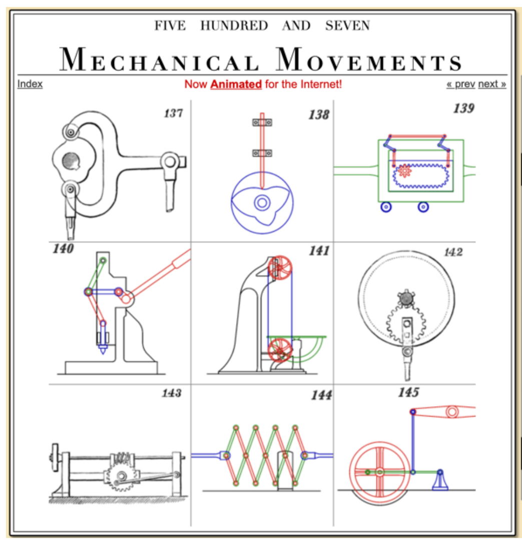
“Mechanism Models” Project - ME 21 Spring 2021

Project Overview

It can be challenge to visualize and truly reason about systems that include rigid body motion – that is, systems where objects are both rotating *and* translating, and where the motion of one object causes the rotation and translation of other objects. To help you gain more concrete intuition about the relationships between velocities, accelerations, positions, forces, and energies within rigid body motion, we would like each of you to be equipped with a tangible mechanical system that you have made with your own hands.

For an initial bank of mechanical systems, we'll use the “507 Mechanical Movements” animated website (http://507movements.com/), named after the book of the same name. Over the course of this project, you'll each (1) build a functional but low-fidelity (cardboard) prototype of one of these mechanisms, (2) develop a mathematical model relating two or more of its parameters over its range of motion, (3) develop a CAD model of the mechanism and compare the output of your mathematical model to simulation data produced by your CAD model, (4) tweak the design of your mechanism and produce a higher-fidelity working model using Nolop fabrication resources (or alternatives to be arranged with remote students).

Here's how we'll break down these steps over the next few weeks:



<u>Phase 1: Low-Fidelity Prototyping</u>
(Preface to Chapter 16 work on rigid body kinematics)
In-class session on March 4; due March 8

- Construct a low-fidelity prototype of a “507Movements” mechanism out of cardboard and brads. Eligible 507 mechanisms are those that translate rotational motion to linear motion via one or more connecting elements that move with general plane motion. List of eligible mechanisms will be provided.
- Do some research into the applications of your chosen mechanism
- Propose what function it could carry out in the real world if made of higher-fidelity materials (e.g., move a load, press a stamp, animate an artistic expression). Discuss the possible parameters of that function (speed of motion, force required, range of motion, etc.).

<u>Phase 2: Comparing Data from Theory and Simulation</u>
(Application of Chapter 16 & 17 work on rigid body motion analysis)
In-class session on March 23; due March 29

- By hand, mathematically model the input/output kinematics between driver shaft and output motion
- Create a CAD model of the mechanism
- Extract input/output kinematics data from the CAD model
- Compare CAD-generated data to the results of your by-hand math model (to check the accuracy of your own mathematically model and to understand what's going on “under the hood” in CAD simulation)

<u>Phase 3: High-Fidelity Prototyping</u>
Mostly independent work outside of class; due May 3

- Decide on the specifics of the function that you final mechanism model will carry out (distance, force, etc.). Use your math model + CAD model to propose design changes to your mechanism design parameters (diameters, lengths, input rate, etc.)
- Create (with laser cutting, 3D printing, etc.) a higher fidelity prototype that carries out desired mechanical function
- Small Nolop materials budget allotted to each student (alternatives provided for remote students)

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Learning Goals for the Mechanisms Model Project

1. Independently fabricate a functional mechanical device that transfers motion and energy from one location to another.
2. Produce kinematic equations and/or equations of motion for a moving system in two dimensions.
3. Compute rigid body motion (position, velocity, and acceleration) and/or associated forces in two dimensions.
4. Use moving coordinate systems to analyze motion of two or three interconnected rigid bodies, including linkages.
5. Use computer-based modeling, analysis, and/or numerical solution tools to determine and represent the motion of a body as a function of time, and when appropriate, use this information to infer active forces.

