Take-home Exam

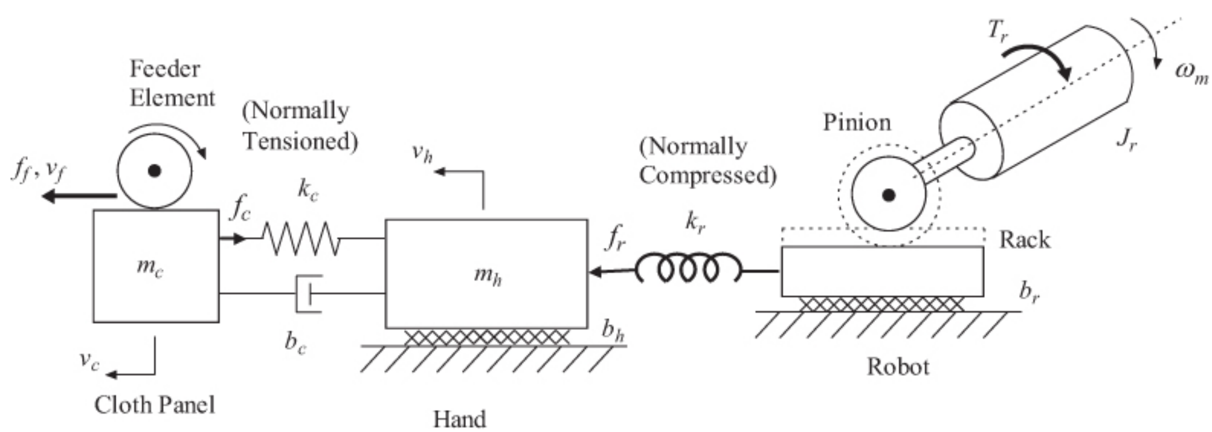
a. List several advantages of using LGs in the development of a state-space model of a dynamic system. **(10 points)**

b. A robotic sewing system consists of a conventional sewing head. During operation, a panel of garment is fed through by a robotic hand into the sewing head. The sensing and control system of the robotic hand ensures that the seam is accurate and the cloth tension is correct, in order to guarantee the quality of the stitch. The sewing head has a frictional feeding mechanism, which pulls the fabric in a cyclic manner away from the robotic hand, using a toothed feeding element. When there is slip between the feeding element and the garment, the feeder functions as a force source and the applied force is assumed cyclic with a constant amplitude. When there is no slip, however, the feeder functions as a velocity source, which is the case during normal operation. The robot hand has inertia. There is some flexibility at the mounting location of the hand, in the robot. The links of the robot are assumed rigid, and some of its joints can be locked to reduce the number of degrees of freedom, when desire

   Consider the simplified case of a single-degree-of-freedom robot. The corresponding robotic sewing system is modeled as in the figure below. Here the robot is modeled as a single moment of inertia J_r, which is linked to the hand with a light rack-and-pinion device whose speed transmission parameter is given by:

$$\frac{\text{Tanslatory movement of the rack}}{\text{Rotatory movement of the pinion}} = r$$

   The drive torque of the robot is T_r, and the associated rotatory speed is ω_r. Under conditions of slip, the feeder input to the cloth panel is force f_r. With no slip, the input is the velocity v_f. Various energy dissipation mechanisms are modeled as linear viscous dampers of damping constants b (with corresponding subscripts). The flexibility of various system elements is modeled by linear springs with stiffness k (with corresponding subscripts). The inertia effects of the cloth panel and the robotic hand are denoted by the lumped masses m_c and m_h, respectively, having the corresponding velocities v_c and v_h, as shown in the figure below.



Note: The cloth panel is normally in tension with tensile force f_c. In order to push the panel, the robotic wrist is normally in compression with compressive force f_r.

First consider the case of the feeding element with slip:

1. Draw an LG for the model, orient the graph, and mark all the element parameters, through-variables, and across-variables on the graph. **(20 points)**
2. Write all the constitutive equations (element physical equations), independent node equations (continuity), and independent loop equations (compatibility). **(40 points)**
3. Develop a complete state-space model for the system. The outputs are taken as the cloth tension f_c and the robot speed ω_r, which represent the two variables that have to be measured to control the system. Obtain the model matrices **A**, **B**, **C**, and **D**. **(30 points)**