

National Exams December 2009

04-Agric-B3, Machine Design for Agricultural, Biosystems & Food Industries

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is an OPEN BOOK EXAM.
3. Any non-communicating calculator is permitted.
4. Students may answer 5 out of the 6 questions.
5. The first five questions as they appear in the answer book will be marked.
6. All questions require calculation.
7. Each question is of equal value.

1. A plate of 1045 steel in the hot-rolled condition is subjected to the following stresses: $\sigma_x = 3,300$ psi; $\sigma_y = -29,000$ psi; $\tau_{xy} = 0$. Please see the following two tables.

- Find the value of the safety factor (F_s) by the maximum shear theory
- Find the value of the F_s by the maximum distortion energy theory
- Find F_s if the plate is made of Class 25 cast iron.

Table for Question 1.

Steel	Condition	Tensile Strength, psi	Yield Strength, psi	% Elong. in 2 in.	% Red. in area	BHN	Rockwell	Machinability, %
1035	Hot-rolled	85,000	54,000	30	53	183	B90	65
	Cold-drawn	92,000	79,000	25	50	201	B94	
	Water Q1550°F							
1045	Drawn 1000°F	103,000	72,000	23	59	201	B94	56
	Hot-rolled	98,000	59,000	24	45	212	C16	
1060†	Cold-drawn	103,000	90,000	14	40	217	C18	60
	Hot-rolled	95,000	59,000	25	52	197	C14	53
1095	Oil Q1550°F							
	Drawn 1000°F	122,000	90,000	19	53	255	C25	
1137	Hot-rolled	142,000	83,000	18	38	293	C28	
	Water Q1450°F							
3140†	Drawn 800°F	200,000	118,000	12	37	388	C42	
	Hot-rolled	92,000	57,000	27	61	192	B92	70
4140	Cold-drawn	105,000	90,000	15	38	207	C15	75
	Oil Q1550°F							
4340	Drawn 1000°F	112,000	88,000	21	56	255	C25	
	Hot-rolled	96,000	64,000	26	56	195	C12	57
4640†	Cold-drawn	115,000	98,000	17	45	248	C24	
	Hot-rolled	89,000	62,000	26	38	187	B91	57
52100†	Cold-drawn	102,000	90,000	18	50	223	C19	66
	Hot-rolled	101,000	69,000	21	45	207	C15	45
6150	Cold-drawn	111,000	99,000	16	42	223	C19	55
	Oil Q1530°F							
8740	Drawn 1000°F	182,000	162,000	15	40	363	C39	
	Hot-rolled	100,000	87,000	21	50	201	C12	60
9260†	Cold-drawn	126,000	97,000	14	39	269	C27	
	Hot-rolled	109,000	80,000	25	57	235	C22	45
9260†	Oil Q1550°F							
	Drawn 1000°F	185,000	170,000	9	34	415	C43	
8740	Hot-rolled	103,000	70,000	27	51	217	C18	50
	Cold-drawn	118,000	94,000	20	43	255	C25	
9260†	Hot-rolled	95,000	64,000	25	55	190	B92	56
	Cold-drawn	107,000	96,000	17	48	223	C19	66
9260†	Hot-rolled	142,000	92,000	18	38	302	C31	

*See notes at bottom of Table 14-4.

†Steels 1060, 3140, 4640, 52100, and 9260 usually not stocked by steel warehouses.

Table for Question 1.

TABLE 14-16 Strength of Gray Cast Irons*

Class No.	Tensile Strength Min., psi	Average Transverse Load,† lb	Compressive Strength‡, psi	Average Shear Strength, psi	Modulus of Elasticity, psi	BHN	Usual Min. Wall Thickness, in.
20	20,000	1,800	80,000	32,500	11,600,000	110	1/8
25	25,000	2,000	100,000	34,000	14,200,000	140	1/8
30	30,000	2,200	110,000	41,000	14,500,000	170	1/4
35	35,000	2,400	125,000	49,000	16,000,000	200	3/8
40	40,000	2,600	135,000	52,000	18,100,000	230	1/2
50	50,000	3,000	160,000	64,000	22,600,000	250	1/2
60	60,000	3,400	150,000	60,000	19,900,000	275	3/4

*For SI units, divide stress values by 145, being the conversion factor for psi to MPa.

