ME 380: Kinematics and Machine Dynamics
Velocity and Acceleration Analysis

1 How to use this assignment

In this assignment, students will learn how to perform velocity and acceleration analysis of mechanisms. This will involve first performing displacement analysis and following this up with velocity- and subsequently acceleration-level analyses.

- The instructor will provide questions and provide intermittent help.
- This activity provides the opportunity for the students to learn how to perform velocity-level analysis by means of several examples. They will form the relevant kinematics equations and solve them numerically.
- Students will spend approximately 30 minutes on this activity.
- This activity will be submitted and graded.

2 Learning objectives

After completing this assignment, students will be able to

- Students will be able to solve position-, velocity-, and acceleration-level kinematic equations.
- They will use differentiation rules to come up with the velocity- and acceleration-level kinematics equations.
- They will solve velocity- and acceleration-level kinematics using techniques from linear algebra.

3 Assignment completion instructions

1. Planning
   - What will the instructor need before the activity?
   - What will the student need before the activity?
     - Pencil and paper
     - Calculator
2. Source material(s) for the activity
   - Lecture notes
   - Resources placed on Canvas.

3. Introduction and warm-up practice activity for the students
    - Introduction and instructions
        - Write down the loop equations in vector form.
        - Use differentiation rules to take time derivatives of these equations to find the velocity-ldevel equations.
        - Use differentiation rules a second time to take derivatives of the velocity-level equations to find the acceleration-level equations.
        - Express the equations in a certain coordinate frame (e.g. base frame).
    - Warm-up and practice
        - Brainstorm
        - Think, pair, share:
            * Remember how to differentiation in two frames (this is the most important formula!)
            * Think about how to effectively use differentiation in two frames formula; remember, time derivative of a constant function is zero.
            * When do we use Newton-Raphson to solve equations and when can we use linear techniques?
4. Main activity
    - Students can submit a soft-copy via email or hand-in a hard-copy per group.
    - This activity graded.
5. Wrap-up / reflection
    - Peer review
        - Have a neighboring group review your work.
        - Neighboring group should provide opinion about whether or not the solution and its development are correct.
        - After the peer review is done, the owner group tries to incorporate the suggestions and improve the solution.
    - 3-2-1 Countdown
    - One-minute paper

4 Conclusion and moving forward

This activity is aimed to teach the students how to write down position and velocity-level kinematic equations, differentiate them to form the velocity- and acceleration-level equations and solve them using linear techniques.

5 Grading criteria

- Preparation
- Critical thinking
- Technical expertise
- Adherence to assignment guidelines
- Timeliness

5.1 Peer reviewer notes

1. Check if position level equations are correct
2. Check if the vector form of the velocity- and acceleratin-level equations are correct.
3. Check if the expressions of the velocity- and acceleration-level equations in the form $Ax = b$ is correct.

5.2 Preparation and content

Students can prepare for this assignment by reviewing the lecture notes. Specifically, students should review ...

5.3 Creativity and communication

Students should be able to explain their thinking process to a fellow student in order to make sure that they have learnt the material.

5.4 Critical thinking

Students should try and visualize how the links would move if a given driver link moves in a given direction. This will help verify the results found after the mathematical manipulations.

5.5 Engagement with topic

Every student should be able to and attempt to explain how they think about the problem to a fellow student.

5.6 Technical expertise

Calculus 1, Linear algebra

6 Questions

Let k denote the unit vector that points perpendicularly out of the page.

1. [20 points] Referring to Figure 1, let $l_0 = 30$, $l_1 = 15$, $l_2 = 35$, $l_3 = 20$, and $\theta_1 = \frac{\pi}{3}$. Calculate θ_2, θ_3, ${}^0v^C$, ${}^0\omega^2 = \omega_2 k$, and ${}^0\omega^3 = \omega_3 k$ for ${}^0\omega^1 = \omega_1 k$ with $\omega_1 = 20\,{}^{\text{rad}}/\text{s}$.

