Activity: **Introduction to Instrumentation: Building a Motor/Propeller Testing Device (a force gauge)**

GRADE LEVELS: 9-10

SUMMARY:

Students will learn the engineering design process through the creation of their own force gauges. These force gauges will be used to determine the best propeller/motor combination, per the request of a mock engineering company. They will also learn about measuring applied forces and techniques of technical writing.

LEVEL OF DIFFICULTY [1 = Least Difficult : 5 = Most Difficult]

4- Difficult

TIME REQUIRED

10 - 40 min class periods (varies depending on class)

COST

$150.00 per class (12-15 students). Cost does not include batteries, alligator clips, or standard masses. Using power sources instead of batteries will significantly reduce cost. (All materials can be reused for Fan Car Activity & future classes)

STANDARDS:

1.1 Identify and explain the steps of the engineering design process, i.e., identify the problem, research the problem, develop possible solutions, select the best possible solution(s), construct a prototype, test and evaluate, communicate the solution(s), and redesign.

1.2 Demonstrate knowledge of pictorial and multi-view drawings (e.g. orthographic projection, isometric, oblique, perspective) using proper techniques.

1.3 Demonstrate the use of drafting techniques with paper and pencil or computer-aided design (CAD) systems when available.

2.1 Distinguish among tension, compression, shear, and torsion and explain how they relate to the selection of materials in structures.

WHAT WILL THE STUDENTS LEARN?

The Engineering Design Process

Group communication skills

The differences between tension, compression, shear and torsion

Application of the laws of physics pertaining to Forces (Hooke's Law)

BACKGROUND INFORMATION:

This activity should coincide with a lesson on applied forces and work including spring constants and Hooke's Law. (Fan Car would be a Good follow up Activity)

There are two ways to transfer energy into or out of a mechanical system, work and heat. Work transfers energy using force and motion, while heat is energy transfer due to a difference in temperature. This activity concentrates on energy transfer due to work, i.e. force and motion.

Science and engineering are both quantitative. We want to know not just that work is done, but how much work is done; we need hard and fast numbers with their proper units. We need to measure things, to record and analyze the data, using data to drive our design changes. Measuring can be easy if you have the right instrument. Take length , for instance; the right instrument, a ruler, is simple to use, easy to obtain and measuring length is a snap.* Applied tension and compression forces can be measured as well using an instrument called a force gauge.

A force gauge can use different methods to measure the force produced by a certain action. In this case, the force will be generated by a motor and propeller apparatus. The objective is to have students design a device that will measure the amount of push or pull that a fan blade apparatus will produce.

*Of course, the difficulty in taking any measurement relates directly to the accuracy and precision necessary. With regard to precision, measuring lengths to the nearest micrometer is obviously much more difficult than measuring to the nearest centimeter.

MATERIALS:

Per group:

2-1/2" Extension Springs, 0.04 lbs/in.,0.04 lbs. I.T., McMaster-Carr prt# 9654K49

2-1/2" Extension Springs, 0.20 lbs/in.,0.21 lbs. I.T., McMaster-Carr prt #9654K63

1-7/8" Extension Springs, 0.57 lbs/in.,0.30 lbs. I.T., McMaster-Carr prt #9654K45

1-1/2" Extension Springs, 0.09 lbs/in.,0.04 lbs. I.T., McMaster-Carr prt #9654K45

12" Ruler

5" Nose Cone Propeller (3 blade), Kelvin part #850891

5" Propeller (2 blade), Kelvin prt # 850632

7" Propeller (2 blade), Kelvin prt #850890

Hi-Speed DC Motor, Kelvin prt #850647

Hi-Performance, Hi-Torque Motor, Kelvin prt #850887

2- 8 1/2 x 11" pieces of paper

Assorted Balsa and Pine Hobby size wood pieces

Alligator clip wires

9V Batteries, power sources

Duct Tape

Hot glue gun, glue sticks

String, twine

Standard masses, 1g. - 200g., mulitple sets

Per Class:

Sample Force Gauge, to be shown after the activity

PREPARATION:

Collect materials; create your own Force Testing Device

DIRECTIONS:

(See Problem Statement Worksheet)

The students should work in groups of two or three.

