Cornell TAM 2020

No calculators, books or notes allowed.

5 Problems, 150 minutes (no overtime, as per university policy)

Final Exam

December 10, 2010

How to get the highest score?

Please, please, please do these things:

- Draw **Free body diagrams** whenever force, moment, linear momentum, or angular momentum balance are used.

- Use correct **vector notation**.

A+ Be   (I) neat,   (II) clear and   (III) well organized.

☐ TIDILY REDUCE and $\boxed{\text{box in}}$ your answers (Don't leave simplifiable algebraic expressions).

>> Make appropriate `Matlab code` clear and correct.
    You can use shortcut notation like "$T_7 = 18$" instead of, say, "`T(7) = 18`".
    Small syntax errors will have small penalties.

- Clearly **define** any needed dimensions ($\ell, h, d, \dots$), coordinates ($x, y, r, \theta \dots$), variables ($v, m, t, \dots$), base vectors ($\hat{\imath}, \hat{\jmath}, \hat{e}_r, \hat{e}_\theta, \hat{\lambda}, \hat{n} \dots$) and signs ($\pm$) with sketches, equations or words.

- **Justify** your results so a grader can distinguish an informed answer from a guess.

- If a problem seems *poorly defined*, clearly state any reasonable assumptions (that do not oversimplify the problem).

≈ Work for **partial credit** (from $60-100\%$, depending on the problem)

  - Put your answer is in terms of well defined variables even if you have not substituted in the numerical values.

  - Reduce the problem to a clearly defined set of equations to solve.

  - Provide Matlab code which would generate the desired answer (and explain the nature of the output).

☐ **Extra sheets.** Put your name on each extra sheet, fold it in, and refer to it at the relevant problem.
    Note the last page is **blank** for your use. Ask for more extra paper if you need it.

Problem 10: _____ /25

Problem 11: _____ /25

Problem 12: _____ /25

Problem 13: _____ /25

Problem 14: _____ /25

10) A horizontal W12×96 I-beam, has flanges at top and bottom, and has length $L = 100$ in. The complete free body diagram of the beam shows a moment M_0 and a vertical force $P = 1000$ lbf at one end and the opposite force at the other end. Neglect the weight of the beam. Write a clear ordered sequence of formulas that would calculate the quantities in parts (a), (b) and (c) below. The right side of each formula can only have variables which have been on the left side of the formulas above it. For example, the first three formulas in this list are:

$$P = 1000 \, \text{lbf}$$
$$L = 100 \, \text{in}$$
$$M_0 = LP$$
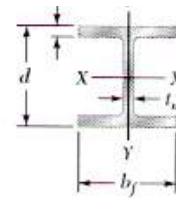
a) The maximum tension stress in the beam?

b) The maximum shear stress in the beam (on a surface whose normal is along the length of the beam)? Clearly explain any estimates you make to do this calculation. You need not repeat formulas used in part (a).

c) What is the weight of this beam? (Use the table below and or numbers you remember and do approximate arithmetic.) Full credit for answers within 50% of correct. Was it reasonable to neglect the weight of this beam?

APPENDIX B Properties of Rolled-Steel Shapes
(U.S. Customary Units)
Continued from page 680

W Shapes
(Wide-Flange Shapes)

