MAE 292 2020 Spring Final

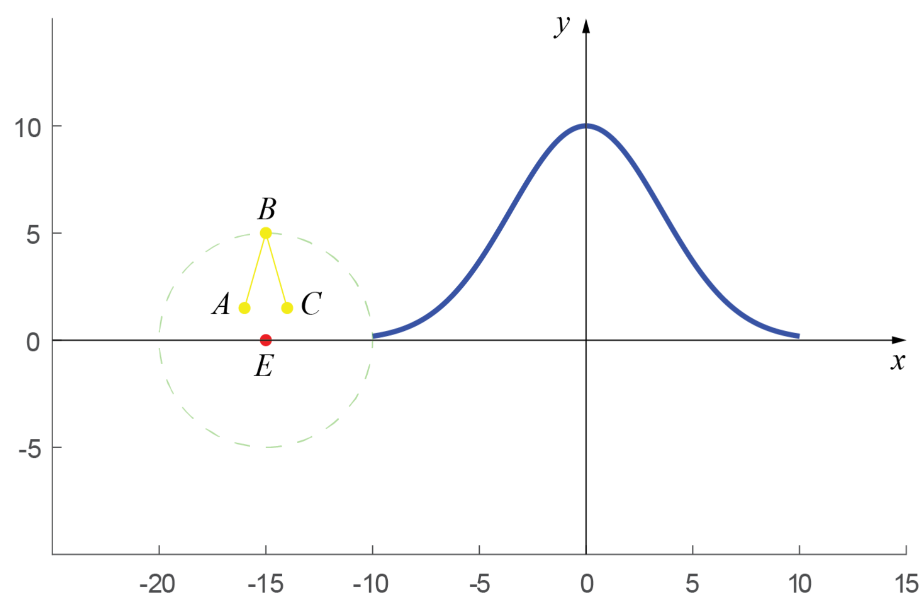
Assigned June 7
Due Wednesday June 10, midnight

1. Consider the following figure. There are four points:

$$A\,(-16,\ 1.5),\ B\,(-15,\ 5),\ C\,(-14,\ 1.5),\ E\,(-15,\ 0)$$

The curve between interval $[-10,\ 10]$ is

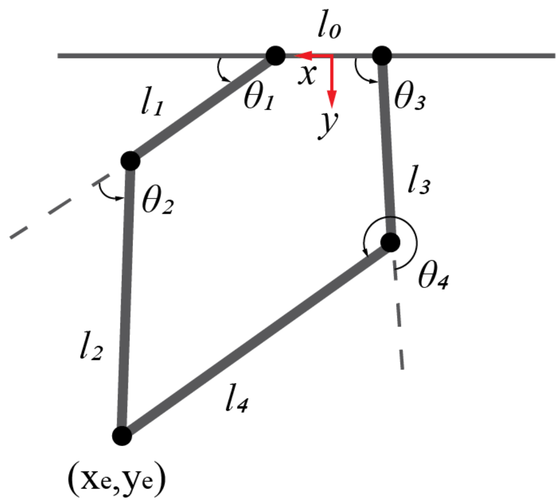
$$y = 10 * e^{-(x/5)^2}$$

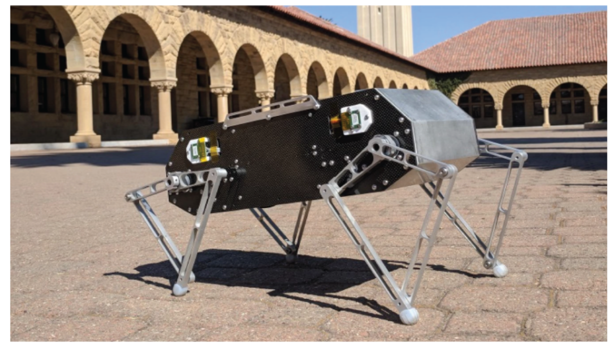


Achieve the following operations in MATLAB.

