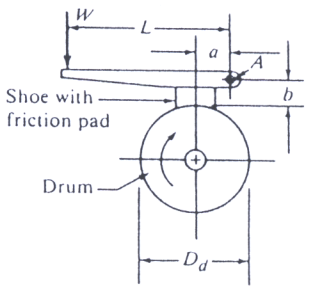
1. (10%) (a) What are the advantages and disadvantages with helical gears, as oppose to spur gears, in mechanical design? (b) What is the main disadvantage with the $14\frac{1}{2}^{\circ}$ system, as oppose to 20° system, involute gears?

2. (10%) Given a bevel gear set, the pitch cone angles of the pinion and gear are γ and Γ, respectively. Show that $\gamma = \tan^{-1}\frac{N_P}{N_G}$, where N_P and N_G denote the number of teeth of the pinion and gear, respectively.

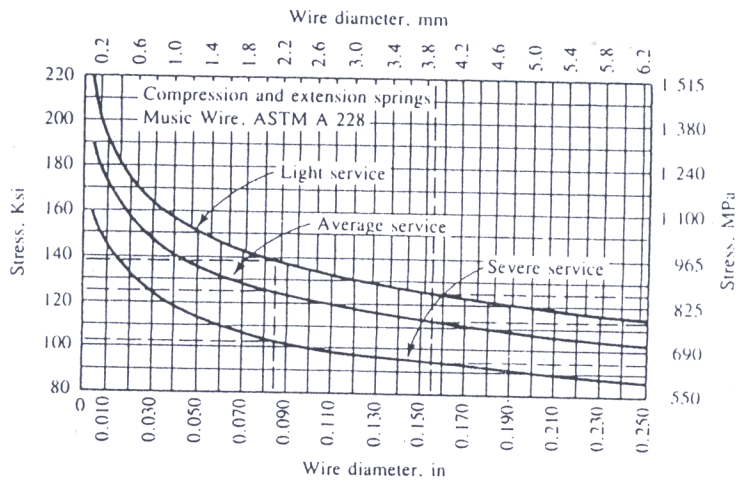
3. (15%) (a) For the short shoe brake shown in the figure, derive the friction torque. The friction coefficient of the pad is denoted by f. (b) Let D_d=10.0 in, a=3.0 in, f=0.75, and L=15.0 in. What is the value of b in order for the brake to be self-locking.



4. (15%) A helical compression spring made from ASTM A228 steel (shear modulus G=11850 ksi) is in an average service condition. The following features are measured:
Operating length: L_o=0.679 in; Operating load: F_o=14 lb;
Number of active coils: N_a=8; Outside diameter: OD=0.561 in;
Wire diameter: D_w=0.055 in.
(a) Calculate the spring rate of the spring.
(b) Consider stresses at the operating length and solid length. Is it safe to use this spring?
The formula for shear stress, deflection, and Wahl factor are given as follows:

$$\tau = \frac{8KFD_m}{\pi D_w^3} \qquad f = \frac{8FD_m^3 N_a}{GD_w^4} \qquad K = \frac{4C-1}{4C-4} + \frac{0.615}{C}$$

where C is the spring index.



5. A class 8.8, M10x1.5 bolt with rolled threads (S_u= 830Mpa, S_y=660Mpa, endurance limit $S_e(S_n)$=373Mpa, proof strength S_p= 600Mpa, tensile stress area A_t= 58mm^2, fatigue stress concentration factor k_f=3) is used in a joint having a soft gasket such that the clamped member stiffness is only half the bolt stiffness. The bolt initial tension corresponds to 0.9 S_pA_t. During operation, there is an external separating force that fluctuates between 0 and P. This application involves negligible bending of the bolts.
   (a) Estimate the maximum value of P that would not cause eventual fatigue failure. (10%)
   (b) Estimate the maximum value of P that would not cause joint separation. (10%)

6. A straight roller bearing is subjected to a radial load of 10KN. The life is to be 3500h at a speed of 800rev/min. What load rating should be used to enter the bearing catalog? (10%)

7. (a) In what loading situation should we consider buckling failure in design of machine parts? (5%)
   (b) What property of the material is highly related to the phenomenon of buckling failure? (5%)

8. (a) What is the maximum shear stress theory? (5%)
   (c) Please explain the modified Goodman criteria by using both the equation and the fatigue diagram. (5%)