Problem 1. The AISI 1030 cold drawn steel bar shown in Figure 1 is simply supported at each end. The diameters of the non-rotating bar are D = 2.4 in and d = 1.6 in and the radius of the groove is r = 0.4 in. The bar is subjected to the repeated load $0 \leq F_A \leq 1300$ lb at section A which is in-phase with the repeated load $0 \leq F_B \leq 500$ lb at section B. The Marin modification factors for load, temperature, reliability, and miscellaneous-effects are $k_c = k_d = k_e = k_f = 1$.
(i) Determine the maximum and the minimum bending moments at sections A and B.
(ii) Neglecting the effects of stress concentration, determine the factor of safety guarding against yielding for the critical element of the bar using the Langer line.
(iii) Including stress concentration effects with notch sensitivity for reversed bending $q = 0.88$, determine the fatigue factor of safety for the critical element using the Gerber failure criterion.

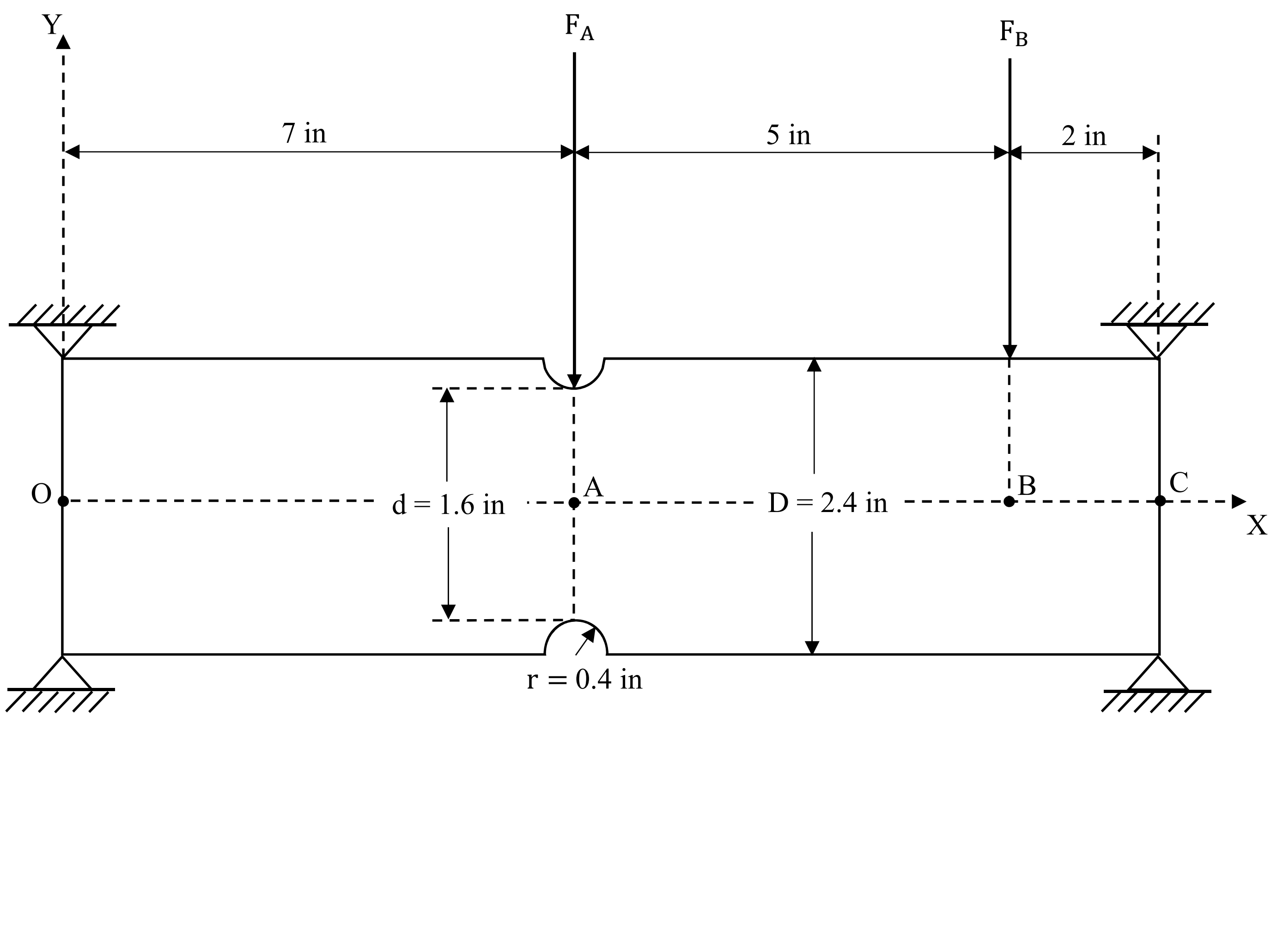

Figure 1. A simply supported steel bar. (Not drawn to scale).