a. Perform four circular rotations of shape *ABC* with respect to point *E* to form a five pointed star. Connect the gaps if necessary.
b. Scale down the star in part a by 0.5 in both x and y direction with respect to point *E*. Plot the original star in part a and the scaled star in part b in the same figure. Set the axis to $[-20,\ -10,\ -5,\ 5]$ and *equal*.
c. Move the star in part b to the left end of the curve. The center of the star should coincide with the end point of the curve, and one point of the star should coincide with the normal direction of the curve.
d. Sweep the star in part c from left to right along the curve. At every instant of the process, the center of the star should coincide with the curve, and one point of the star should coincide with the normal direction of the curve. Plot the snapshots of the star at locations $x = [-10,\ -5,\ 0,\ 4,\ 8]$ in the same figure. Set the axis to $[-15,\ 15,\ -5,\ 15]$ and *equal*.

2. As shown in the figure below, the five-bar linkage mechanism is a widely used kinematic design for robot legs.





The Stanford Doggo

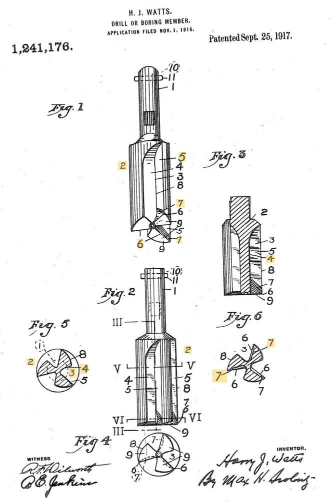
a. Assume all points that connect links are revolute joints. Analyze the mobility of the mechanism.

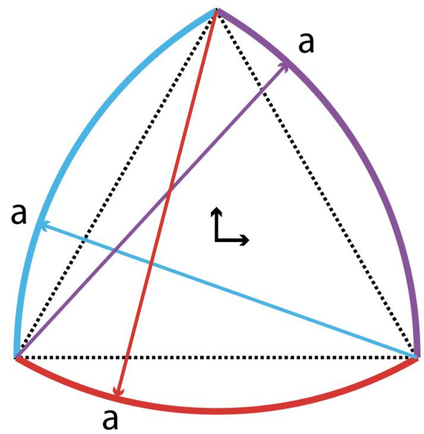
b. Similar to the four-bar mechanism derive the constraint equations for the five-bar leg design. You do not need to solve these.

c. Discuss how you would solve the constraint equations using matlab? (you don't have to solve). How many variables do you have to solve for if the link lengths are provided?

d. Imagine you want to optimize the link lengths l_0 through l_4 so that the leg can generate the fastest movements. Describe the two functions you could use in matlab to perform an optimization of the link lengths. Compare these two functions and discuss which one would be better given the leg requirements. (You do not need to go into details and do not need to perform any optimization).

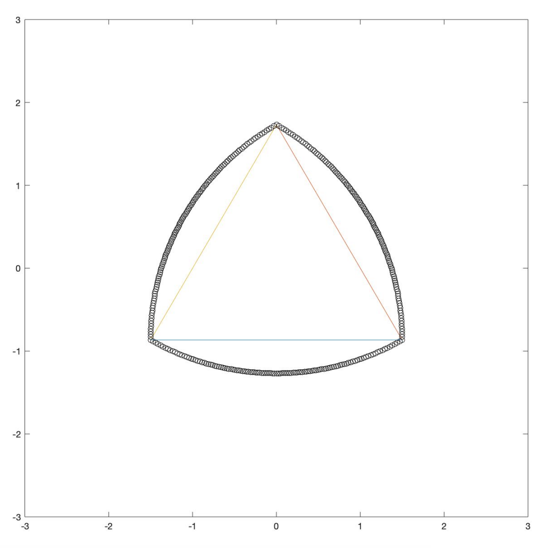
3. In 1917 the Watts Brothers Tool Works patented a method to bore square holes using the concept of a non-circular curve of constant width. A curve of constant width is one that projects the same “shadow” from any angle, the square hole bore was based on the Reuleaux triangle which is a three-sided curve of constant width.



