Machine Design 2
Sheet 1 – Brakes

1. A long-shoe brake in a car is designed to give as high a braking torque as possible for a given force on the brake pedal, as shown in Figure 1. The ratio between the actuating force and the pedal force is given by the hydraulic area ratio between the actuating cylinder and the cylinder under the pedal. The brake shoe angles are $\theta_1 = 10^\circ$ and $\theta_2 = 170^\circ$. The maximum brake shoe pressure is 5 MPa, the brake shoe width is 40 mm, and the drum radius is 100 mm and d_5 equals to 25 mm. Find the distance d_7 that gives the maximum braking power for a coefficient of friction of 0.2. What braking torque would result if the coefficient of friction was 0.25?

2. Figure 2 shows four long shoes in an internal, expanding rim brake. The brake drum has a 400-mm inner diameter. Each hinge pin (A and B) supports a pair of shoes. The actuating mechanism is to be arranged to produce the same actuating force W on each shoe. The shoe face width is 75 mm. The material of the shoe and drum produces a coefficient of friction of 0.24 and a maximum contact pressure of 1 MPa. Additional dimensions for use in Fig. 18.13 are as follows: d = 50 mm, b = 165 mm, and a = 150 mm.
   Find:
   (a) Which shoes are self-energizing and which are deenergizing?
   (b) What are the actuating forces and total torques for the four shoes?

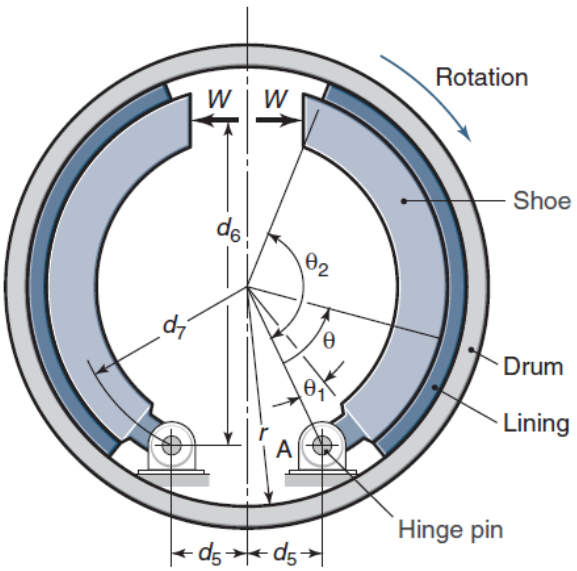

Figure 1

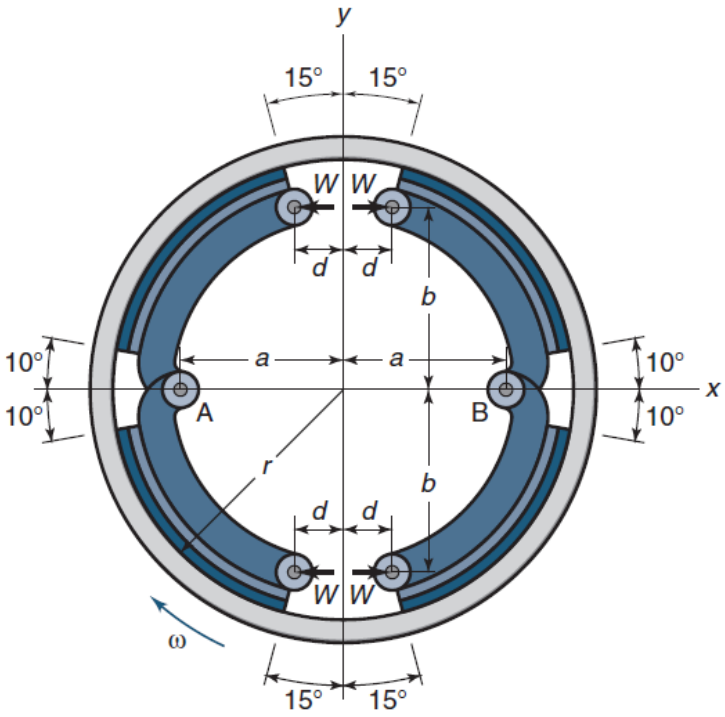

Figure 2

3. The hand brake shown in Figure 3 has a constant average pressure of 600 kPa across the shoe and is 50 mm wide. The wheel runs at 150 rpm and the coefficient of friction is 0.25. Dimensions are in millimeters. Determine the following:
   (a) If x = 150 mm, what should the actuating force be?
   (b) What value of x causes self-locking? What torque is transferred?
   (c) If the max pressure of the shoe is 600 kPa, repeat step a and b.
   (d) If the direction of rotation is reversed, how would the answers to parts (a) to (c) change?

