**ENGR 2120: Dynamics**
Project #2b

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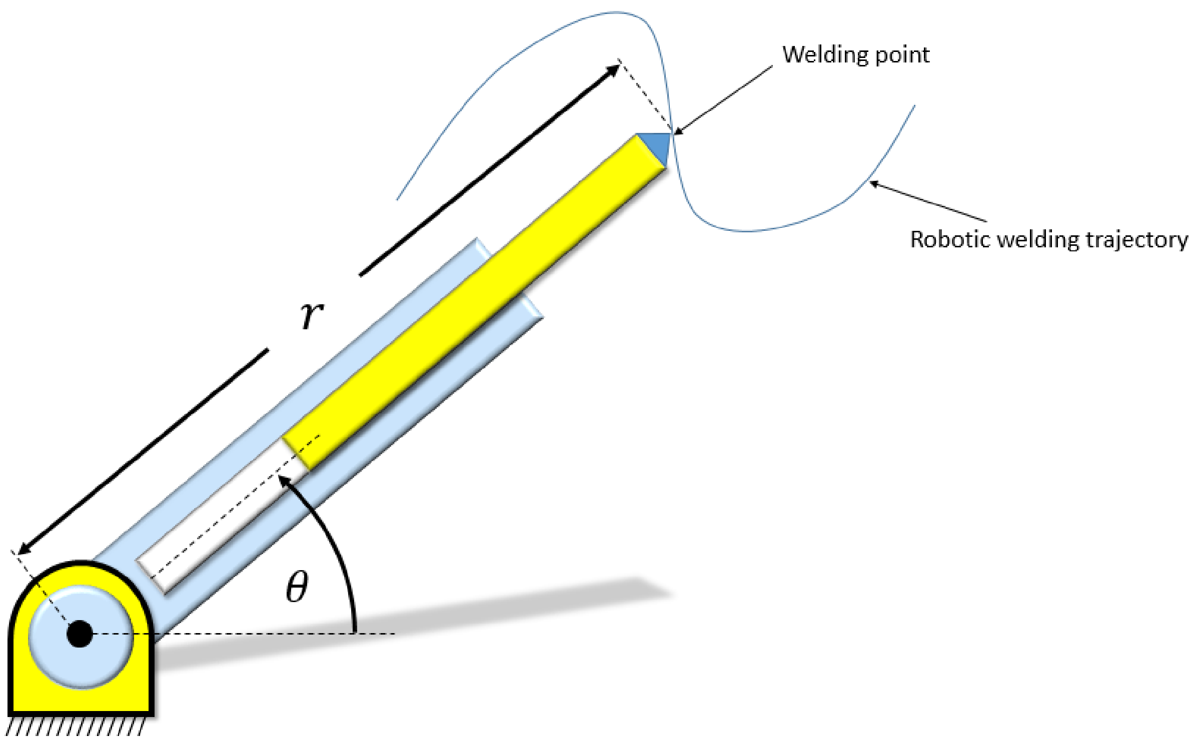
**Project Assignment**

For this project, you will re-visit the robotic welder that was analyzed previously. Instead of performing the position, velocity, and acceleration analysis in Cartesian Coordinates, you will repeat this analysis using normal and tangential and polar coordinate. This will allow you to compare and contrast different coordinate systems and allow you to determine which one is best for this type of application. As you will see, the choice of coordinate system can drastically change the complexity of the problem at hand!




1. Create a new sections/subsections in your report for both "Polar Coordinate Systems" and "Normal and Tangential Coordinate Systems"

2. Within these sections, please answer the following questions in paragraph form:
   a. What are polar coordinate systems and why do we use them in dynamics?
   b. What are normal and tangential coordinate systems and why do we use them in dynamics?
   c. Where do you place the origin of a polar coordinate system?
   d. Where do you place the origin of a normal and tangential coordinate system?
   e. Do polar coordinate systems and normal and tangential coordinate systems change with time? Do they move with the particle are they fixed in space? Please comment.

f. Given all the coordinate systems in dynamics, how can you decide which one to use for a given problem?

3. Add a polar coordinate system to your robot. Please choose the origin to be the center of the rotational joint and be sure to include an updated figure in your report. This should go in your polar coordinate systems section.