Problem 2. The AISI 1020 cold drawn steel shaft shown in Figure 2 is rotating at a constant speed in simply supported bearings at O and C. The diameters D = 1.5 in and d = 1.3 in, and the radius of the groove is r = 0.1 in. The shaft transmits a constant torque T = 600 lb-in and the constant loads at sections A and B are $F_A = 250$ lb and $F_B = 500$ lb. The Marin modification factors for temperature, reliability, and miscellaneous-effects are $k_d = k_e = k_f = 1$. The fatigue stress-concentration factors are: (i) for normal stress $K_f = K_{f_m} = 1.57$; and (ii) for shear stress $K_{fs} = K_{fs_m} = 1.33$. The effects of shear stress due to shaft flexure can be neglected.
(i) Determine the reaction forces at ends O and C and the bending moments at sections A and B.
(ii) Determine the fully corrected endurance limit of the shaft.
(iii) Including the effects of stress concentration, determine the fatigue factor of safety for the critical element of the shaft using the distortion energy-modified Goodman failure criterion.

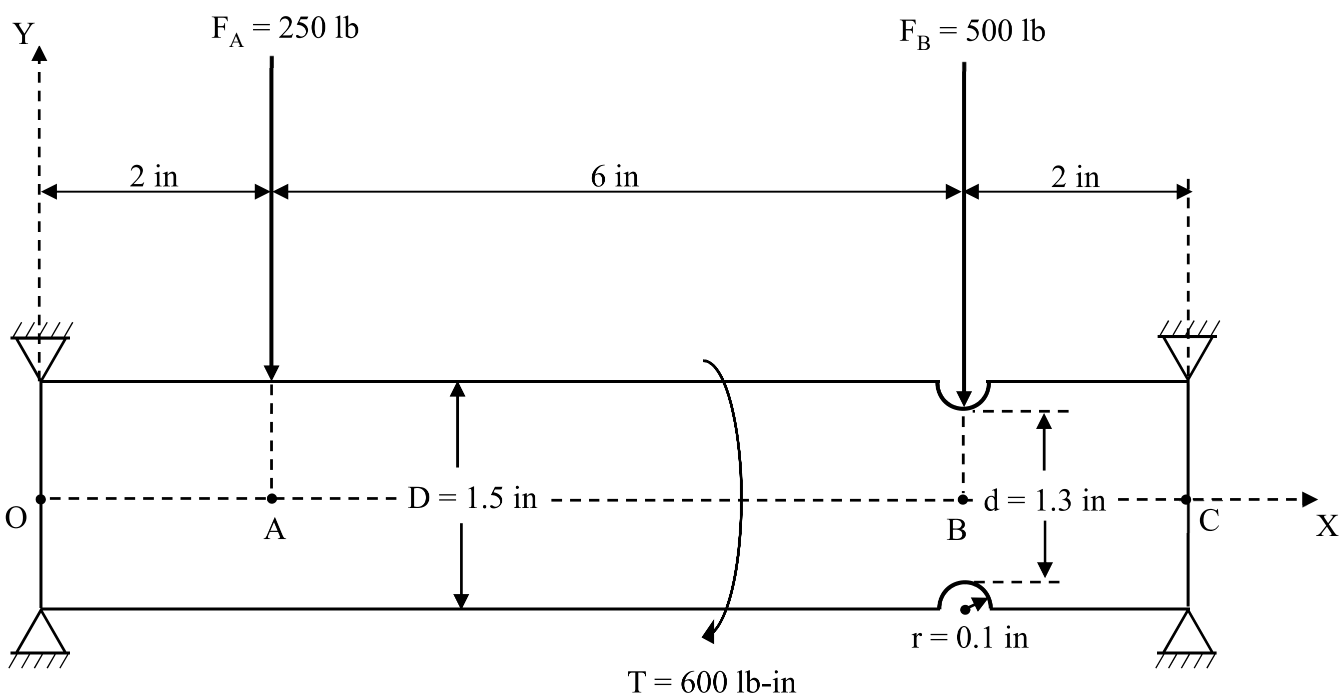

Figure 2. A simply supported rotating shaft. (Not drawn to scale).