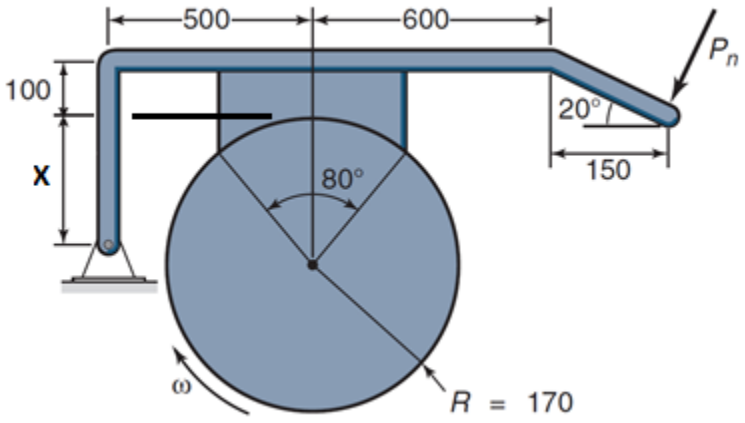

Figure 3

4. An external, long-shoe rim brake is to be cost optimized. Three lining geometries are being considered, covering the entire 90˚ of the shoe, covering only 45˚ of the central portion of the shoe, or covering only 22.5˚ of the central portion of the shoe. The braking torque must be the same for all three geometries, and the cost of changing any of the brake linings is half of the cost of a 22.5˚ lining. The cost of the lining material is proportional to the wrap angle. The wear rate is proportional to the pressure. The input parameters for the 90˚ lining are d7 = 100 mm, r = 80 mm, b = 25 mm, $\theta 1 = 0^{\circ}$, $\theta 2 = 90^{\circ}$, $\mu = 0.27$, and T = 125 N-m. Which of the wrap angles (90˚, 45˚, or 22.5˚) would be the most economical?

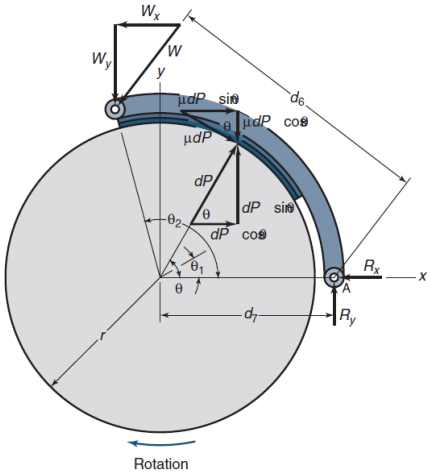

Figure 4

5. The band brake shown in Sketch I is activated by a compressed-air cylinder with diameter dc. The brake cylinder is driven by air pressure p = 0.7 MPa. Calculate the maximum possible brake torque if the coefficient of friction between the band and the drum is 0.20. The mass force on the brake arm is neglected, dc = 50 mm, r = 200 mm, l_1 = 500 mm, l_2 = 200 mm, and l_3 = 500 mm.

