MECH2210 (Dynamics) Class Project information

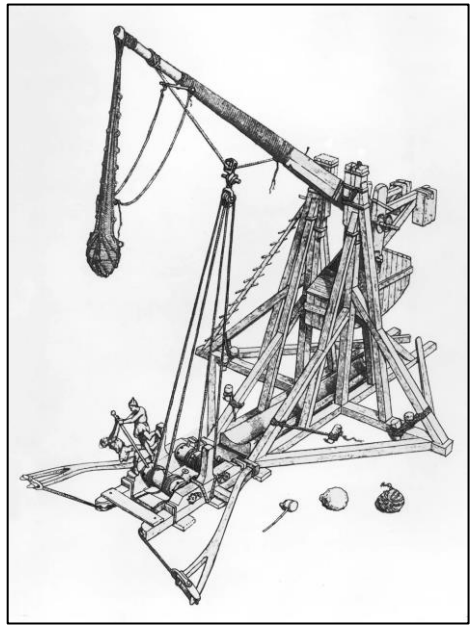
Course: Tribology: Matls & Mfg Aspects (MECH4840-1/MATL8813-1)

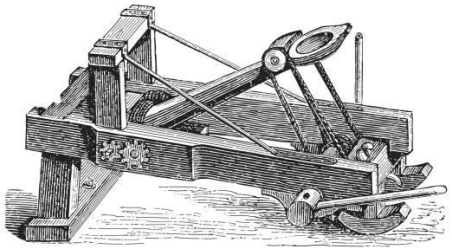
Instructors: Dr. John A. Magliaro, EIT & Dr. Bruce Minaker, P Eng

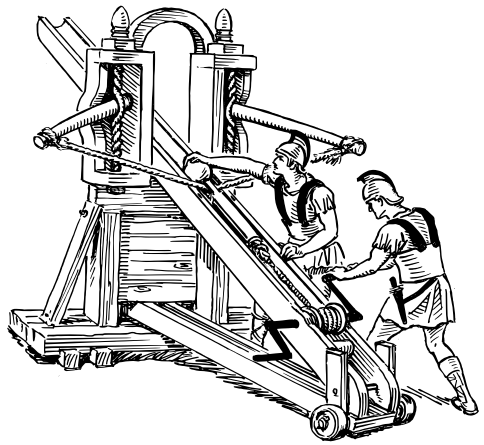
May 23rd, 2023

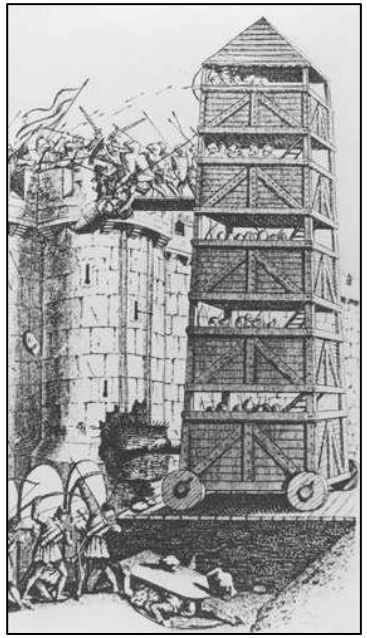
Motivation:

- Mechanical engineers build **weapons**:

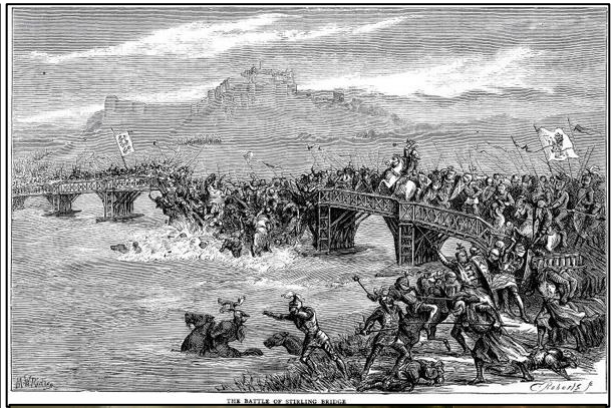








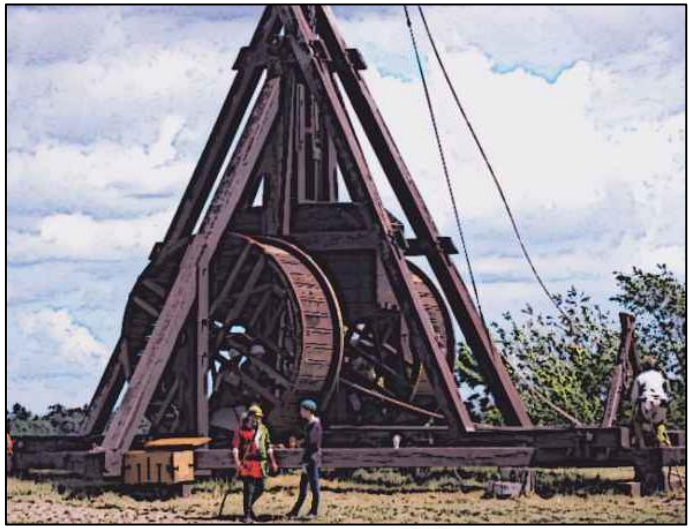
- Civil engineers build **targets**:



- (Mostly) a joke, but historically Mechanical Engineering has been driven by military projects and Civil Engineering by cities and public works

History:

- King Edward I (Edward Longshanks), and his chief engineer Master James of St. George, march on Stirling Castle, Scotland ca. 1304
  - English army possesses a new weapon called “Warwolf”
  - Longshanks only accepted the Robert the Bruce’s surrender ***after*** demonstrating the weapon: https://www.youtube.com/watch?v=_KntpV7t90Q&ab_channel=theismagelssen

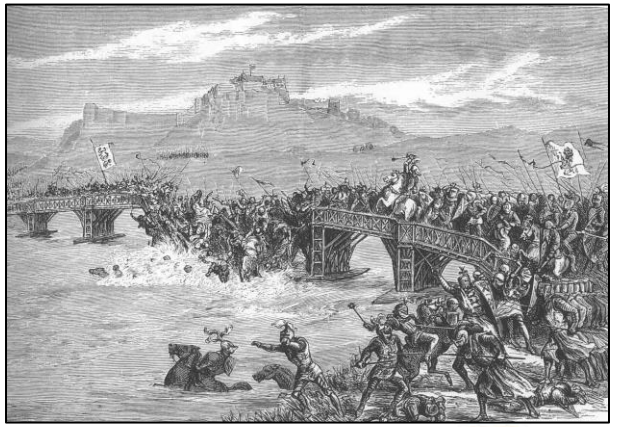


History: Pop culture check

- King Edward I (Edward Longshanks) was depicted alongside his nemesis William Wallace in the 1995 film “Braveheart”

- Longshanks’ army was previously defeated by Wallace in 1297 (pre-Warwolf) at the **Battle of Stirling <u>Bridge</u>**
  - This battle is depicted in the film, but the bridge is missing…