			Flange		Web		Axis X-X			Axis Y-Y		
				Thick-	Thick-							
	Area	Depth	Width	ness	ness							
Designation†	A, in²	d, in.	b_f, in.	t_f, in.	t_w, in.	I_x, in⁴	S_x, in³	r_x, in.	I_y, in⁴	S_y, in³	r_y, in.
W12 × 96	28.2	12.7	12.2	0.900	0.550	833	131	5.44	270	44.4	3.09
72	21.1	12.3	12.0	0.670	0.430	597	97.4	5.31	195	32.4	3.04
50	14.6	12.2	8.08	0.640	0.370	391	64.2	5.18	56.3	13.9	1.96
40	11.7	11.9	8.01	0.515	0.295	307	51.5	5.13	44.1	11.0	1.94
35	10.3	12.5	6.56	0.520	0.300	285	45.6	5.25	24.5	7.47	1.54
30	8.79	12.3	6.52	0.440	0.260	238	38.6	5.21	20.3	6.24	1.52
26	7.65	12.2	6.49	0.380	0.230	204	33.4	5.17	17.3	5.34	1.51
22	6.48	12.3	4.03	0.425	0.260	156	25.4	4.91	4.66	2.31	0.848
16	4.71	12.0	3.99	0.265	0.220	103	17.1	4.67	2.82	1.41	0.773
W10 × 112	32.9	11.4	10.4	1.25	0.755	716	126	4.66	236	45.3	2.68
68	20.0	10.4	10.1	0.770	0.470	394	75.7	4.44	134	26.4	2.59
54	15.8	10.1	10.0	0.615	0.370	303	60.0	4.37	103	20.6	2.56
45	13.3	10.1	8.02	0.620	0.350	248	49.1	4.32	53.4	13.3	2.01
39	11.5	9.92	7.99	0.530	0.315	209	42.1	4.27	45.0	11.3	1.98
33	9.71	9.73	7.96	0.435	0.290	171	35.0	4.19	36.6	9.20	1.94
30	8.84	10.5	5.81	0.510	0.300	170	32.4	4.38	16.7	5.75	1.37

11) Water is held back by the rotary dam shown. The whole dam is a big plate that is held at the top. Assume the following quantities are given:
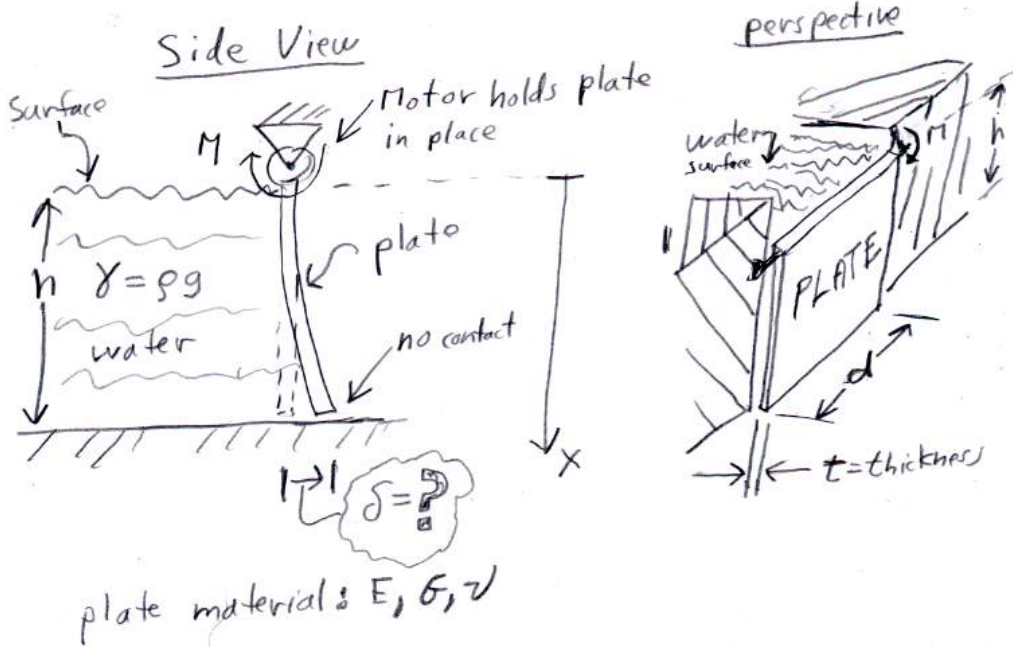
E, G, v Elastic moduli of plate
 d, t, h width, thickness and height of plate (h is also the depth of the water)
$\gamma = \rho g$ density of water (weight per unit volume)

Find the deflection δ of the bottom of the plate due to the water pressure. Answer in terms of the given quantities. [Hint, first find M.]