Following lectures on force, work, and energy, each group should design and build a force gauge device that will help them to choose which combination of motor and propeller to use in a new fan car prototype. Each group should be careful to follow all the steps of the Engineering Design Process including: identify the problem, research the problem, develop possible solutions, select the best possible solution, construct a prototype, test and evaluate, communicate the solution (See Force measuring device and fan testing lab report guidelines), and redesign.

There are two viable options for testing the forces produced by the motor and propeller combinations. One device involves suspending the motor and propeller from a spring and measuring the amount of displacement in the spring as the amount of force being produced. To do this, the spring must be calibrated using known masses. For example, hang a 20g. mass from the spring and record how far the spring stretches. You now know that that distance corresponds to a 0.196 N force. Some considerations in this design are ensuring the torque produced by motor does not "wind" the spring. In addition, balancing the fan blades is important to reduce the amount of vibration in the system, making data collection more difficult.

The second viable method for testing the forces is to set up a balance. This device is a simple lever with a fulcrum in which the motor and propeller push at one end and known masses balance out the force at the other end. A lecture on moments and torque should be included for this design to help the students understand the

relationship between distance and forces in this case. A balance device has proven to produce quite accurate results thus far.
The teacher should try to construct both of these designs before introducing the project to the class; this will create a familiarity with the designs and help with trouble shooting in the future. Designs should stay away from measuring something in the airstream created by the propeller because air currents will corrupt the data produced.

Other options and equipment should be made available for the students. The motors should be powered using either a 9V battery or a power source set to 9V of direct current; using power sources will greatly reduce cost. See attached worksheet titled Internal Instrumentation Solutions Group Memo for some other project rules and guidelines. Each group of students were hired as instrumentation specialists to design and construct the instrumentation apparatus and perform testing on the given motors and propellers.

The collected data should be the forces produced from all possible motor/propeller combinations. The students should have sufficient data to conclusively decide which motor/propeller combination produces the most force.

INVESTIGATING QUESTIONS:

Which combination of motor and propeller should the Volpe Center use to power their prototype car?
What is the best way to figure this out?
What do you need to measure and how will you measure it?

REFERENCES:

Developed by: Alfred Fordiani and Douglas Prime

Rubric for Performance Assessment

Activity Title: **Introduction to Instrumentation: Building a Motor/Propeller Testing Device (a force gauge)**

Grade Level: 9-10

	1	2	3		
Criteria	Developing	Proficient	Advanced	Weight (X factor)	Subtotal
Testing/Data Collection	Missing some data and doesn't appear accurate.	All motor fan combinations tested and data collected but not organized	All data is collected for each combination. Everything is accurate, organized and graphed.		
Cooperation	No group work.	Little contribution to group work.	Contributes as expected to group work.		
Testing apparatus	Completed prototype drawing but little else	Completed prototype drawing and construction but apparatus does not work properly	Completed prototype drawing and construction. Testing apparatus cab accurately measures the applied force of all Motor/Propeller combinations.		
Final Report	Report is not completed	More than half of the issues presented in the lab report guidelines are addressed.	All of the issues presented in the lab report guidelines are addressed in addition to original ideas		
				Total:	

Teacher Comments:

Problem Statement:

To: Chief of Design and Research, Instrumentation Solutions Group
From: Fan Car Project Manager, Power Dynamics Corp.

Re: Instrumentation and performance testing of electric-motor-driven propellers

Dear Chief:

As you know, The Volpe Center of the US Department of Transportation has shown great interest in fan-powered cars and recently awarded a contract to produce a test prototype fan car to our company, Power Dynamics Corp. The stipulations in the contract limit our choice of electric motors and also propeller blades to several that are commercially available. We need to choose which combination of motor and fan to use in our prototype. We do not have the instrumentation capabilities to perform proper test on these motors and fans in our own facility, so we have contracted your group of instrumentation specialists to design and construct the instrumentation apparatus and also to perform testing on the motors and propellers.