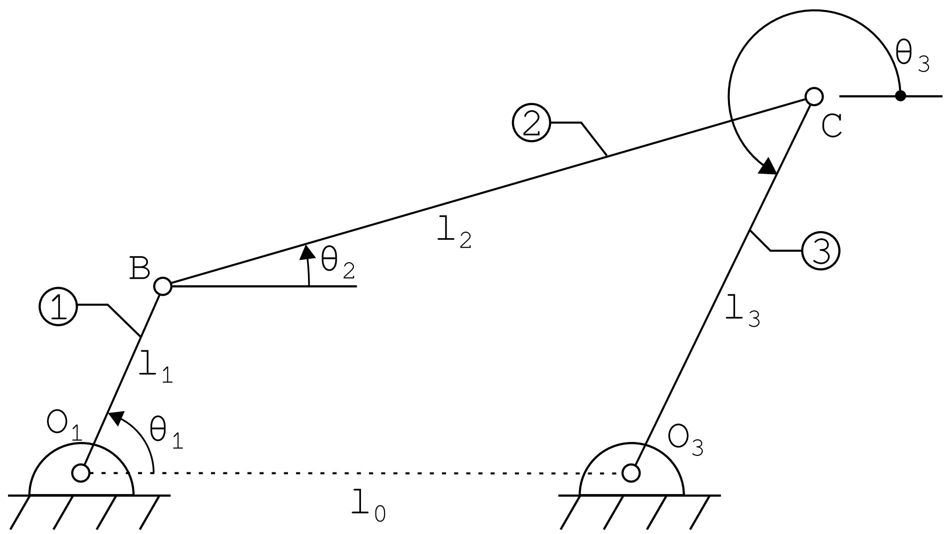

Figure 1: `Four-bar linkage`

2. [20 points] Referring to Figure 2, let $l_1 = 35$, $l_0 = 50$, $\theta_1 = {}^{\pi}/_{10}$ and ${}^0\omega^1 = \omega_1 k$ with $\omega_1 = 7.5\,{}^{\text{rad}}/\text{s}$. Compute the following quantities: l_2, θ_2, ${}^0v^B$, and ${}^0\omega^2 = \omega_2 k$.

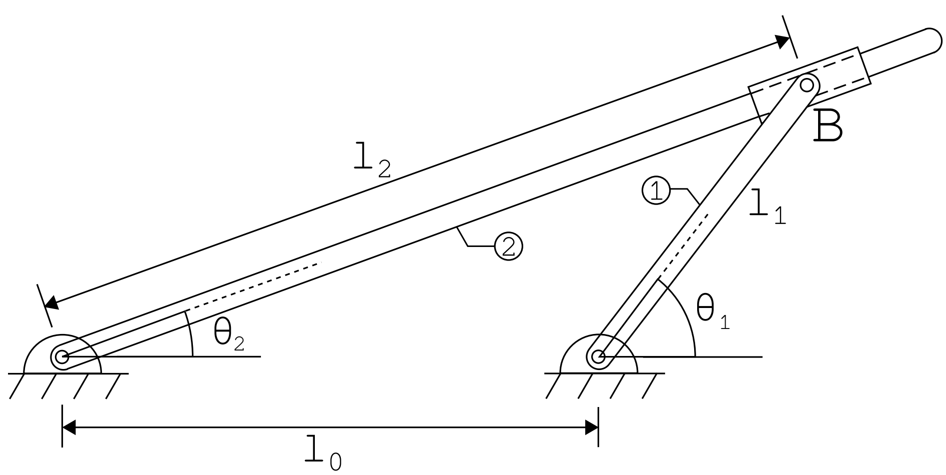

Figure 2: `Sliding contact linkage`

3. [15 points] Plot ${}^{\omega_3}/_{\omega_1}$ versus θ_1 curve for the linkage depicted in Figure 1 if ${}^{l_0}/_{l_1} = 2$, ${}^{l_2}/_{l_1} = {}^{7}/_{3}$, and ${}^{l_3}/_{l_1} = {}^{4}/_{3}$.

