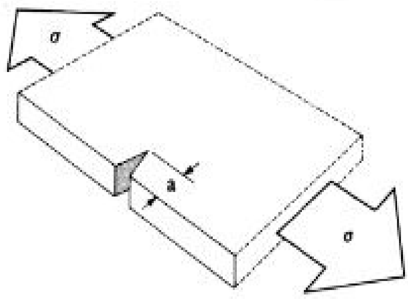
Fracture mechanics

Table: Y values for plates loaded in tension



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

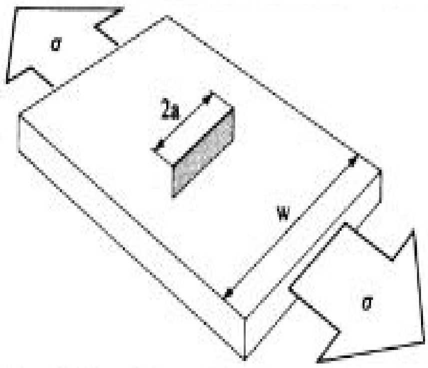
$Y = 1$



(2) Edge crack of length a in an *infinite* plate

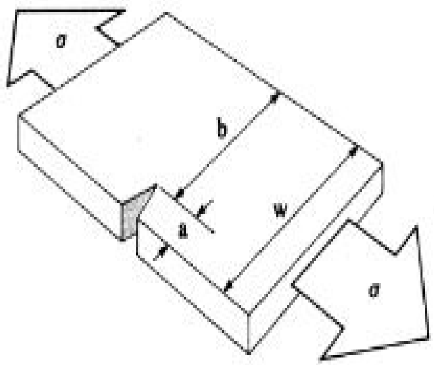
$Y = 1.12$

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.

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



(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

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

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

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

Composite materials

$$E_c = \eta E_f V_f + E_m\left(1 - V_f\right)$$

<u>Miners Rule.</u>

Miners Rule

$$\sum \frac{n_1}{N_1} + \frac{n_2}{N_2} + \frac{n_3}{N_3} + \ldots = 1$$

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Plastic Hinges

DIMENSIONS AND PROPERTIES

Designation Size D B mm	Thickness t mm	Mass per Metre kg	Area of Section A cm²	Ratios for Local Buckling (1) d/t	(1) b/t	Second Moment of Area Axis x-x cm⁴	Axis y-y cm⁴	Radius of Gyration Axis x-x cm	Axis y-y cm	Elastic Modulus Axis x-x cm³	Axis y-y cm³	Plastic Modulus Axis x-x cm³	Axis y-y cm³	Torsional Constants J cm⁴	C cm³	Surface Area per Metre m²
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	12.8	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

END OF FORMULA SHEET

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