National Exams December 2019

16-Mec-B1, Advanced Machine Design

Notes

- Time: 3 hours.
- This is an open book exam.
- **Answer all questions of Part I (i.e. Questions 1, 2), and only THREE questions from Part II of the examination.**
- Make sure your answers are neat and clear.
- State all assumptions clearly. If doubt arises as to the interpretation of any question, write down a clear statement of any assumptions made.
- All answers must be clearly annotated with a summary of the approach, method, and results written in clear and correct English.
- Document your sources of information whenever you use a tabulated value or an equation.
- Any non-communicating calculator is permitted.
- Assume any missing data and make sure to properly state in your answer.
- The examination marks 100 in total.
- Failure to follow the above directions will result in grade penalties.

Problem 1. Briefly answer the following questions:

                                                          (2 mark)

(a) Name at least five green design criteria.

(b) Why is a hollow shaft preferred over a solid shaft? What are the disadvantages of a hollow shaft? **(3 marks)**

(c) For a stress element with a set of applied stresses as shown below (unit: MPa), what are the values of principal stresses and the maximum shear stress? **(5 marks)**
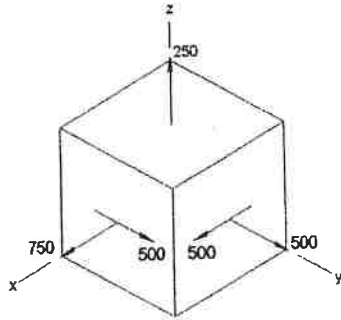
Problem 2. An overhung diving board is shown in the following figure with a cross-section of 305 mm x 32 mm. Find the largest principal stress that will result when a 100-kg person jumps up 25 cm at the free end and lands back on the board. Assume that the board weighs 29 kg and deflects 131 mm statically when the person stands on it. What is the static safety factor if the material has an ultimate stress of 130 MPa in the longitudinal direction? Take the diving board as a beam in your calculation. **(30 marks)**
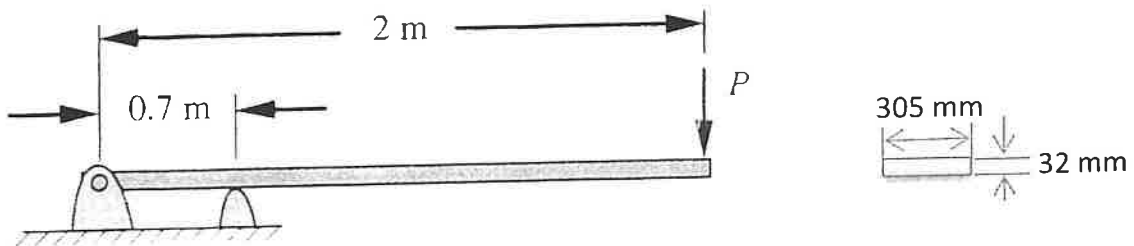
Part II

Problem 3. Design a single-surface disk clutch to transmit 120 N.m of torque at 500 rpm using a molded lining with a maximum pressure of 1.5 MPa and friction coefficient of 0.3. Assume uniform wear. Find the outside and inside diameters required using an inside to outside diametral ratio of 0.7. What is the power transmitted? **(20 marks)**

Problem 4. A steel bar, 22 mm x 30 mm in cross-section, is loaded axially in tension with $F_{min} = -4 \ kN$, $F_{max} = 12 \ kN$. A 10-mm hole passes through the centre of the 30-mm side.
Find:
(1) The fatigue stress concentration factor;
(2) Worst case mean and alternating stresses;
(3) Fatigue safety factor for infinite life.
Assume machined surfaces and room temperature, $S_{ut} = 500 \ MPa$ and reliability of 99.999%. **(20 marks)**

