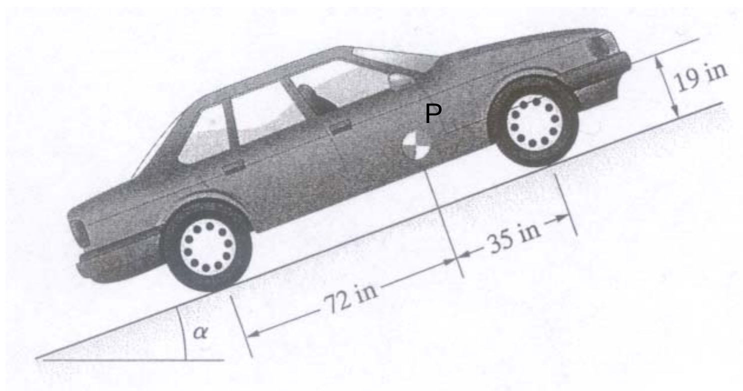
1. The center of gravity of a car is at P. The rolling friction between the road and any wheel without engine power is negligible.

   i). If the coefficient of static sliding friction between the car's tires and the road is $\mu_s = 0.5$, determine the steepest grade (the largest value of the angle $\alpha$) the car can drive up at constant speed, if the car has
      (a) rear-wheel drive,
      (b) front-wheel drive, and
      (c) four-wheel drive.

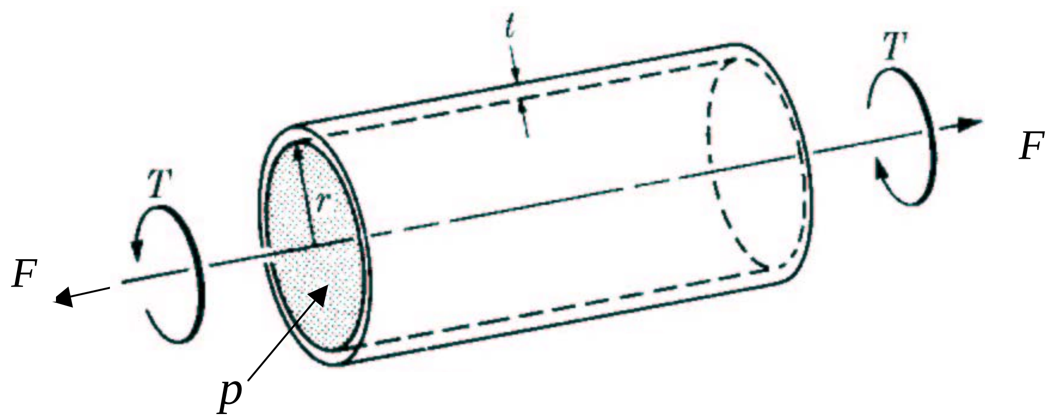
   ii). If the coefficient of static sliding friction is infinite, determine the steepest grade the car can drive up at constant speed.



2. A copper tube (assume isotropic linear elasticity with E = 130 GPa, ν = 0.34) has an internal diameter of 500 mm and a wall thickness of 30 mm. The yield strength of copper is 70 MPa. It is subjected to complex loading consisting of:

- an internal pressure *p* of 5 MPa
- a torque *T* of 250 kN-m
- an axial force F of 1 MN

For the purpose of this analysis, assume that internal pressure does not contribute to axial stress in the tube.




Within the section of interest, parts (a)-(c) below pertain to the given loading conditions:

a) Determine the location and value of the *maximum principal stress* $\sigma_{max}$

b) Determine the location and value of the *minimum principal stress* $\sigma_{min}$

c) Determine the factor of safety on yielding for the tube based on the von Mises and Tresca yield criteria

If the loading (*T*, *F*, *p*) increases in a proportional manner such that $p = \lambda_1 F = \lambda_2 T$ where $\lambda_1, \lambda_2$ are constants, starting with the initial values specified above for (*T*, *F*, *p*),

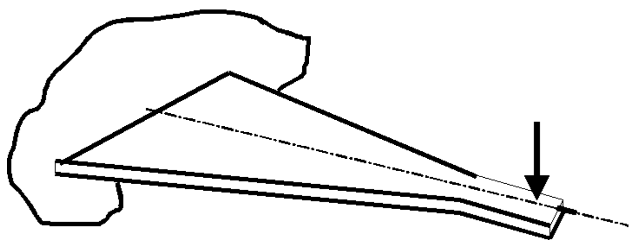
d) Determine the value of (*T*, *F*, *p*) at which initial yielding will occur based on the von Mises and Tresca criteria for this particular state of stress

e) Using the von Mises flow rule (yield surface), derive the ***ratio*** of plastic strain component in the circumferential direction to the component in the axial direction as a function of *F*, *p*, *T* and tube dimensions with increasing load for the given proportional loading conditions.

If no torque is applied, and the values of *F* and *p* are not specified,

f) Is there some relation between *F* and *p* such that yielding would ***never*** occur according to the Tresca criterion? Explain.

3. In this problem you will analyze and design a cantilever beam that has a **constant stress** under an end point load. The general shape of the beam is provided below (it is tapered in the plane perpendicular to the cantilever loading direction). The material is a 7075-T6 aluminum alloy with a yield modulus of E = 70 GPa, a yield strength of 500 MPa, and a density of 2.8 g/cm$^3$. You may use conventional beam theory, but please comment on the assumptions and limitations of your analysis.



(a) Assuming a 1mm thick beam material, and a 10 mm length from the base to the loading point, calculate the base width and tip width to maintain a constant stress below the yield strength of the aluminum for a cantilever load of 100 N.

(b) Please calculate the weight of this beam.

(c) If you were unable to taper the beam, and had to use a rectangular cross section to design a beam that would not yield with a 1 mm thickness (same length), how much heaver (%) would such a rectangular beam be, compared to the tapered beam.

4. Please answer each of the following questions related to Fracture Mechanics:

    (i) You have a piece of mild steel that has a plane strain fracture toughness of 200ksi-in$^{1/2}$. The yield strength is 180 ksi. The steel has a rectangular cross section that measures 2 inches by 4 inches. At the center of a 4 inch face there is a surface flaw that is thumb-nail shaped. 2a = 0.5 inches. The geometric correction factor is 1.1. At what applied tensile load would you expect the piece of steel to fail?

    (ii) If you had the same material but instead of the part being 2 inches thick, it was only 0.05 inches thick, what do you think would change in the above stated problem? How would it change?

    (iii) If the specimen in (i) above was very slowly loaded and submersed in salt water, which parameter above would change and how?