ME 380: Kinematics and Machine Dynamics
Gear Trains and Cam Design

1 How to use this assignment

In this assignment, students will learn how to perform kinematic analysis of gear trains and design cams for desired output motion.

- 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 calculate velocity/torque ratio of gear trains.
- They will be able to design cam profiles for required output motion.

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 Piazza.
3. Introduction and warm-up practice activity for the students
    - Introduction and instructions
        - Understand the gear diagram.

    - Equate the velocity of the pitch point on both gears.
    - Learn how to perform polynomial function interpolation.
  - Warm-up and practice
    - Brainstorm
    - Think, pair, share:
      * Compute velocities of points on rigid bodies.
      * Set-up a system of linear equations to solve for all gear velocities.
      * Remember fundamental law of cam design and come up with proper boundary conditions.

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 perform kinematic analysis of gear trains and design cam profiles that results in a desired output motion.

5 Grading criteria

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

5.1 Peer reviewer notes

1. Check if position- and velocity-level equations are correct.
2. Check if the vector form of the acceleration-level equations are correct.
3. Check if the expressions of the 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 familiarize themselves to alternative depictions of gear trains. They should be comfortable with equating velocities of the pitch points.

5.5 Engagement with topic

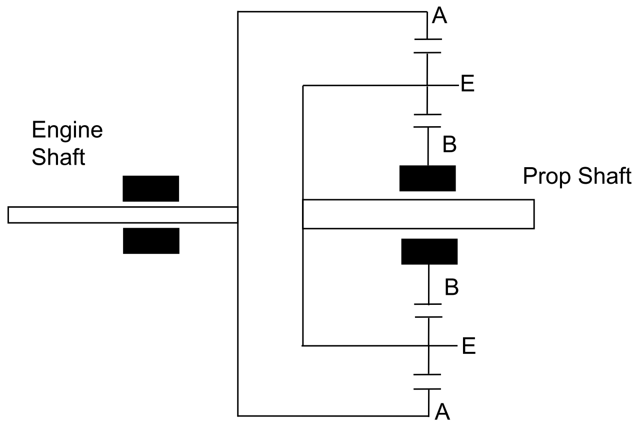
Every student should be able to and attempt to explain how they think about the problem to a fellow student.

5.6 Technical expertise

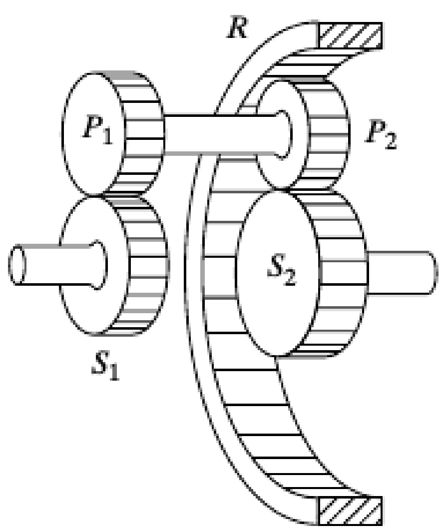
Calculus 1, Linear algebra

6 Questions

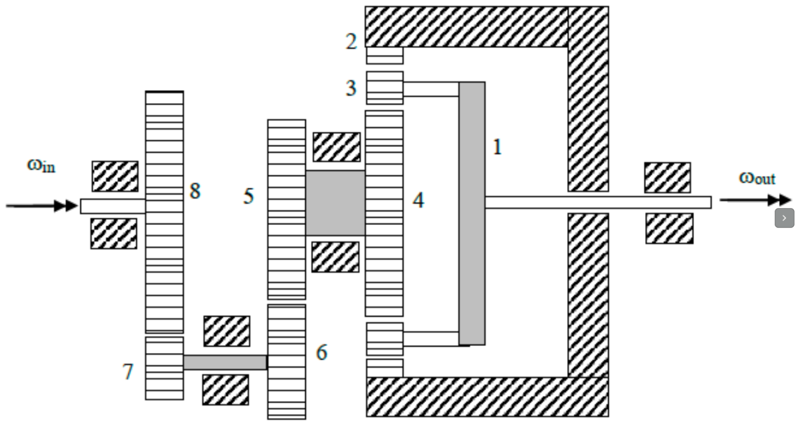
1. [25 points] The following skeleton diagram illustrates a planetary speed reduction system for an airplane propeller. The solid black boxes denote the ground, i.e., gear B is fixed to the ground. Find the propeller speed if $N_A = 193$, $N_E = 25$, $N_B = 143$, and the engine shaft speed is 4000 rpm.



2. [25 points] In the planetary train shown below, the input gear is sun S_1 and the output gear is sun S_2. Ring gear R is fixed. Planets P_1 and P_2 rotate at the same speed. Find the output-to-input speed ratio $\frac{\omega_{S_2}}{\omega_{S_1}}$ (in terms of tooth numbers N_{S_1}, etc.).



3. [25 points] Gear 2 in the system shown below is fixed to the ground. Note that gears 6 and 7 are on the same shaft, as are gears 5 and 4. Use the following tooth numbers: $N_2 = 90$, $N_3 = 15$, $N_4 = 60$, $N_5 = 50$, $N_6 = 40$, $N_7 = 20$, $N_8 = 80$.
   (a) [10 points] Find the ratio $\frac{\omega_5}{\omega_8}$.
   (b) [15 points] Find the ratio $\frac{\omega_{\text{out}}}{\omega_{\text{in}}}$.



4. [25 points] Design a double-dwell displacement function, s, that meets the requirements of the following DRDF cam timing description

- Dwell for $\frac{2\pi}{3}$ rad at $0\,\text{m}$ (low dwell),
- Rise to $\frac{15}{100}$ m in $\frac{\pi}{3}$ rad,
- Dwell for $\frac{\pi}{3}$ rad at $\frac{15}{100}$ m (high dwell),
- Fall to $0\,\text{m}$ in $\frac{2\pi}{3}$ rad.

Turn in your derivation of the polynomial s as well as your SVAJ diagram.