†Specimen 1.2-in. diameter, 18-in. supports, load at center.

‡Subject to variations up to ± 10 percent.

2. A 3.4375 inch (in.) diameter shaft is made from material with a yield strength of 58,000 psi. A 0.875 x 1 in. (width x height) key is to be used and it is made of material with a yield strength of 48,000 psi. Let $\tau_{yp} = 0.5 \sigma_{yp}$. Assuming the shaft strength is sufficient for any length of the key. Find the required length of the key based on the torque value of the shaft. Assume $F_s=2$.
3. Gears
 - a) A 20-tooth pinion with a diametral pitch of 8 rotates 2,000 rpm and drives a gear at 1,000 rpm. What are the number of teeth in the gear, the theoretical centre distance, and the circular pitch?
 - b) A pair of involute gears have base circle diameters of 60 and 120 mm. If the centre distance is 100 mm, what is the pressure angle?
4. The tractor shown in Fig. 1 below is a 184 kW, rear-wheel-drive tractor. The tractor has a mass of 15,400 kg, 40% of which is distributed on the front wheels and the rest on the rear wheels. The tractor has a total of twelve wheels, each of which has a width of 58.7 cm and outside diameter of 180.8 cm. The tractor works in a field having soil's cohesion $c=10$ kPa and friction angle $\phi=25$ degree. Assume that the contact length of each tire on the ground is half of the outside diameter of the tire.
 - a. What is the maximum gross traction force that the rear wheels of this tractor can develop on this field?
 - b. When the tractor travels at 5 km/h, the rolling resistance of each wheel is 0.75 kN. If the aerodynamic force is negligible. What will be the maximum force available to pull an implement in this field?

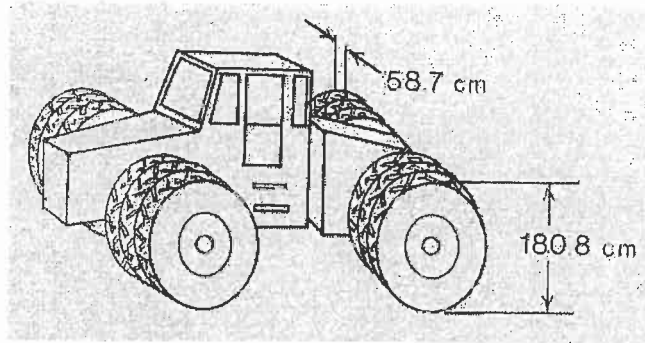
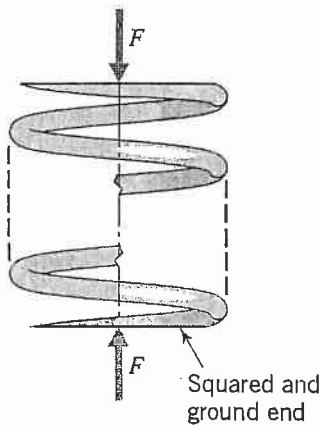
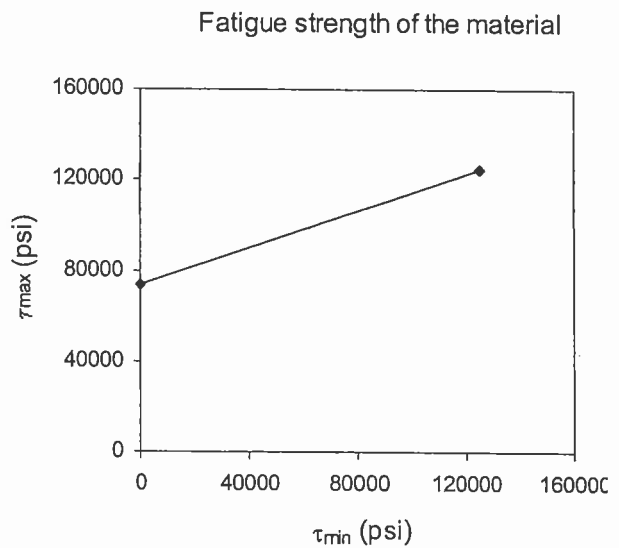


Fig. 1. For Question 4.

