ME 115(b): Solution to Problem Set #4

Problem #1: Problem 1(b,c) in MLS text.

Part (b): The object can be force closure.

Part (c): The object can not be force closure, as there are not enough forces.

Problem #2: Problem 2(b,d) in MLS text.

Part (b): Yes, the grasp is force closure.

Part (d): The grasp will be force closure for sufficiently large friction.

Problem #3: Problem 3(a) in MLS text.

The grasp is not force closure. It could be force closure if the friction cone angle were larger.

Problem #4: Problem 4(a) in MLS text.

Depending upon your assumptions, there may be more than one answer to this problem. A reasonable answer follows. Choose a contact frame whose z-axis is normal to the planar contact surface, and whose x-axis is parallel to the contact edge. Clearly, normal forces and tangential frictional forces can be supported by this contact. It seems reasonable to assume that no torque can be supported about a line collinear with the contact edge. It also seems reasonable to assume that torque can be supported about the contact normal. The only point of debate centers on the possibility to support a torque about the y-axis of the contact frame. We will assume that it can be supported, but opposing arguments can also be made. In this frame, the wrench basis is thus:

$$B = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

The friction cone is defined by

$$f_n \quad \geq^0$$

$$\begin{aligned} \sqrt{f_x^2 + f_y^2} &\leq \mu f_n \\ |\tau_n| &\leq \gamma_n f_n \\ |\tau_y| &\leq \gamma_y f_n \end{aligned}$$

where f_n is the normal force, f_x and f_y are the tangential frictional forces, τ_n is the torque about the contact normal, and τ_y is the torque about the y-axis.