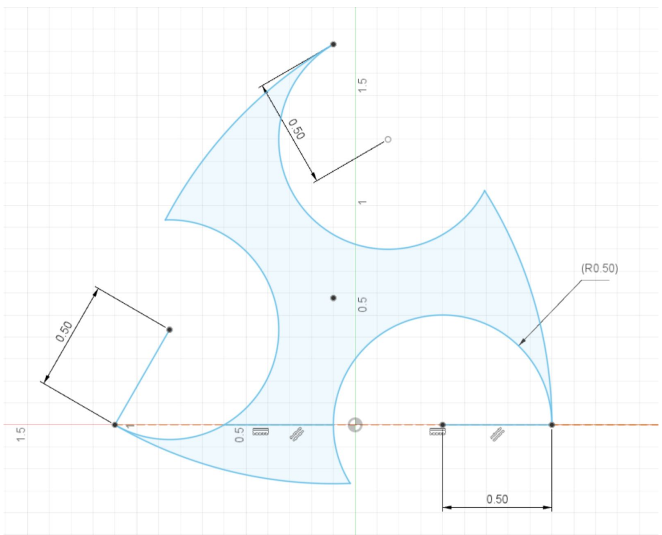


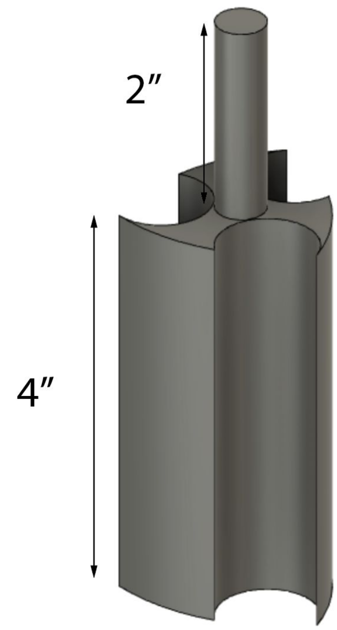
a. The Reuleaux triangle is constructed from an equilateral triangle of side lengths *a*. Three circular arcs of radius *a* are drawn between two triangle endpoints, centered on the third point (see diagram above). Assume the triangle is centered so that it’s centroid is at the origin as shown by the axes above. Determine the three constraint (also called implicit) equations in polar form that describe the three curves of the Reuleaux triangle using the origin noted above.

b. Using matlab, solve the constraint equation for the curve points and plot the Reuleaux triangle for $a = 3$ as shown below. Provide the matlab code used to plot the data.



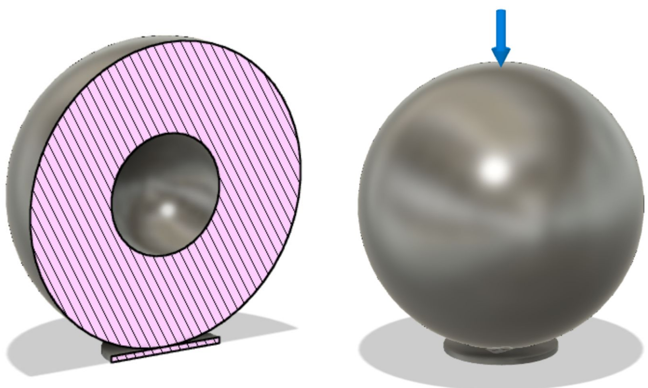
c. Develop a CAD model of the square hole bore with a 4" cutting length and a 2" long, 0.5" diameter shaft as shown below. The Reuleaux triangle side-length is 2". The mill cutting flutes are formed from circles that are 0.5" in radius, and are a distance 0.5" from the endpoints of the equilateral construction triangle. See below for details and dimensions.





4. Engineers have created hollow ball bearings for reduced rolling inertia applications. However these balls can't support as large a normal force as solid ball bearings. For a 5 mm diameter ball bearing, use FEA to determine the maximum size (to the nearest 0.1 mm) for the inner hole that can support a point load of 3N on the top safely (SF > 5).

Model the bottom surface as a 1 mm radius disc of thickness 0.1 mm. Apply load force to the ball bearing as a remote force located at the top and pointed down. Apply a fixed displacement constraint to the bottom of the support disc.



Provide a snapshot of your FEA results and the final inner diameter.