5. A coil spring with squared and ground ends (Fig. 2a) is to operate with a fatigue load that fluctuates between 45 and 90 lb. During the load change from 45 to 90 lb, the deflection of the spring is to vary by 0.5 in. Steel spring wire corresponding to the fatigue strength shown in Fig. 2b is to be used. If the spring index is selected as 12, determine appropriate values for the mean coil diameter (D) and the spring wire diameter (d).



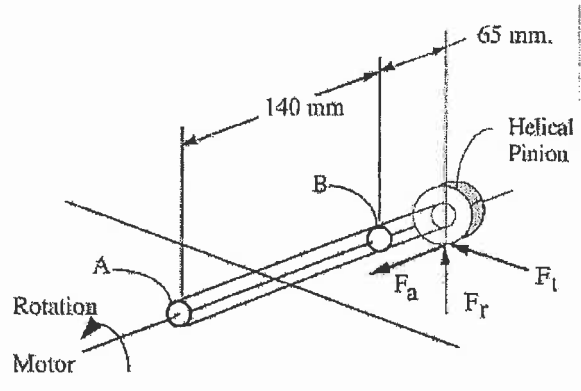
(a)



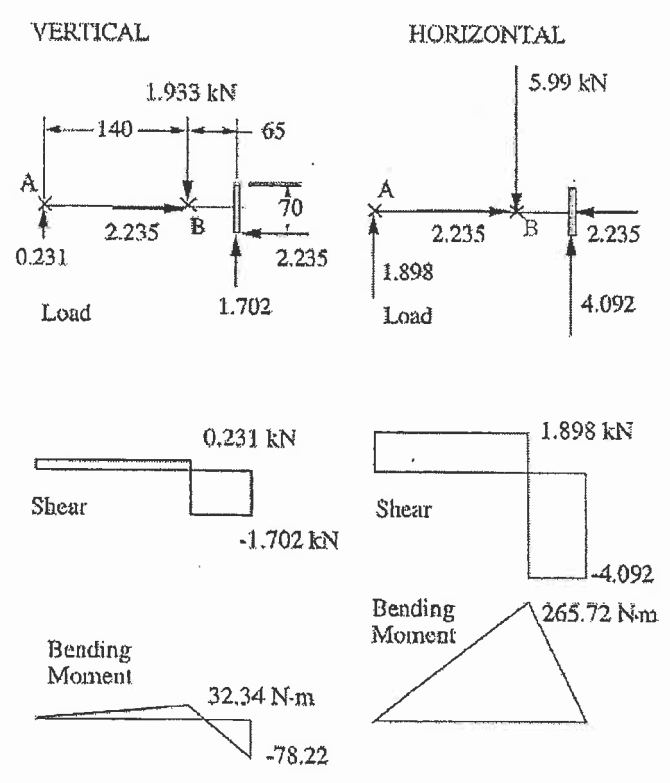
(b)

Fig. 2. For Question 5.

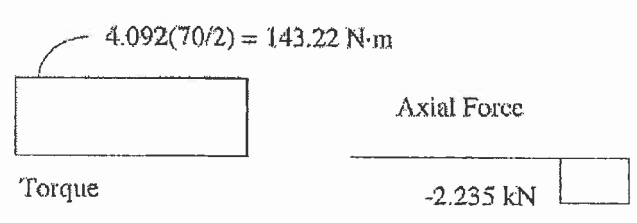
6. Bearings A and B support a helical gear mounted on the shaft (Fig. 3a). The load diagrams for the shaft are given in the horizontal and vertical planes (Fig. 3b), as well as the shaft torsional and axial force loadings (Fig. 3c). The material to be selected has the strength: $S_u = 600 \times 10^6 \text{ N/m}^2$ and $S_n = 300 \times 10^6 \text{ N/m}^2$. Stress concentration factors: 1.2 for bending and 2.2 for torsion. Safety factor: $SF=1.8$. Determine the shaft diameter.



(a)



(b)



(c)

Fig. 3. For Question 6.