Specific Instructions for Phase 1 (due Mon., Mar. 8) on page 3

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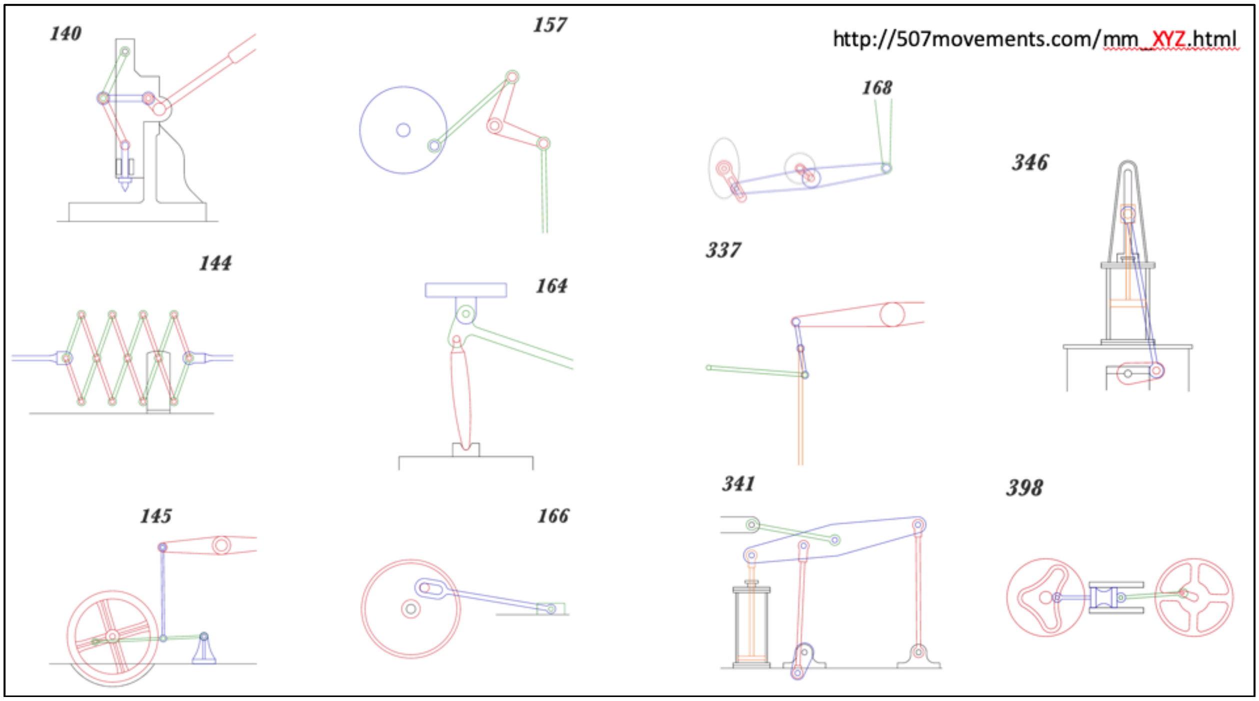
Specific Instructions for Phase 1 - ***Due Monday, March 8, 11:59pm on Canvas***

1) Choose one of the following mechanisms from “[507 Mechanical Movements]” as your focus for this assignment. Eventually you’ll be able to adapt it to add your own design elements or changes, but for now, stick with what you see shown on the website.

   507 mechanisms that have at least one element each with general plane motion, rotation only, or translation only:

   - 140
   - 144
   - 145
   - 157
   - 164
   - 166
   - 168
   - 337
   - 341
   - 346
   - 398



2) Gather the following materials:
   a. Lightweight chipboard, about 12” by 12” total
   b. Brass fasteners (brads), ½” or ¾” , about 10
   c. Scissors
   d. Tape (any kind) – to hold back of brass fasteners flush against cardboard
   e. Pen, small screwdriver, hole punch, or other tool for poking holes in chipboard

3) Create a “low-fidelity” prototype of your focus mechanism – that is, a version that successfully demonstrates its core interacting elements but that is made of materials that won’t last forever or be included in a final product (but that are easy to work with and quick to iterate on). Its elements should move and interact in the same way as the links depicted on the website’s animation.

   Be sure to reserve some substantial portion of your cardboard as a rigid backing for your mechanism, and use the rest of it to cut links, discs, and other elements.

Some questions to consider:

- Which links, at which points, should be pinned to each other but not to the backing?
- Which links, at which points, should be pinned to the backing?
- Where do you need to create slots (perhaps with strips of cardboard and tape) or other pathways (perhaps with pencils or straws taped to your backing) to constrain the motion of a point or link?
- When might you need to add weight (with anything you can find) to a link so that friction becomes more negligible?
- Where might you need to add cardboard spacers/bushings to allow one link to travel over top or underneath a brass fastener or another link?

Front and back view of a chipboard prototype for mechanism #92

Your end result doesn't need to look pretty! It just needs to have links that move relative to each other as shown in the animation.

(see next page)

4) 1-page memo on mechanism applications: Do some internet research into the applications of your chosen mechanism. Write a 1-page (or less) memo to
   a. Describe what kind of tasks it is or was used to carry out, and
   b. Propose what function it could carry out in the real world (e.g., move a load, press a stamp, animate an artistic expression if made in three dimensions and with higher-fidelity materials). Discuss any parameters that would be essential for that function (speed of motion, force required, range of motion, etc.).

5) Take a photo and a very short video (a few seconds) of your prototype and post both files, along with your 1-page memo, to Canvas – by Monday, Mar. 8, 11:59pm