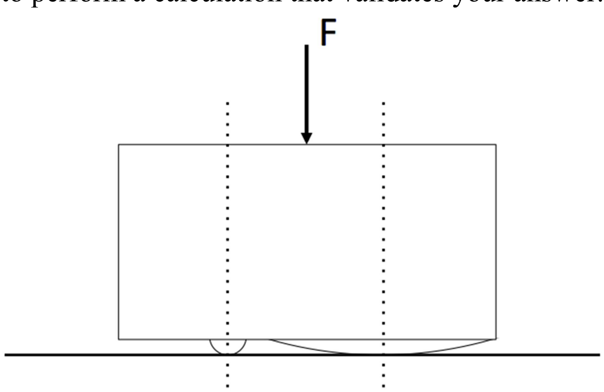
**Tribology Ph.D. Qualifying Exam**
**Fall 2016**

**Instructions:**

1. You must solve all problems. They are of equal weight.
2. Write your work clearly in dark ink. Define all your variables. If you need to make assumptions, justify those briefly. 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 as necessary.

**Problem 1**

A punch with two spherical indenters and geometry shown below and made from Al alloy (E = 70 GPa, Poisson's ratio = 0.3) is used to indent a softer material (E = 1 GPa, Poisson's ratio = 0.3). The radius of the left indenter is 1 mm and the radius of the right indenter is 100 mm. A force F = 200 N is applied. Assume this force also includes the weight of the punch. Also assume that both the punch and the material being indented remain elastic. (a) What is the Hertz pressure and contact size at the left indent? (b) As the force is being applied, will the punch tilt, and if so, which way does it tilt (please draw to make clear)? For full credit for part (b), you need to perform a calculation that validates your answer.




**Problem 2**

Car skidding on a wet pavement is a problem that can be analyzed by the lubrication theory. The reason is because the ratio of the minimum film thickness, *C*, and the tire radius, *R*, is of the order of $10^{-5}$. The real problem involves, of course, the solution of the Reynolds Equation along with elasticity since the tires will deform under the weight of the car and the hydrodynamic pressure that is built between the tire surface 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 thicknesses, then the pressure gradient along the tire axis is negligible compared to the pressure gradient 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.

**Problem 3**

The steering system of one of the WWII fighter aircrafts, located close to vibrating engine, was built from bars connected using joints (see image below, red circles highlight the joints). Each joint was a sliding bearing that could rotate ±35° around the pin having a diameter of 30 mm. After a relatively small number of flights, these sliding bearings were significantly worn. The bearings surfaces were reported to have elliptical form instead of originally circular one and the pins lost about 1/3 of their initial diameter, which has obviously led to the generation of a large amount of powder-like wear particles. The appearance of large clearances and the decrease of the joint strength endangered the fighter life and, hence, until a solution to this problem was found, the maintenance crew simply replaced these joints every other flight. What was the dominant wear type in this case? Why do you think so? How, in your opinion, this problem could be solved? What is another type of damage that could develop in these joints, should they be not replaced in time?