Problem 3. The circular stepped bar shown in Figure 3 is not rotating and is simply supported at each end. The diameters are D = 3 in and d = 2 in and the fillet radius at section A is r = 0.05 in. The sinusoidal fluctuating load at section A is $-1000 \text{ lb} \le F_A \le 2000 \text{ lb}$. The bar is cold-drawn steel with an ultimate tensile strength S_{ut} = 150 kpsi and a yield strength S_y = 90 kpsi. The Marin surface modification factor for a cold-drawn surface finish is k_a = 0.716 and the remaining modification factors are specified as $k_b = k_c = k_d = k_e = k_f = 1$.

Part I.

(a) Neglecting the effects of stress concentration, determine the nominal values of the maximum and minimum normal stresses acting on the critical element of the bar.

(b) Including the effects of stress concentration, and using the ASME-elliptic failure criterion, determine the factor of safety guarding against fatigue for the critical element.

Part II. Your boss indicates that the fatigue factor of safety in Part I(b) is not acceptable and you must perform either:

Case (a): Increase the fillet radius to r = 0.15 in; or

Case (b): Use a ground surface finish with the original fillet radius r = 0.05 in.

If no other changes are permitted, then use the ASME-elliptic failure criterion to determine the fatigue factors of safety for the critical element for Case (a) and for Case (b).

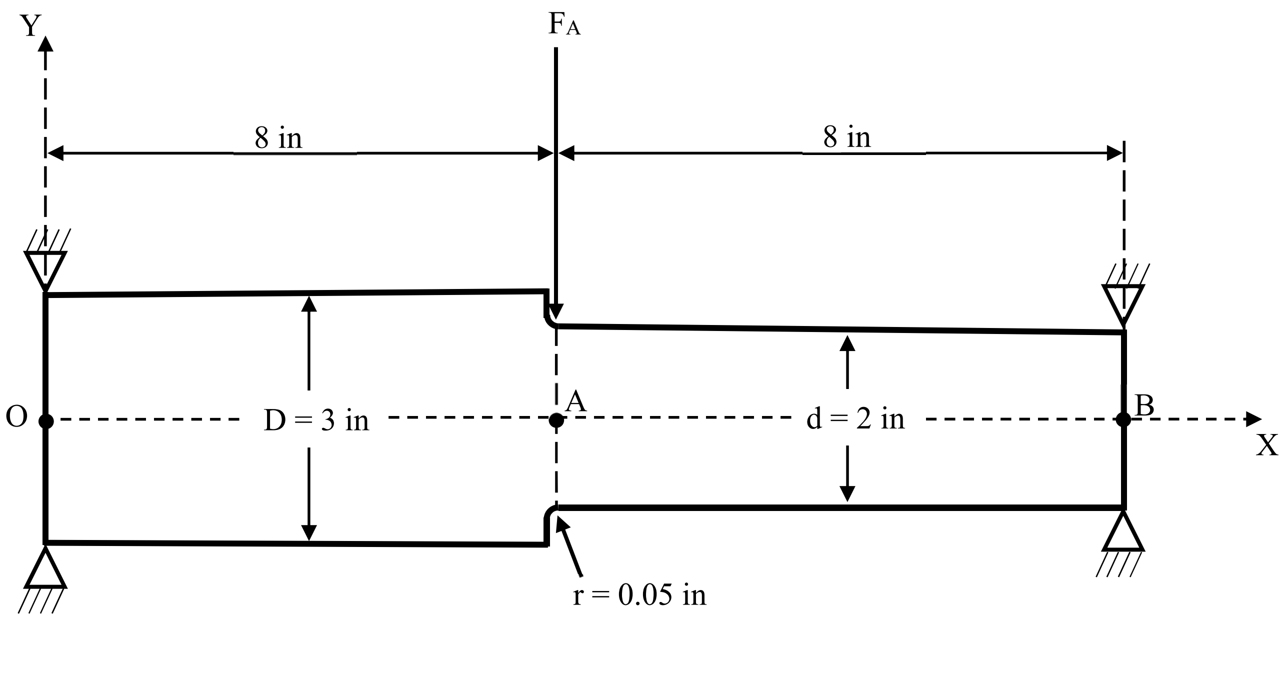

Figure 3. A simply supported circular stepped bar. (Not drawn to scale).

Problem 4. The shaft shown in Figure 4 is rotating at a constant speed of 400 rpm. The shaft is supported on the left (location A) by a single-row 02-series angular contact ball bearing and supported on the right (location B) by a journal bearing. For the ball bearing, the bore diameter is 50 mm, the constant radial load is $F_r = 25$ kN, and the axial load is $F_a = 12$ kN. The rating life for the manufacturer's catalog is $L_{10} = 1 \times 10^6$ revs and the Weibull distribution parameters are $x_0 = 0.02$, $\theta = 4.459$, and $b = 1.483$. The ball bearing has poor seals and the reliability is required to be 96%. Determine: (i) the equivalent radial load acting on the ball bearing, and (ii) the design life as a dimensionless multiple of the rating life.

