

ME 3011 Kinematics & Dynamics of Machines
Capstone Term Project

Dr. Bob
Fall 2024

Due Friday, November 22, 2024, start of class

NO LATE ASSIGNMENTS ACCEPTED!

You may work singly or in pairs (pairs turn in one report with both names, same grade).

The goal of the project is to perform complete kinematics and dynamics analysis of a practical mechanism for one motion cycle. Each team must choose a real-world mechanism for analysis in this project. For real-world project ideas, see people.ohio.edu/williams/html/PDF/MechanismAtlas.pdf.
Guidelines:

- The mechanism must come from the real world.
- It must be planar and one degree-of-freedom.
- It must not be too simple (e.g. single rotating link, parallel four-bar).
- Avoid gear and cam mechanisms – choose a linkage.
- Four-bar and slider-crank mechanisms are fine, but must come from a real-world machine.

Specific steps to complete (see schedule on following page):

1. Find a practical mechanism and **APPROVE IT WITH DR. BOB BEFORE THE DEADLINE!!** (Your Project Grade is 0 if your name is not on my paper by the deadline)!
2. Kinematic model of your mechanism: draw the kinematic diagram including the joint arrangements and measure or estimate the link lengths. Calculate the number of degrees-of-freedom. You must also specify the complete input motion (position, velocity, and acceleration of the input variable).
3. Perform complete position, velocity, and acceleration kinematics analysis for the entire range of motion given your kinematic model and input motion assumptions from above. Plot all results vs. the independent variable (joint angle for constant velocity input, otherwise use time). Include a point of interest for translational values (the most important point in the operation of your mechanism). Calculate the motion limits for your mechanism and check vs. your plots. You must use MATLAB to animate your mechanism to the screen for the full range of motion. Perform a snapshot hand check of all MATLAB kinematic results, along with a graphical check of your snapshot position solution.
4. Completely state the inverse dynamics problem your team will solve.
5. Estimate link masses, CGs, and mass moments of inertia. Perform complete inverse dynamics analysis (calculate driving input force/torque requirement given desired motion). Plot all results vs. the input value (or vs. time). Include shaking force and moment.
6. Choose a or b: a. Build a working hardware model of your mechanism OR b. make a CAD animation of your mechanism.
7. Submit interim written project report on the proper day. Interim results must have all steps 1 – 4 above.
8. Present your project results orally to the class according to the schedule. This must be a professional presentation. We must hear from all team members. If you skip this oral presentation, your final project grade will be 0.
9. The written report must be submitted on the due date.
10. The project schedule and suggested report format are given on the next page, followed by the project checklist.

Be Neat! Provide clear and complete results! Discussion is Important!!

Support with sample calculations and code!

Note: The first page must be a MEMO summarizing the project and results!

ME 3011 Capstone Term Project Schedule

- **Register mechanism** with Dr. Bob before class on **Wednesday September 18, 2024**, NO EXCEPTIONS! On a photograph of your mechanism, overlay the kinematic diagram using computer drawing tools; email this to me when signing up. See the on-line Atlas of Structures, Mechanisms, and Robots for examples.
- Turn in **Interim Report** at the start of class on **Wednesday October 23, 2024**: you must complete steps 1 – 4 on the previous page, including the MATLAB animation. **If you skip this interim report, your maximum final project grade will be 70%.**
- **Present results orally** to the class on **Monday or Wednesday November 18 or 20, 2024**. ATTENDANCE IS REQUIRED FOR BOTH PRESENTATION SESSIONS! **If you skip this final presentation your final project grade is 0%.**
- Submit **Final Formal Technical Report** at the start of class **Friday November 22, 2024**, NO EXCEPTIONS!

Suggested Capstone Term Project Written Report Format

Cover Sheet – MEMO – serves as Abstract

1. Introduction
2. Mechanism Description and Modeling
3. Analysis (derivations, etc.)
 - Kinematics
 - Dynamics
4. Results (MATLAB plots, etc.)
 - Kinematics
 - Dynamics
5. Discussion
6. Conclusions
7. Appendices (code, hand calculations to check results, etc.)

