Pseudo-situation: Lulay Industries, LLC is seeking a new agricultural vehicle design. It is to have good speed on flat level terrain, and also be able to pull or carry loads up a steep incline. They have asked students to develop the vehicle through prototype demonstration. In ME328, the students will design a functioning small-scale proof-of-concept prototype. Lulay Industries will host a competition to evaluate the various proof-of-concept designs and select a winner based on prototype’s performance and the team’s demonstration of engineering skills.

Objective: design a vehicle prototype composed entirely from the supplied LEGO Mindstorm kit (plus a small amount of cardboard). The vehicle must be capable of meeting the following three general criteria:

- Design work (analysis and testing) demonstrates sound engineering principles
- Capable of high speed in the flat track event
- Capable of sufficient speed in the steep-incline pull event (as defined below)

The vehicle must be capable of carrying up to 1 kg (10N) of weight.

**Scoring Criteria**

**Design Work:**
Design work will be evaluated and scored on the following criteria:

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Max Score</th>
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<tbody>
<tr>
<td>All Design Increment Documents (DID’s) demonstrate justification for</td>
<td>30 pts</td>
</tr>
<tr>
<td>engineering decisions</td>
<td></td>
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<tr>
<td>Incremental (iterative) and appropriate integration of both testing and</td>
<td>30 pts</td>
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<tr>
<td>analysis</td>
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</tr>
<tr>
<td>Clear communication of engineering decisions and conclusions</td>
<td>30 pts</td>
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**Safety Requirement:**
Safety is a critical design criterion for this project. The vehicle must not tip when placed on a 30 degree incline (as if it were traversing sideways across the incline).

**Cost**
Economics is always an engineering criterion. For this event, teams will be “charged” 20 points for each gear or sheave used.

**Weight and size**
Weight is often an important criterion, especially with transportation vehicles. For this event, teams will be penalized 2 points for each gram over 430 grams that the vehicle weighs (the controller unit will be included in the total weight). Size is often a criterion for vehicles as well. The entire vehicle **must** fit inside a 10X8X6 inch volume.
Dynamic events:

1) The first event (flat track) will measure the time required for the vehicle to travel 30 feet across the competition room floor (area outside SH110). It will not be carrying payload for this event.

2) The second event (hill pull) will measure the time required to traverse plywood (about 7 feet in length) inclined at any one of the following angles: 5, 10, 15, 20, 25 degrees. The vehicle will carry a 500 g load during the hill climb. The angle to be used during the event will be announced 1 week prior to competition.

Scoring for the dynamic events will use the following algorithms:

\[ \text{Flat Track Score} = 100 \times \frac{t_{\text{longest}} - t_{\text{yours}}}{t_{\text{longest}} - t_{\text{shortest}}} \]

- \( t_{\text{shortest}} \) fastest time by any vehicle
- \( t_{\text{yours}} \) time for your vehicle
- \( t_{\text{longest}} \) the lesser of: a) slowest time by any vehicle; b) \( 4 \times t_{\text{shortest}} \)

Hill climb: Scoring for this event is “all or nothing” – 150 points will be awarded to teams completing the hill climb in 15 seconds or less and zero points for times greater than 15 seconds.

Failure to complete either event will result in a score of zero for that event. Details as to the weight to be pulled will be released after the final Design Increment Documents have been submitted; therefore, the final report should discuss how the design might vary depending upon the actual angle for the hill climb. In other words, what gear ratio, tires, etc. would be used if the hill climb was 10 degrees compared to 25 degrees, etc. It is reasonable to expect to have several different designs; each one better than the others for specific inclines. Only one gear ratio may be used for both events (same ratio for both flat track and hill climb events). It must be the same ratio from the motor to the ground (so using different wheel diameters or different gears within the competition violates this requirement).

Limits: only parts from the assigned LEGO Mindstorm may be used, and from that only one motor may be used. Only the batteries provided may be used. If you have problems with your battery charge, please contact Paige Hoffert (technician). The same drive ratio (motor, gears, drive tires, etc.) must be used for both the hill-climb and flat track events. In other words, only one gear “speed” – you may not “shift” gears between events in any capacity. In addition to the LEGO materials, you may use up to one piece of cardboard, 6X6 inch maximum, to place the weights on in vehicle. In other words, you may use cardboard for the truck bed. Other than supporting the weights directly, the cardboard cannot be used for any other purpose. Cardboard will not be provided.

Deliverables:

~ February 10: Submit a Project Plan (described by the ME481 Project Plan – link on ME328 course web page). This is to be your project as you see it as a student in ME328. In other words, don’t pretend you are working for a company that will actually build a vehicle. The vehicle to be designed, tested, fabricated in ME328 will use LEGO mindstorm kits. Actual expenses will be zero. For the Project Plan, identify 4-6 milestones (including dates) and at least one or two tasks.
to complete each milestone. Creating the plan must be a team activity where all members agree upon the tasks, milestones and dates. This should NOT be viewed as a “hoop to jump through.” Planning is a very important part of every engineering project and should be taken seriously. By the process of creating the plan, the team has the opportunity to better understand what really does need to be accomplished, how to accomplish it, and when it needs to be accomplished. After creating the plan – use it! Hold yourself and each other accountable for following it as closely as possible.

