Tribology Ph.D. Qualifying Exam
Fall 2011

Instructions:

1. You must solve all three problems. They are of equal weight.

2. Write your work clearly in dark ink. Define clearly your variables. If you need to make an assumption you must briefly justify it. Do not assume that the examination committee can "guess" what you "mean."

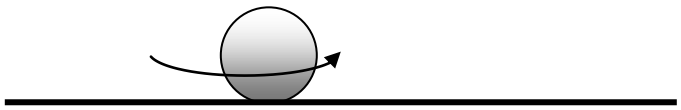
3. Budget your time. Concentrate on concepts and setting up the solution first. Then work out the math.

Problem 1

Suppose an elastic ball is set spinning about the vertical axis while supported by rigid table. Find the torque due to friction by appealing to Hertzian contact theory and applying a local friction coefficient. Express your answer in terms of the sphere's elastic constants, the sphere radius (R), the sphere weight (W) and the coefficient of friction (μ) .

$$a = \left(\frac{3}{4}\frac{WR}{E'}\right)^{\frac{1}{3}} \qquad \delta = \frac{a^2}{R} \qquad \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} \qquad \frac{1}{E'} = \frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2}$$

$$p = p_o\sqrt{1-\left(\frac{r}{a}\right)^2}$$



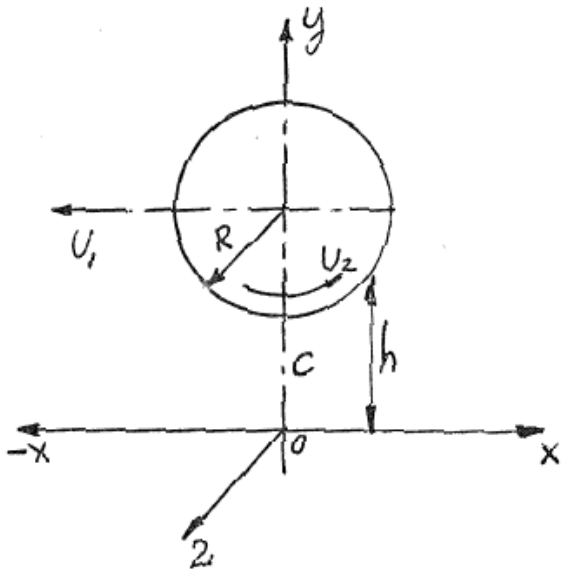
Problem 2

Car skidding on a wet pavement is a problem that can be analyzed by the fluid-film lubrication theory. This is because the ratio between the minimum film thickness, *C*, and the tire radius, *R*, is of the order of 10^{-5}. The figure below, though not to scale, is a schematic of a wheel skidding to the left at a velocity U_1, while also having a rotation about its center resulting in surface velocity U_2. The real problem involves, of course, the solution of the Reynolds Equation along with the elasticity equation since the tires will deform under the weight of the car and the hydrodynamic pressure that is being built between the tire and the pavement. For simplicity (and as a first approximation) we shall neglect here all elastic deformations and assume the pavement and the tires to be perfectly rigid. We shall also assume that because the tire is much wider than the film thickness, then all pressure gradients along the tire axis are negligible compared to the pressure gradients that develop along the direction of motion.

a. Form the problem mathematically, and state the boundary conditions.

b. Solve for the pressure between the tire and the pavement. Carry the solution as far as you can mathematically, and schematically plot the pressure profile under the tire.

c. New cars are being built today with anti-lock breaking systems (ABS). Explain how such a system may (or may not) help in reducing the skidding problem. You must corroborate your arguments with physics and engineering concepts, and the corresponding math. For example, pure rolling has no friction losses, whereas friction caused by sliding in rubbing contact is much higher than viscous friction.



Problem 3

It is well known that there are different types of wear and that each depends on external variables (temperature, gaseous environment, etc.) and the properties of the materials in sliding contact. Surface roughness, hardness, yield strength, fracture toughness, and the work hardening rate are also materials properties that influence wear.

One example of a type of wear is adhesive wear which refers to the sticking/adhesion of the surfaces and the eventual shearing of one or both of the materials. Yield strength and temperature play a big role in this process.

Provide a description of Adhesive Wear by drawing a schematic diagram and describing the role of temperature in this wear process. Is wear reduced or increased if the temperature is elevated? What role does yield stress play in this process?