4. [20 points] Perform position, velocity, and acceleration analysis for the mechanism depicted in Figure 3 using analytical methods. Assume ${}^0\omega^1 = \omega_1 k$, ${}^0\alpha^1 = \alpha_1 k$ with $\omega_1 = 5\,{}^{\text{rad}}\!/\!_{\text{s}}$ and $\alpha_1 = 2\,{}^{\text{rad}}\!/\!_{\text{s}^2}$.

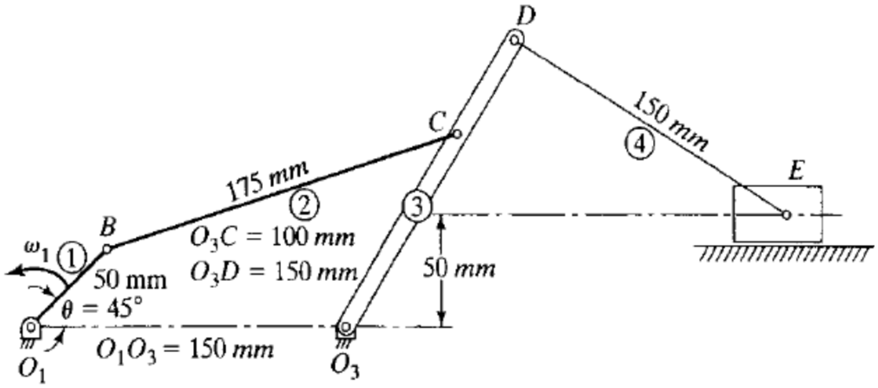

Figure 3: `Fourbar with slider`

5. [20 points] Perform position, velocity, and acceleration analysis for the mechanism shown in Figure 4 using analytical methods. Take $\theta_1 = 20°$, ${}^0\omega^1 = \omega_1 k$, ${}^0\alpha^1 = \alpha_1 k$ with $\omega_1 = {}^1\!/\!_2\,{}^{\text{rad}}\!/\!_{\text{s}}$, and $\alpha_1 = 1\,{}^{\text{rad}}\!/\!_{\text{s}^2}$ (ignore the value of ω_1 that is provided within the figure).

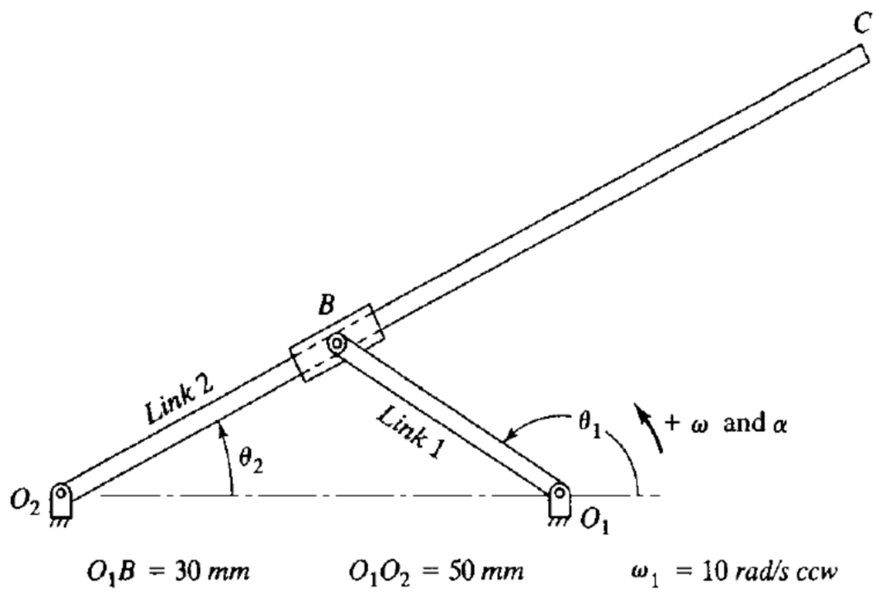

Figure 4