Robotics Engineering

DoDEA – Career and Technical Education

Simple and Compound Machines

Exercise 1a – Levers

Objective: At the completion of this exercise, you will demonstrate the effects of mechanical advantage regarding the use of levers. You'll build models of the different lever classes and then calculate, test, and verify the results of your lever machines.

Deliverables: *Copy and paste the required deliverables to another document for submission. All deliverables must be word processed with the required student ID information in the footer of the document. The header of the document should contain the title of the assignment. Both the question and answer must be included in the deliverable with the answers highlighted. All work must be complete and accurate to receive credit.*

1. Detailed definitions for each of the terms found in the Nomenclature section.
2. Detailed answers to the queries listed in the Questions section.
3. Completed table from the Materials Lab.

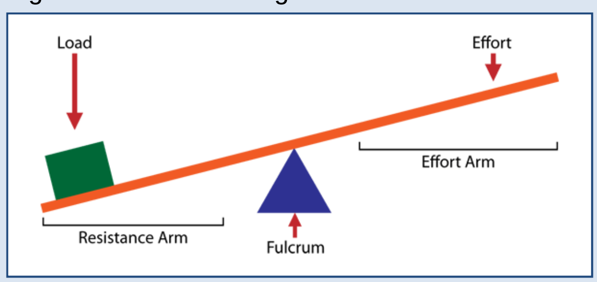
Information: Archimedes of Syracuse was a Greek astronomer, mathematician, physicist, engineer and inventor. He lived during the Classical Period between 287 BC and 212 BC. He is regarded as one of the leading scientists of the ancient Greco-Roman world focusing much of his work upon the machines of warfare. In fact, he was killed during a siege on his hometown. His greatest achievement in physics is probably his explanation of the mathematical principles of the lever. He once said, "Give me a lever long enough, and a prop strong enough, I can single-handed move the world." The lever is the simplest of the simple machines. However, knowing how a lever works reveals the principles of how other simple machines reduce effort and… Isn't that the reason why we build machines to begin with?

The Math:

Terms - W = Work F = Force d = Distance MA = Mechanical Advantage

Equations - W = Fd Load x d_1 = Effort x d_2 MA = length of effort arm / length of load arm

*We define work as applying force to move an object through to a distance. Mathematically, we can express this as **Work = Force x Distance** or… **W = Fd**. For instance: If a stack of books weighs 18 pounds and we lift them from the floor 3 feet up to a shelf, we will have performed 54 foot-pounds of work (54 ft-lb = 18 lb x 3 ft). This is also true when using a lever. When force is applied to the Effort Arm, the Resistance Arm will lift the Load a specific distance. The amount of Work performed is the product of the weight of the Load and the distance the Load is lifted.*



*In physics and engineering, mechanical advantage (**MA**) is the factor by which a machine multiplies the force put into it. One reason we invent machines is to multiply force (or make work easier). The mechanical advantage of a lever can be calculated using the equation **MA = length of Effort Arm / length of Resistance Arm**. However, to determine the amount of Effort required to lift the Load, we will have to incorporate this equation into the ratio **Load × d_1 = Effort × d_2**, where **d_1** represents the length of the Effort Arm and **d_2** represents the length of the Resistance Arm. Algebraically manipulating the equation will allow the solution of any single term in the equation.*

Research Resources: *The WWW changes all the time. If the listed links do not work, first inform your instructor then use a search engine to research information regarding the described subject.*

Web Site	Description
http://iqa.evergreenps.org/science/phy_science/ma.html	Math for all simple machines
http://www.enchantedlearning.com/physics/machines/Levers.shtml	Explains different classes of levers and how they work
http://www.cosi.org/files/Flash/simpMach/sm1.html	Describes levers and how they multiply force
http://ronleigh.com/ivytech/_ref-levers.htm	Applies math to levers with sample problems
http://www.vernier.com/products/sensors/force-sensors/dfs-bta/	Vernier Dual-Range Force Sensor information

Nomenclature: *Research and develop a detailed (two to three sentences) definition for each of these terms. It's important to realize that many words have multiple definitions. Some of which may have nothing to do with this course of study. Make sure your definitions fall within the context of this lesson.*

- *Work*
- *Force*
- *Load*
- *Lever*
- *Distance*
- *Resistance*
- *Pivot*
- *Newton*
- *Effort*
- *Fulcrum*
- *Foot-Pound*
- *Mechanical Advantage*
- *Levers of the 1st Class*
- *Levers of the 2nd Class*
- *Levers of the 3rd Class*