12) A standard paperclip is partially unfolded and held at the edge of a rigid table as shown. The folded part is held firmly on the table at A and B. The part overhanging has force P applied at D. Neglect the bending of segment CD (treat it as rigid). Consider only the torsion of the segment AC. In terms of some or all of
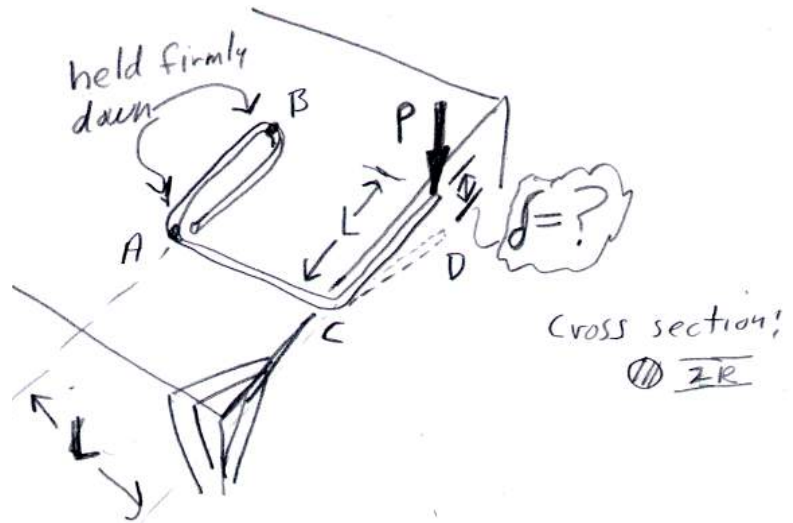
E, G, v Elastic moduli of paper clip
$\quad\quad L$ length of torsion segment AC and of rigid segment CD
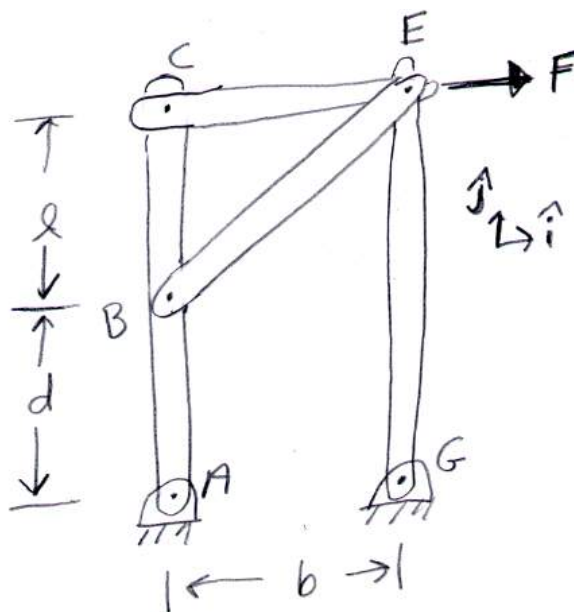$\quad\quad R$ radius of paperclip
$\quad\quad P$ applied force

a) find the deflection δ.

b) What is the Young's modulus E of the paper clip? A numerical answer is desired. Answer in any units you like. Full credit if answer is within 20% of correct.

13) Four rigid bars (EG, EC, BE and ABC) are connected with pins as shown with the force F applied to the end of bar CE at E. Find the force of bar CE on bar ABC at C. Answer in terms of some or all of $F, b, d, \ell, \hat{i}$ and $\hat{j}$.

14) A uniform solid rigid cube with sides $2a$ and mass m has edges parallel to the xyz axis. The cube is held in place by 6 rods each with length ℓ. Each rod is parallel to one of the axes. Find the tensions in the 6 rods in terms of some or all of m, g, a and ℓ. [Hint, at least one tension is zero.]

Answer here:

$T_{KJ} =$

$T_{HI} =$

$T_{EH} =$

$T_{CN} =$

$T_{CD} =$

$T_{AB} =$