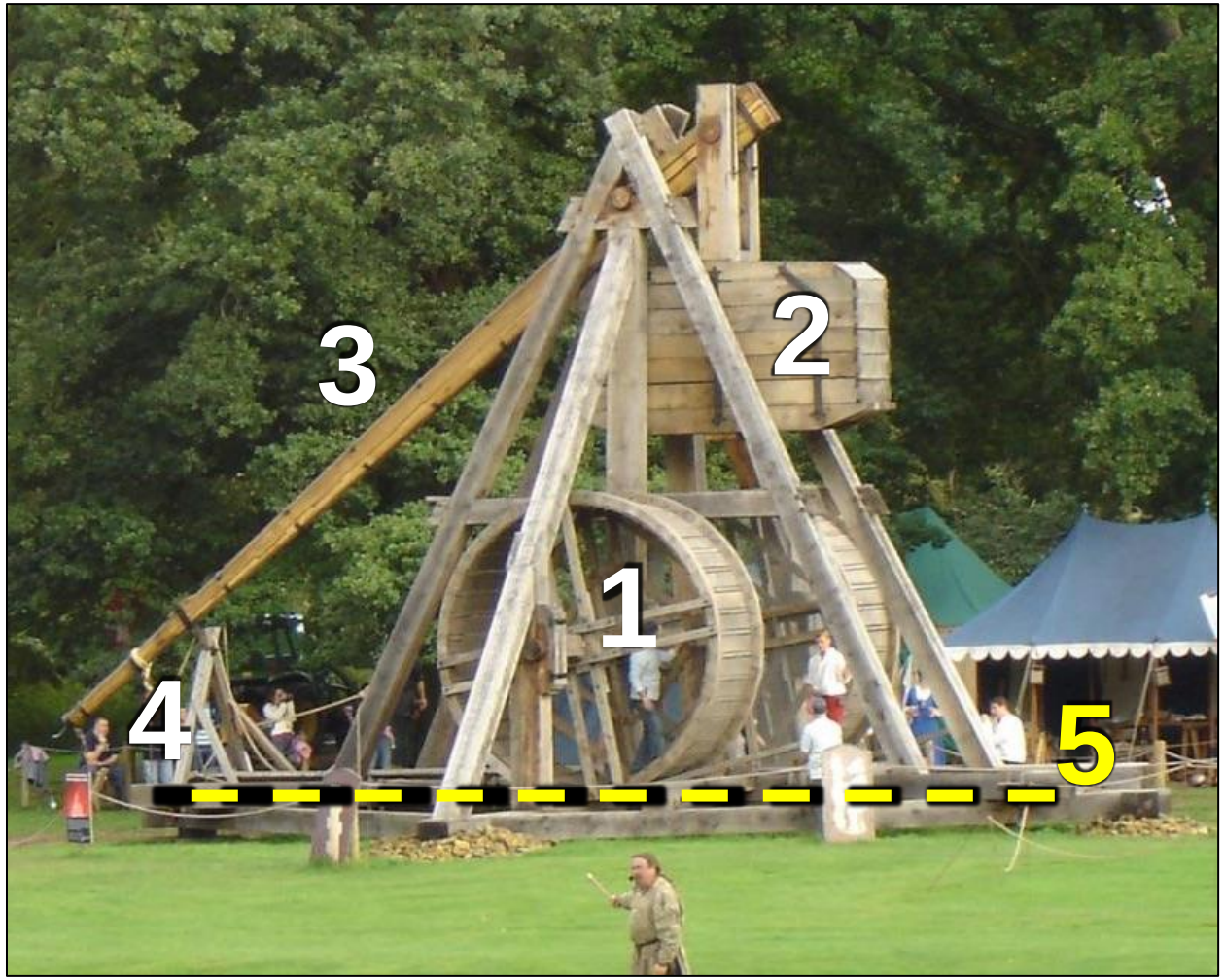





Definition:

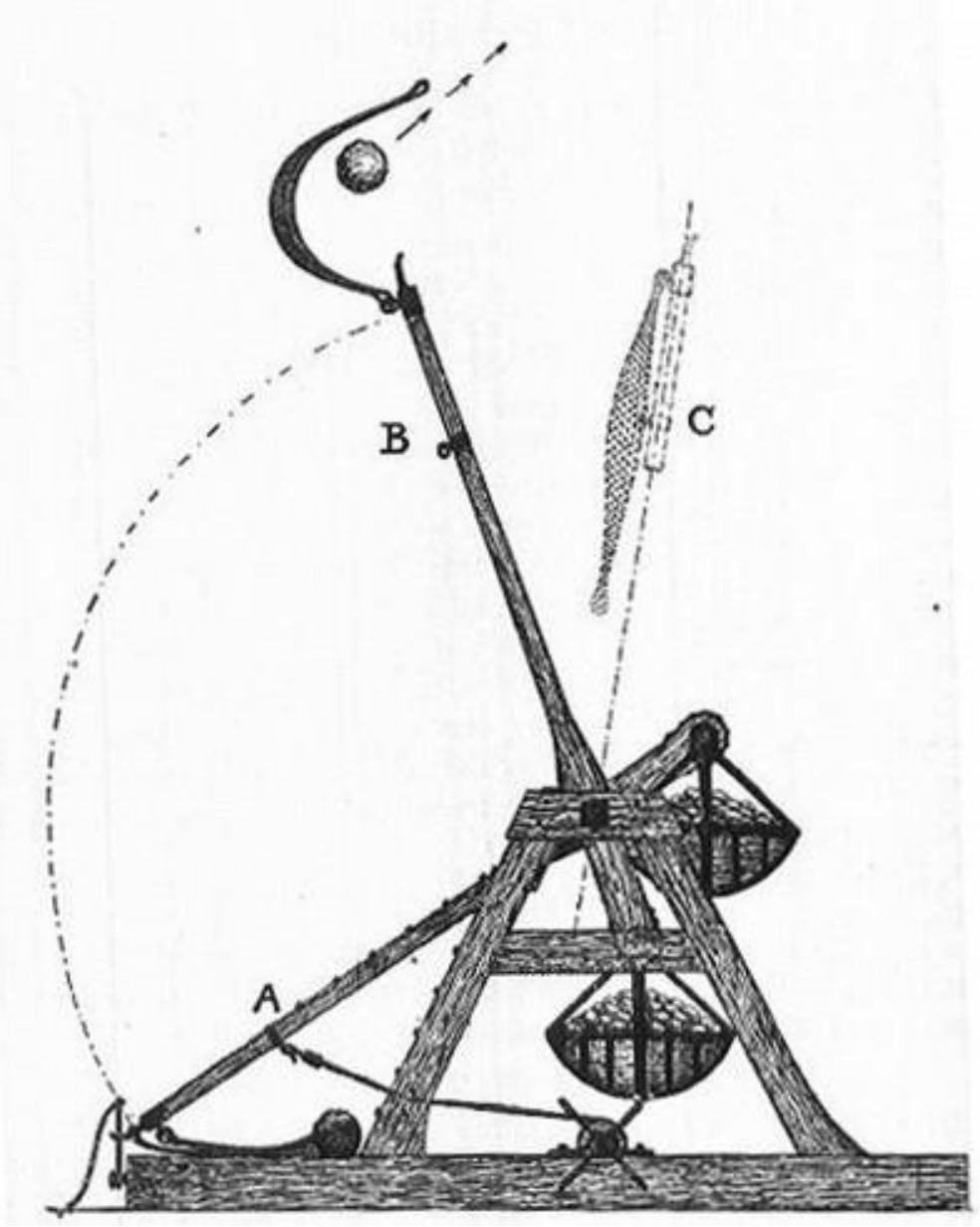
- Warwolf was the world's largest 'trebuchet', a devastating medieval siege engine
  - Etymology is French, tre(s) = to fall, buc = trunk of body

- Five key components:
  1. Frame
  2. Counterweight
  3. Beam
  4. Sling
  5. Guide chute



Your mission:

- You are tasked with the:
  - Design,
  - Numerical modeling and analysis,
  - Physical construction, and
  - Physical demonstration
- of a small-scale trebuchet, with the objectives of:
  - Maximizing range, and
  - Repeatability (accuracy)



Constraints:

- The project will be standardized, *more details to follow*, after first milestone
- Size and weight of the device will be limited
  - Controlling the range of your trebuchet can be done with some clever engineering principles
- **Must be powered by gravity only (NO elastic strain energy, illegal and unsafe!)**

Constraints: Detailed

- Fixed axis rotation is allowed BUT there will be a **15 % bonus applied to the entire for project groups that attempt <u>general plane motion</u>** (e.g., floating arm trebuchet)
- The height of the highest point of the frame cannot exceed 1.0m from the base of the guide chute
- The mass of the trebuchet (without counterweight) cannot exceed 2.0kg
- The trebuchet frame must be portable
  - Mounted to 4 wheels (on axles) in the provided kit
- Structural members must be fabricated from wood in the provided kit
- **Any team which does not comply with these rules <u>will not be allowed to demonstrate</u>**

Constraints: Continued

- The provided kits will contain the following materials:
  - Wood: 3/8” X 3/4” poplar strips, approx. 48” to 72” in length
  - Wood: Round, 3/8”-diameter dowels, approximately 24” in length
  - Glue: Common, fast-setting carpenter’s glue
  - String: Common household cotton
  - Fabric: 12”x12” sheet (for sling)
  - Plastic (PETG) Wheels compatible with a 3/8” axle
- The counterweight must consist of 3, 355mL **non-alcoholic** drink cans
  - The cans (not provided) must be fully removable
- Any materials which are not mentioned (e.g., screws, nails, paperclips or other fasteners, fishing line, …) are NOT permitted
- Any lost, stolen or damaged materials must be replaced, **at your own expense**, with exact duplicates

Demonstration date:

- **The demonstration date is tentatively set for <u>Friday, August 4th, 2023</u> from 8:30AM to 11:30AM**
  - Location to be determined/announced later
- This period will be sufficiently long to test all groups, all groups must be present by/before 9:30AM and will be required to sign in
- You will only have one opportunity to demonstrate your device
- **If no teams are present and waiting to demonstrate at the event for a period of 15 min**, the event will be deemed complete, and **no further evaluations will be conducted**

The rules of engagement:

The following rules will be enforced for the project:

- You will be attempting to destroy a crude replica of Stirling Castle
  - **You will be allowed one calibration shot (not counted) followed by up to six (6) official shots**
  - Based on your calibration shot, you may select your starting point to maximize damage to Stirling Castle
  - Any team which can destroy the castle in under 6 shots will receive a 10 % bonus on their demonstration score
  - The **range** will be measured as the **horizontal distance from the start line to the location where the projectile passes the horizontal ground at first impact**

Stirling Castle, ca. 2023

The rules of engagement:

The following rules will be strictly enforced:

- Each team will have six (6) minutes to complete their demonstration
- Any trebuchet that violates the rules will be assessed a penalty on its performance score, on a case-by-case basis
- Any decisions as to legality are at the sole discretion of the instructors, and will consider the ‘spirit’ of the rules, as well as the ‘letter’ of the rules
- Any penalties are at the sole discretion of the instructors, and may range from minor deduction to complete disqualification
- **If you are trying to gain an unfair advantage by any means other than clever application of engineering principles, then you are breaking this rule**

Working in groups:

- This is a group-based project; **a group must consist of at least two (2), but no more than four (4) members**
  - A common grade will be assigned for all group members, so choose wisely!
  - Team member(s) can file a grievance against any one of their team members if they choose to do so
  - Grievance must be filed by **noon** on June 30th, 2023.
  - Grievances must be completed in writing with suitable justification as to why it is being made
- **You will provide your group information in the Preliminary Report**
  - You will have until 11:59PM on 5/30/2023 to submit your Preliminary Report on Brightspace, submissions outside Brightspace will not be considered
  - Students who do not form a group by this date/time will be placed in groups at random and given an additional 24 hours to submit their preliminary report
- Once your information has been submitted, it cannot be changed
  - In the event a group member drops the course before completion, the team must continue with the remaining member(s)
  - Team mergers are not allowed