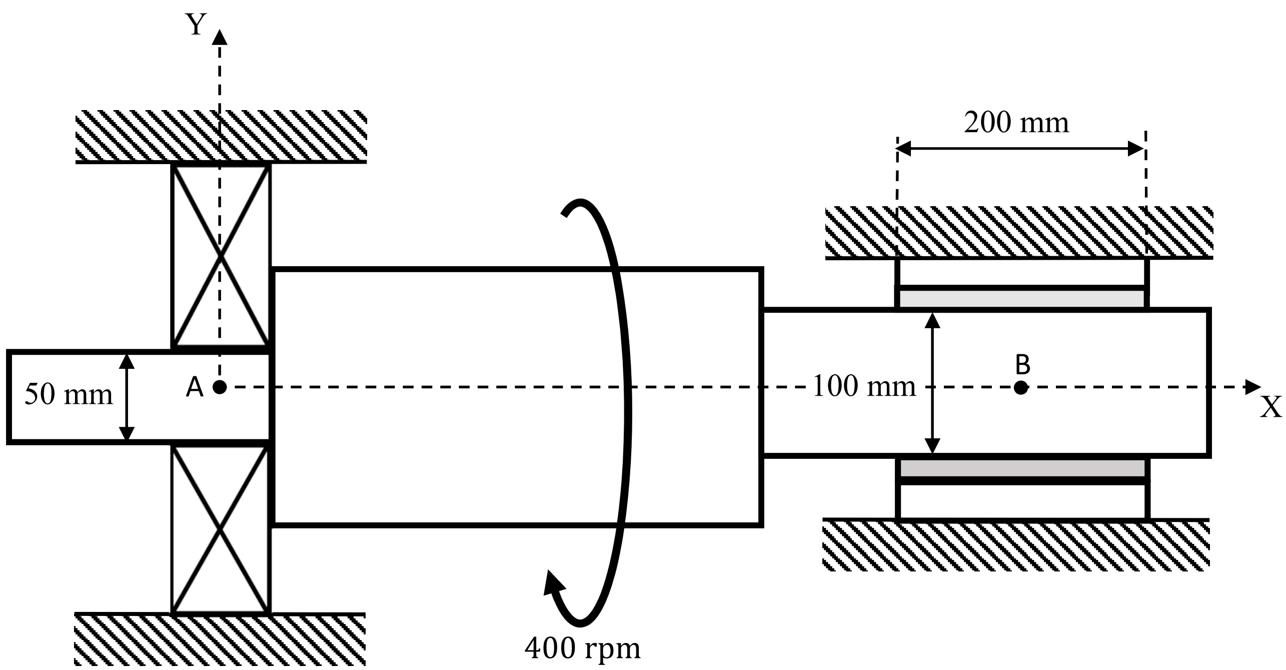

Figure 4. Shaft supported by a ball bearing at A and a journal bearing at B. (Not drawn to scale).

Problem 5. A UNC $5/8$ inch-11-SAE grade 7 steel bolt with rolled threads clamps two identical 1.25 inch thick plates. The length of the bolt is 3.25 inches and the diameter of the washer face under the bold head is $1.5\,d$ (where d is the bolt shank diameter). The half-apex angle of the pressure cone distribution in the plates is $\alpha = 30^0$. The bolt is preloaded to 20 kips and then the bolted connection is subjected to a load which fluctuates between 750 lbs and 2 kips. The modulus of elasticity of the bolt is $E_b = 28\,\text{Mpsi}$ and each plate is $E_p = 34\,\text{Mpsi}$. Determine:

(i) The stiffness constant of the joint.
(ii) The factor of safety guarding against joint separation.
(iii) The factor of safety guarding against overloading.
(iv) The fatigue factor of safety using the Goodman criterion.

Problem 6. The mean coil diameter of a linear helical compression spring is D = 1.75 inch and the spring index is C = 10. The spring has squared and ground ends and is to be placed between two flat parallel plates. The spring is peened and the material is music wire A228. When the spring is assembled between the two plates, the spring is subjected to a preload of 25 lbs and the length is 3.5 inches. Then the spring is subjected to a fluctuating load. At the maximum working load of 65 lbs, the length of the spring is 2.25 inches. Determine:

(i) The stiffness and the total number of coils of the spring (round up to the nearest quarter of a coil).
(ii) The solid height and the pitch of the spring.
(iii) The alternating and mean components of the shear stress in the spring.
(iv) The fatigue factor of safety using the Gerber-Zimmerli failure criterion.