~February 22: resubmit the revised Project Plan (if needed)

~Due March 2: submit a document that briefly discusses and contains two Design Increment Documents. One DID is to focus on analysis which determines the appropriate gear ratio for hill climb. The other DID is to focus on validation testing. These two DID’s should be combined in this deliverable to show that the team is capable of determining through analysis what gear ratio should be used to carry 500g load successfully up a 15 degree incline. The testing is to validate the analysis (aka, validation testing). The test DID should contain a brief but detailed test plan used for the validation testing, photos of testing, and the results. NOTE: DID’s are NOT like formal reports (although, formal reports may include many DID’s). They are more like homework assignments.

Also, submit/resubmit updated tables (criteria, milestones, and task schedule).

Due March 23: submit a DID - through analysis, determine the recommended gear ratio which will successfully complete the hill climb for each of the potential angles (5, 10, 15, 20, 25 degrees); possibly, five different ratios. Validation testing with at least three different loads on a 15 degree incline should be completed and included in this DID (this provides further evidence that the team can meaningfully analyze various conditions for the hill climb). Include analysis and validation testing for the flat track event. Include photos documenting test work. Submit/resubmit updated tables (criteria, milestones, and task schedule).

April 11 – Final report. One page text maximum (12 pt, Times New Roman, single space), plus tables, figures, all previously submitted DID’s (originals or copies), any addition engineering work (DID’s), action item log and decision log. Include a new table that duplicates the criteria table but adds a column which concisely describes what was done to design and demonstrate each specific criterion was met or not met. If appropriate, it simply could reference the DID that demonstrates accomplishing the criterion. This report should include a table defining what gear ratios should be used based on the potential hill climb angles (5, 10, 15, 20, or 25 degrees). Different gear ratios may be selected for different inclinations. Results of testing should be included. Include a sketch or photograph of your design.

April 20, Competition: An in-class competition will be held to determine which teams best satisfied the requirements. The configuration of the vehicle used in competition must match the configuration described in the final report for the given hill climb inclination; therefore, it must be clear in your report what the design would be for all possible inclines. “Awards” will be given to the top teams in the form of extra homework points as follows:
Homework points = 40 X (YourScore - LowestScore) / (HighestScore - LowestScore)

YourScore is based on the event scores (design work, cost, weight, hill climb, flat track). At least one team will receive 50 “extra credit” homework points, and at least one team will receive zero extra credit points. All other teams will receive something in between depending upon how close they come to highest or lowest score.

Your “Team Project” grade (10% of the class grade) will be based completely on the score of the design work – so effectively, it counts twice in your class grade.

Be sure to charge the Mindstorm battery before the competition and bring the entire kit (box) with you. We will collect them immediately after the competition.

Project Management: each team is to maintain an action item log and decision log throughout the project. Each team member will act as the lead engineer at various times throughout the project. The lead engineer will be responsible for at least one meeting (creating agenda, etc.). The lead engineer will also be responsible for weekly email updates to all stakeholders (the instructor and team members). The course web page shows the schedule for who will be the lead engineer and when.

Here are some things to consider when developing engineering project plans:

- Modified Murphy’s rule: things don’t always work the way you think they should. That’s one reason why testing is so important.
- Analysis is an effective design tool. It is usually faster and less expensive than testing. But at best, it can only answer the question you ask it; it doesn’t reveal your ignorance – testing does.
- Design is iterative. Do not view testing as the last thing you do. Make mistakes early and often – that’s how you learn, and “early” is when mistakes are least costly. “Early” testing should be simple and inexpensive. Later in the project, when your ignorance becomes less, you can afford to do more refined and comprehensive testing.
- “Early testing” is done with the assumption things won’t work quite as you thought. What will you do if the test reveals surprises – does your project schedule allow for surprises?
- Does/can/should any of the following types of testing make sense for your project:
  - Material testing – testing done to determine material behavior (may be fatigue testing, corrosion testing, stress-strain testing, etc.)
  - Validation testing – testing conducted to confirm analysis is valid
  - Component testing – testing done on a single component or small sub-system to study its behavior before it becomes integrated in the final design.
  - Proof of concept testing – testing done to demonstrate the viability of a concept. This can be done on parts, subsystems, or for the overall design concept.
  - Demonstration testing – does the completed design function as intended – does it satisfy the project criteria?
Engineering design is an iterative process proceeding from ignorance to a state of less ignorance. Really, most of engineering can be expressed as five major “steps” (applied iteratively – not linearly):

1) Preparing to do “step” 2 and “step” 3 (defining and understanding problems, literature search, planning, acquiring resources, etc.):
2) Gaining some knowledge through analysis
3) Validating knowledge and/or exposing ignorance through testing (don’t wait until the end of the project to learn you are ignorant).
4) Make sense out of “steps” 1, 2, and 3 and reach conclusions.
5) Repeating any of the above, in any sequence as needed.

The milestones are a list of things you need to have completed to complete the project. They can include the production of hardware, acquisition of knowledge, etc. Use the criteria to help identify milestones – what do you need to learn to satisfy all the criteria? Milestones are NOT tasks:

This is poorly described task (because it does not clearly say what the testing is), and it is NOT a milestone: test the prototype.
This is a m/s: testing of prototype completed.

Tasks are the things done to complete a milestone. Each m/s requires one or more task to complete it. Example: testing - carrying a 200g up a 15 degree incline to compare with analytical prediction.