Questions:

1. Research and develop a detailed definition for each of the terms found in the Nomenclature section of this document.
2. You and a friend come upon a teeter-totter in a neighborhood playground. You weigh 135 lbs and your friend weighs 220 lbs. Determine how you would have to change the location of the pivoting point so that the teeter-totter is balanced with both of you on it. Show the math.
3. You're helping your neighbor move 16 bags of concrete from the floor to the top of a workbench in his garage. Each bag weighs 25 Kg and the surface of workbench is 1 M off the floor. You neighbor had already stacked half the bags. How much "Work" did you perform? Show the math.
4. Create a table listing several examples of tools that fall into each of the three classes of levers.
5. What were the circumstances of Archimedes' death? What were his last words?

Procedure: *In this activity, you'll closely examine the mechanical advantage inherent to the lever. You'll build a study model of a lever and then use lab equipment to measure the multiplied force of the simple machine. Finally, you'll load your measurements into a Excel mathematical model to compare and contrast the results between the measured and calculated values.*

Required Materials and Equipment: *Get these materials and tools from your instructor.*

Lego NXT Mindstorms Kit   Vernier Dual-Range Force Sensor   Ring Stand or Other Support   Rubber Band

Figure 1. Lever Model

Steps: *Complete each of the following steps in the assigned order:*

1. ( ) Build a model of a lever similar to the one shown in Figure 1.
2. ( ) Setup the test apparatus as shown in Figure 2. For reliable readings, insure that the connected components are tight and stable. The rubber band applies a relatively constant force to the Effort end of the lever. The Load end of the lever is situated pressing up against the rubber cap of the Force Sensor. More detailed photos are available on the website.
3. ( ) Connect the Force Sensor to the NXT Intelligent Brick using the NXT adapter and can cable. You'll also have to connect the Brick to the USB port of the computer. *Note: You may have to download and install the Vernier NXT drivers using the Block Import/Export feature found in the Tools tab of the NXT Programming program.*
4. ( ) Launch the NXT Data Logging program and turn on the brick. Start a New Experiment, Select the Vernier Force Sensor 50 Newtons and the connected port (You may want to name the experiment.).
5. ( ) Start with lever's fulcrum in the center of the bar. With the rubber band pressing down on the Effort end of the lever, click the green "download and run" button in the data logging software.
6. ( ) Move the fulcrum to the 4th hole on the Load end of the bar, setup the test apparatus and click the "download and run" button to record the results.
7. ( ) Move the fulcrum to the 2nd hole on the Load end of the bar, setup the test apparatus and again click the "download and run" button to record the results.
8. ( ) Record your results in the Levers Excel spreadsheet and analyze the graphic model comparing calculated data to your measurements.
9. ( ) Use the course's website and the parts found in your NXT Mindstorms kit to build models of a <u>wheelbarrow</u> and <u>pliers</u> study models. Experiment by moving the load closer to and further from the pivoting point of each machine. Discuss your observations regarding the amount of effort required to operate the model with the instructor.
10. ( ) Disassemble and properly store your materials and tools.

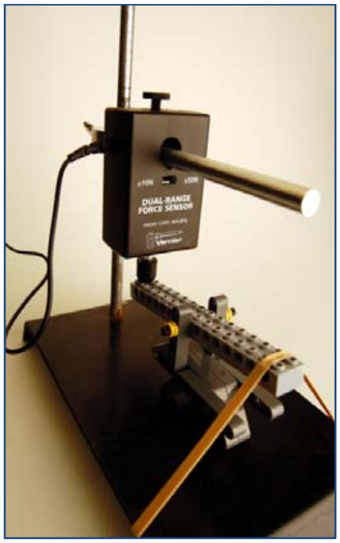


Figure 2. Lever Test Apparatus

Conclusion: In completing this exercise you built models of 1st, 2nd, and 3rd class levers. You used an electronic sensor to measure the amount of force generated with a 1st class lever depending on the position of the pivoting point (fulcrum). By recording your results into a spreadsheet, you used a mathematical model to graph the performance of your machine, and as a result, determined that when the load is closer to the fulcrum, the amount of effort required to lift the load is reduced by a proportion determined by the length of the Effort Arm as related to the Resistance Arm. Finally, you verified your results by "doing the math" and found that although the performance pattern was similar, measured results are seldom the same as the calculated results. Welcome to the real world.