4. Derive an expression for the position of the end-point of the machine as expressed in your **polar** coordinate system. Keep your answer in variable form. It should be expressed in terms of some or all of the following: $\theta, \dot{\theta}, \ddot{\theta}, r, \dot{r}, \ddot{r}$.

$$\vec{r} = \_\_\_\_\_\_\_ \hat{u}_r + \_\_\_\_\_\_\_ \hat{u}_\theta$$

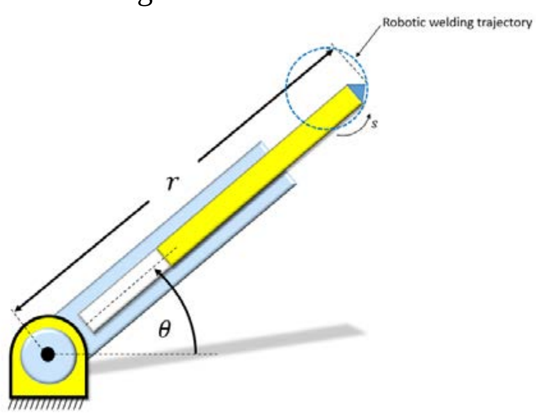
5. Derive an expression for the velocity of the end-point of the machine as expressed in your **polar** coordinate system. Keep your answer in variable form. It should be expressed in terms of some or all of the following: $\theta, \dot{\theta}, \ddot{\theta}, r, \dot{r}, \ddot{r}$.

$$\vec{v} = \_\_\_\_\_\_\_ \hat{u}_r + \_\_\_\_\_\_\_ \hat{u}_\theta$$

6. Derive an expression for the acceleration of the end-point of the machine as expressed in your **polar** coordinate system. Keep your answer in variable form. It should be expressed in terms of some or all of the following: $\theta, \dot{\theta}, \ddot{\theta}, r, \dot{r}, \ddot{r}$.

$$\vec{a} = \_\_\_\_\_\_\_ \hat{u}_r + \_\_\_\_\_\_\_ \hat{u}_\theta$$

7. Add a normal and tangential coordinate system to your robot. You can assume that the robot is performing a circular welding operation. The path of the end-point of the robot is shown in the figure below. Please add a figure to your report that shows a Cartesian coordinate system, polar coordinate system, and the normal and tangential coordinate system for the path shown in the figure below.



8. Derive an expression for the position of the end-point of the machine as expressed in your **normal and tangential** coordinate system. Keep your answer in variable form. It should be expressed in terms of some or all of the following: $\theta, \dot{\theta}, \ddot{\theta}, r, \dot{r}, \ddot{r}$.

$$\vec{r} = \_\_\_\_\_\_\_\hat{u}_t + \_\_\_\_\_\_\_\hat{u}_n$$

9. Derive an expression for the velocity of the end-point of the machine as expressed in your **normal and tangential** coordinate system. Keep your answer in variable form. It should be expressed in terms of some or all of the following: $\theta, \dot{\theta}, \ddot{\theta}, r, \dot{r}, \ddot{r}$.

$$\vec{v} = \_\_\_\_\_\_\_\hat{u}_t + \_\_\_\_\_\_\_\hat{u}_n$$

10. Derive an expression for the acceleration of the end-point of the machine as expressed in your **normal and tangential** coordinate system. Keep your answer in variable form. It should be expressed in terms of some or all of the following: $\theta, \dot{\theta}, \ddot{\theta}, r, \dot{r}, \ddot{r}$. HINT: $\rho \neq r$

$$\vec{a} = \_\_\_\_\_\_\_\hat{u}_t + \_\_\_\_\_\_\_\hat{u}_n$$

11. Comment in your report on why the expressions for the position, velocity and acceleration of the end-point are the same or different in both coordinate systems. How are they related?

12. Assuming that $\theta = 55°$, $r = 4$ m, $\dot{\theta} = 5$ rad/s, $\dot{r} = 10\ \frac{\text{m}}{\text{s}}$ , $\ddot{\theta} = 5$ rad/s$^2$, $\ddot{r} = 10\ \frac{\text{m}}{\text{s}^2}$, determine the magnitude of the position, velocity and acceleration of the end-point in both the polar and normal and tangential coordinate system. Be sure to include appropriate units. Comment on why the magnitude of the vectors are the same or different. Also comment on why the magnitude of the individual components of the vector are the same or different. You may want to show the numerical values directly below the derived equations in your report.

## What to Turn In

Please turn in your assignment packet that contains the following stapled from top to bottom:

1. Assignment cover sheet
2. A copy of your project report with items 1-5 from project part 2a and parts 1-12 from project part 2b.