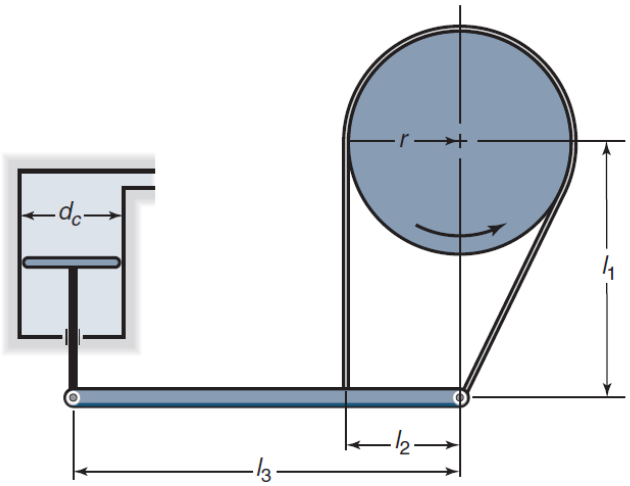

Figure 4

6. The maximum volume of the long-shoe internal brake on a car is given as 10^{-3} m^3 (Volume = $\pi r^2 b$). The brake should have two equal shoes, one self-energizing and one deenergizing, so that the brake can fit on both the right and left sides of the car. Choose values of θ_2 and θ_1 to maximize the torque and allows the mounting of the shoes. Calculate the brake width and radius for maximum braking power if the space available inside the wheel is 400 mm in diameter and 100 mm wide. The brake lining material has a maximum allowed contact pressure of 4 MPa and a coefficient of friction of 0.18. The actuating force is the same for the two shoes. Find the actuating force and the maximum braking torque.
7. A band brake is designed as shown in Figure 5. For the coefficient of friction used, the ratio between the band tensions is 1.75.
    a. What must be the distance (a) in order that the bands be fastened normal to the operating lever?
    b. How much power can the brake absorb?

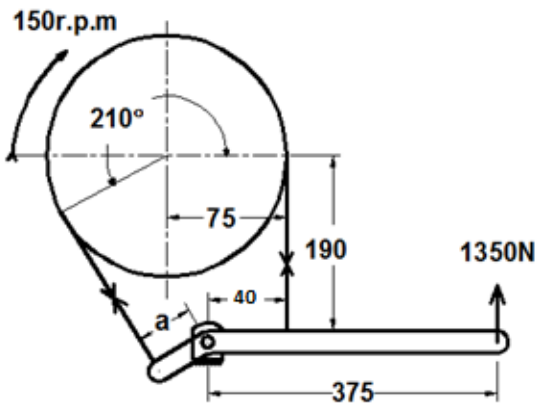

Figure 5

8. For the band brake shown in Figure 6, the following conditions are given: d = 350 mm, p_{max} = 1.2 MPa, μ = 0.25, and b = 50 mm. All dimensions are in millimeters. Determine the braking torque. actuating force and forces acting at hinge 0.

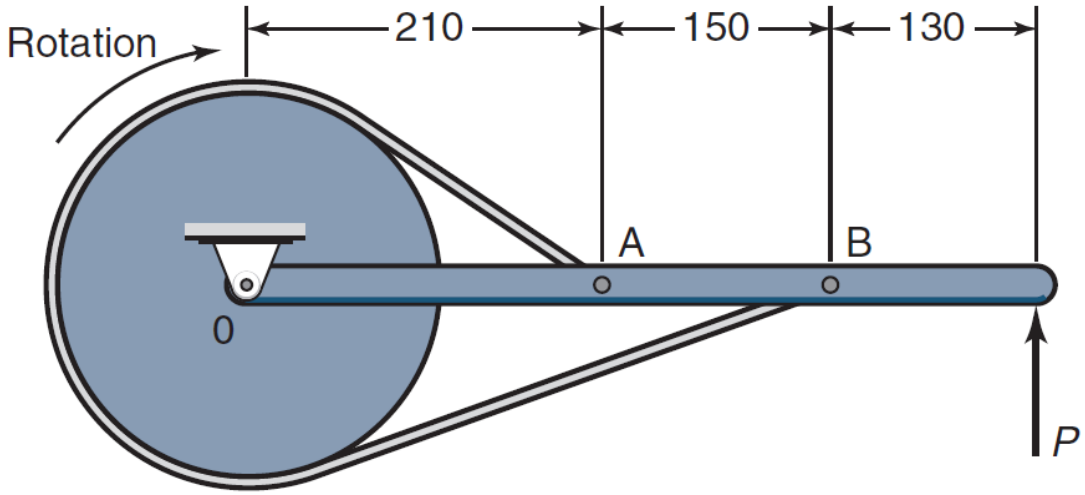

Figure 6

9. Excessive heating of brake materials leads to brake checking, warping, and out-of-roundness for brake drums. Conduct a literature search and investigate the highest temperature that exists between contacting asperities of brake systems.

10. Write a computer program to determine the optimum angular coverage of lining material for the pivot-shoe brake of Example 18.5.

11. Electric vehicles often use regenerative braking to recover some of the kinetic energy when vehicles are brought to rest. Write a one-page summary of the design features and disadvantages of regenerative braking.