Grade distribution:

- Once again, expect a common grade for all group members
- Weighting will be as follows (for a total of 30% of your final grade):
  - Preliminary report, **DUE by 11:59PM on 5/30/2023** (2/30)
  - Progress report – Preliminary design, with sketches, and numerical model, **DUE by 11:59PM on 7/7/2023** (8/30)
  - Device demonstration, in-person, **8:30AM at CEI on 8/4/2023**:
    - Craftsmanship (3/30)
    - Performance (9/30)
  - Final report – Final design and drawings, revised modelling and analytical calculations, **DUE by 11:59PM on 8/4/2023** (8/30)

Performance score:

- Score, S, will be determined based on the range, r_i, of your group's throw, the standard deviation, σ, of your throw and the class maximums and minimums

$$S = \begin{cases} 6 \cdot \dfrac{r_i - \sigma}{r_{max} - \sigma}, \text{if } r_{max} < 2 \cdot r_{min} \\ 3 \cdot \dfrac{r_i - r_{min}}{r_{max} - r_{min}}, \text{if } r_{max} < 2 \cdot r_{min} \end{cases}$$

Performance score:

- The group whose device has the highest performance will receive a perfect performance score (10/10).
- Other groups will receive scores computed by their relative performance.
- The group with the lowest performance (that completes their demonstration) will score at a minimum 50%, but potentially more.
  - A non-functional device will score ‘zero’ and will not affect the minimum performance score.
- If necessary, any statistical anomalies will be removed when finding class maximum and minimum.
- Course instructors have final ruling on any scores and/or adjustments of scores.

Craftsmanship:

- Judged by the course instructors
- Quality, fit, finish of virtual device
- Clever detail design
- Novel concepts

Minimum score is 1

Decent score is 2

Exceptional score is 3

Reporting:

- Reports should follow standard engineering format, i.e.:
  - Summary
  - Table of Contents
  - List of Figures
  - List of Tables
  - Introduction
  - Main Body (not called ‘Main Body’, add sections named as appropriate)
  - Conclusions
  - References
  - Appendix
- Progress Report: 10-page limit, excluding the (unlimited) appendix.
- Final report:16-page limit, excluding the (unlimited) appendix.
- Use Times New Roman 12-point font – no italics.
  - 1 line spacing, print only on 1 side of page, margins 1.5 cm from all edges.
- Automated report document will be provided on Brightspace under \Project

Reporting: Continued

Progress Report details:

- Document should focus on design and numerical modeling and may include:
  - Preliminary design sketches on engineering grid paper.
  - Detailed drawings and/or plans (preferably CAD).
  - Numerical modeling details and range predictions.
  - Due date/time (electronic copy) – 7/7/2023 at 11:59PM.

Final Report details:

- All of the following are suitable for inclusion in the Final Report (e-copy), which is due the evening after the demonstration (8/4/2023 at 11:59PM):
  - Updated detailed drawings of every component, CAD required.
  - Calculations to estimate range.
  - Comparison of analytical, numerical and physical test results.
  - Discussions on differences from analytical, numerical model predictions and physical test results.
  - Any other details and information as appropriate.

Your first task:

- Groups no greater than 4 people should be formed.
- Preliminary report due by May 30th, 2023 by 11:59PM (electronic copy submitted via Brightspace), students who do not find a group and are placed at random will have an additional 24 hours
  - Regular rules for submission timing will be enforced
  - Groups can submit at earlier date if needed
- Preliminary report should be no more than 1 page printed on both sides and contain:
  - Group name (be creative but , funny names get bonus marks)
  - List of members names and student ID #'s
  - Research material or any initial design ideas you have
- Preliminary report will follow identical format guidelines as other reporting documents, refer to the \Projects directory on Brightspace