Often times in industrial practice, engineers must design mechanisms for performing specific functions. Consider the bell crank mechanism shown in Figure 1 and 2 below. Your job for Project 1 is to design all the components shown in the Figure to meet the functions described below.

The function of the linkage is basically to provide a mechanical advantage. Specific design requirements include:

1. The mechanical advantage must be 2.5:1 (i.e. \( D/d = 2.5 \)), where \( D \) should be at least 2 inches but not to exceed 20 inches.
2. The mechanism must be designed to carry a load, \( F \), of 1,000 lbs at the long end as shown in Figure 2.
3. The angle \( \theta \) can vary between 30 and 90 degrees.
4. All components including cables, shear pins, clevis and main crank body should have a minimum factor of safety, \( N \), of 3.
5. The material for the main crank body should be 1040 CRS (\( S_y = 71 \text{ ksi} \), \( S_u = 80 \text{ ksi} \), \( E = 30E6 \text{ psi} \), % elongation = 12%). You are free to use whatever materials you want for the other components but use standard (purchased) sizes whenever possible.
6. The designs can be ranked based on yield load/weight ratio or aesthetics – in either case, the design requirements 1 – 5 must be met (more will be said about this in class).
Project Requirements:

1. Each group will design a complete mechanism. The group will prepare a minimum of THREE design alternatives. The alternatives must be neatly documented on engineering calculation paper. Each of the alternatives will be compared to the good design criteria and the best alternative will be chosen for detailed design. The main crank and other components can be manufactured using any reasonable manufacturing method (machined, cast, welded, extruded, powder metallurgy, etc.).

2. Each component of the structure must be designed/analyzed to support the applied loads with a minimum factor of safety of 3. You should show detailed calculations for \( \theta = 30 \) degrees and \( \theta = 90 \) degrees for points A and B on the main link. You should also show detailed calculations for the other components. You should create an Excel spreadsheet for calculating stresses along the main crank body (top and bottom) as a function of \( \theta \) (See example).

3. Students are permitted to utilize finite-element software to analyze their designs (in particular, the main crank body). The finite-element method will not be covered in class. This is an opportunity for you to practice life-long learning to explore and use the software on your own. Students must verify reaction solutions obtained from ANSYS by solving equations of equilibrium for the structure solved.

4. A detailed assembly drawing and component drawings must be prepared and submitted for your final design. You must use Pro/ENGINEER to prepare the drawing. Drawings can be a-size or b-size. All of the information needed to build the link structure must be included on this drawing, including, size and shape information, materials and a parts list. The parts list must contain proper designations for all standard shapes and fasteners. All standard solid modeling and drawing practices are to be used when creating the drawing. The table to the right lists the drawing options that are to be used on your drawing.

5. Each team will submit a design report at the end of the project. The report will consist of the following:
   - Cover page
   - Executive summary
   - Introduction to the project
   - Description of the work completed including tables and figures necessary to support the text
   - Conclusion
   - Appendix containing design alternatives, calculations, and the detail assembly drawing.