You must include plenty of clearly-drawn figures: physical picture and/or sketch, kinematic diagram(s), vector diagram(s). You must also include a complete table of your modeled mechanism parameters. You also must include a complete set of analysis results plots. Combine these when it makes sense (i.e. θ_3 and θ_4 can appear together if the scale makes sense) to save paper and more easily discuss the mechanism behavior. The most important item is the discussion. Be the instructor, teach the class about your real-world mechanism.

Any questions? Just ask!

ME 3011 Capstone Term Project Report Checklist

Dr. Bob

Name(s): _____

Final term project report grade: _____

_____ MEMO – Abstract with details and summary; briefly discuss project, real-world mechanism, and kinematics and dynamics results

_____ Real-World System

- Photo/physical diagram
- Kinematic diagram
- Kinematic diagram overlaid on photograph
- System description: input/output and functional information

_____ Modeling

- Assumptions
- Constant kinematic terms, estimated dynamic terms; table of parameter values
- Reasonable model for all given external forces and moments
- Kinematics solutions; FBDs and dynamics equations

_____ Kinematic input specification: logical and reasonable for the real-world mechanism

_____ Kinematics results

- Plots – basic position, velocity, and acceleration analysis results (arranged logically); all plots must have a title and axis labels with units. Identify which curve is which. Demonstrate your MATLAB animation.
- Snapshot hand check of all MATLAB kinematic results, along with a graphical check of your snapshot position solution.
- Point of interest motion plots: position, velocity, and acceleration
- Intensive discussion to connect motion plots to real-world mechanism (position is easiest, can also do motion limits, directions of velocity/acceleration, slopes, etc.)

_____ Dynamics results

- Plots – driving force (torque) plus internal joint force analysis results (arranged logically); all plots must have a title and axis labels with units. Identify which curve is which. Also plot shaking force and moment components
- Intensive discussion to connect dynamic results plots to real-world mechanism

_____ Hardware/CAD model – effort, smooth motion, demonstrate motion, validate plots

_____ References

_____ Appendix – MATLAB code, other items as necessary

_____ Professional oral presentation

_____ Clear, concise technical writing

Tips and hints for the Professional Oral Presentation, Dr. Bob

ME 3011 Term Project

- There is a **5 minute time limit**, absolutely enforced. This is a short time so you must **practice** and time yourselves.
- We must hear equally from **both team members**, unless you are flying solo.
- If you skip this oral presentation, your final project grade will be 0.
- Since there is a short time limit, you cannot possibly present everything – there is no limit on the written report, so that can be complete. Your oral presentation can only cover the **Important Highlights**.
- **Important Highlights** for the ME 3011 Term Project:
 - **Introduction** – real-world application of your mechanism, with plenty of photos, kinematics diagrams, and your overlaid photo with terms identified.
 - State your **Assumptions** for analysis.
 - **Results** – present the main MATLAB graphs and leave time for discussion of each. You can show most of the kinematics results, including the point of interest kinematics. However, for inverse dynamics consider only showing the driving torque and shaking force results – all graphs can be given and discussed in the written report.
 - Don't forget to show your **hardware or CAD mechanism model** during results discussions. The silent partner can assist this.
 - You must spend time to **connect your plot results with the behavior of your mechanism in the real-world**. That is, use your hardware or CAD model to show that the position results are correct and focus on any interesting portions of the motion. Though harder, this also must be done through velocity, acceleration, and inverse dynamics.
- Do not run MATLAB during your presentation. Instead you can make a **movie** from your MATLAB simulation and embed it into your PPT.
- If you ignore my advice and run your MATLAB program anyway, be sure to have everything **hard-coded** so you do not have to type in data to get it running, wasting precious time.
- **Practice** in the classroom during off-hours to ensure everything works as you expect it to.
- Leave time for a **question** or two.
- Remember it is better to **present less and have your audience grasp more** (i.e. do not talk fast to beat the 5 minute time limit).
- As an audience member behave as politely as you wish the audience to do when you present.