Problem 5. For a double short-shoe external drum brake with a drum width of 60 mm as shown in the following figure, find the torque capacity and required actuating force F_a for $a = 90$ mm, $b = 80$ mm, $e = 30$ mm, $r = 40$ mm, and $\theta = 25°$. What value of c will make it self-locking? Assume the maximum allowable lining pressure is 1.3 MPa and the friction coefficient for the brake lining material is $\mu = 0.25$. **(20 marks)**
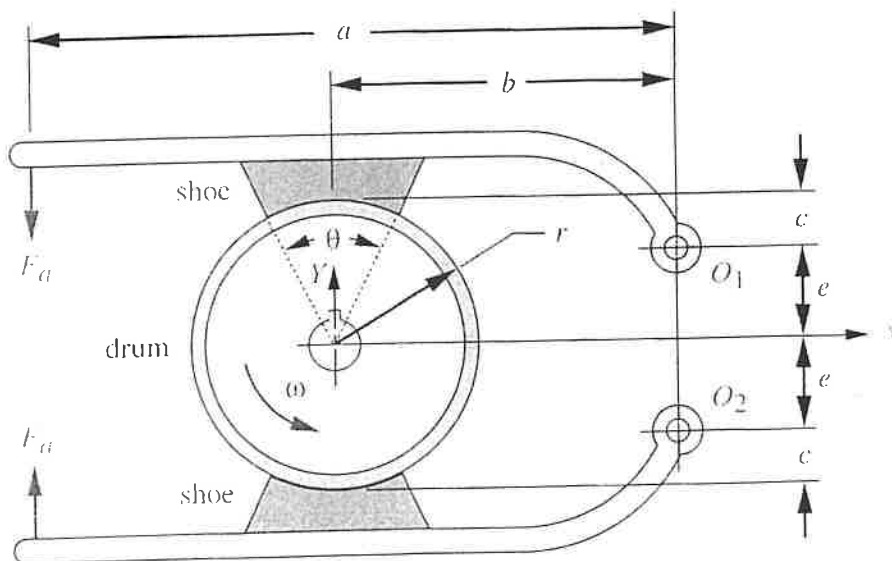
Problem 6. Two identical 3 in. power screws (single threaded) with Acme threads are used to raise and lower a 50 ton sluice gate of a dam. The quality of construction and maintenance (including lubrication) are good, resulting in an estimated friction coefficient of 0.1 for both screws. The collar bearings have an effective diameter of 5 in. and a coefficient of friction of 0.03, as roller thrust bearings are used. Friction of the sluice gate in its tracks adds 2 tons to its weight when raising and reduces its apparent weight by 2 tons when lowering. The gate is designed to move at a speed of 2 ft/min. Find: (a) the torque required to drive each screw to either raise or lower the sluice gate; (b) the rotation speed of the screws; and (c) the horse-power needed by each screw's motor to raise the gate (raising torque × angular velocity). Use the following tables for the sizes of the Acme threads. **(20 marks)**

Major Diameter (in)	Threads per inch	Thread Pitch (in)	Pitch Diameter (in)	Minor Diameter (in)	Tensile Stress Area (in²)
0.250	16	0.063	0.219	0.188	0.032
0.313	14	0.071	0.277	0.241	0.053
0.375	12	0.083	0.333	0.292	0.077
0.438	12	0.083	0.396	0.354	0.110
0.500	10	0.100	0.450	0.400	0.142
0.625	8	0.125	0.563	0.500	0.222
0.750	6	0.167	0.667	0.583	0.307
0.875	6	0.167	0.792	0.708	0.442
1.000	5	0.200	0.900	0.800	0.568
1.125	5	0.200	1.025	0.925	0.747
1.250	5	0.200	1.150	1.050	0.950
1.375	4	0.250	1.250	1.125	1.108
1.500	4	0.250	1.375	1.250	1.353
1.750	4	0.250	1.625	1.500	1.918
2.000	4	0.250	1.875	1.750	2.580
2.250	3	0.333	2.083	1.917	3.142
2.500	3	0.333	2.333	2.167	3.976
2.750	3	0.333	2.583	2.417	4.909
3.000	2	0.500	2.750	2.500	5.412
3.500	2	0.500	3.250	3.000	7.670
4.000	2	0.500	3.750	3.500	10.321
4.500	2	0.500	4.250	4.000	13.364
5.000	2	0.500	4.750	4.500	16.800