This letter is to serve notice that you are to execute the contract and begin work immediately.

Sincerely, Fan Car Project Manager, Power Dynamics Corp.

Internal Instrumentation Solutions Group Memo
To: Motor and Propeller Design Team
From: Chief of Design and Research

Re: Instrumentation and performance testing of electric-motor-driven propellers

Task

- Design and build a motor/propeller testing apparatus.
- Perform a series of scientific tests to quantify motor/propeller performance.
- Document and communicate findings to Power Dynamics Corp.

Overall Goals, Design Goals, and Team Performance Goals

- Win the confidence of an important new client.
- Prototype is as accurate as possible. Accuracy is heavily weighted in alternative design evaluations
- Prototype is as easy to use as possible.
- Prototype is as inexpensive and easy to build as possible.

Design, Testing, and Documentation Requirements

- The device is a force gauge: Device must properly measure the force produced by the propeller in Newtons (N). The effect of other forces on the testing must be eliminated or minimized.
- Apparatus applies no stress to any electrical component.
- Testing apparatus must easily accommodate all of the different motor/propeller combinations.
- A fair and scientific testing procedure must be developed, and tests performed on all possible fan/motor combinations.
- All team members must keep detailed day-to-day documentation in their lab notebooks, including sketches of design ideas and a detailed sketch of the final design. All testing procedures must be documented in detail. All testing results must be documented in properly titled and labeled data tables.

Design Constraints

- Management must approve all materials used. Materials generally limited to those provided by management. However, management may approve use of other materials upon request.

Force measuring device and fan testing lab report guidelines

Now that we have completed building and using our force measuring devices it is time to communicate our findings to the rest of the science and engineering community. To do this, we will write a report. **It is time to do your absolute best work in preparing your report**. While in the lab, mistakes are made and expected, your lab report is what is seen by the world, and it is how the world will judge you.

Your report should have the following format. The questions asked in each section are meant as guidelines and take off points for your analysis. Be sure to answer all of the questions asked in some way or another, but you should not necessarily limit yourself to answering just these questions. The report should flow as one document, not be a question and answer sheet.

1. Introduction. What is force and why do we want to measure it? What are we measuring the force produced by fans? Include background information that you believe is useful.

2. Provide a brief summary of your force-measuring instrument. How does it work? What scientific principles are used in the design of your device? How did you come to the design solution that you shoes? Sell your design to your client: why is this a great design, and why should Power Dynamics Corp. be happy that they chose you to do their instrumentation?

3. Include a sketch of your force instrument.

4. Provide a summary of your testing procedures and any difficulties encountered and how you overcame them.

5. Provide your data from your force testing organized in a neat, easy to read data table. Remember, the number of figures in your data should reflect the precision of your measuring device (significant figures). If figures in your data table are averages from a number of trials, be sure to indicate the number of trials.

6. Discuss your data. Do you believe that your data is accurate? Do any trends stand out? What did you learn from your force measurements? Which fan/motor/power worked best? Did you have any problems taking your data?

7. Conclusion. What motor/propeller combination would you recommend to Power Dynamics Corp.? IS there a clear choice? Include any final thoughts here as well.

PreK-12 ENGINEERING

Activity Evaluation Form www.k12engineering.org

Activity Name: ____

Grade Level the Activity was implemented at:__________

Was this Activity effective at this grade level (if so, why, and if not, why not)**?**

What were the Activity's strong points?

What were its weak points?

Was the suggested Time Required sufficient (if not, which aspects of the Activity took shorter or longer than expected)**?**

Was the supposed Cost accurate (if not, what were some factors that contributed to either lower or higher costs)**?**

Do you think that the Activity sufficiently represented the listed MA Framework Standards (if not, do you have suggestions that might improve the Activity's relevance)**?**

Was the suggested Preparation sufficient in raising the students' initial familiarity with the Activity's topic (if not, do you have suggestions of steps that might be added here)**?**

If there were any attached Rubrics or Worksheets, were they effective (if not, do you have suggestions for their improvement)**?**

Please return to: CEEO
105 Anderson Hall
Tufts University
Medford, MA 02155