EXERCISE 3

Simple machines: Levers

Objectives: In the present laboratory exercise students will build and experiment with three types of levers. They will see how they work and how they make lifting objects easier. Moreover, the students will measure the mechanical advantage for every type of lever.

Theoretical background

Before giving definitions about simple machines, it is useful to see how can we understand a force and the work done by a force. We think a force as a pull or a push that causes an object to move or change its speed, if it is already moving. For example, when we push on a door to open, we are applying force to the door to move. To provide information about a force we have to know the amount of a force and its direction.
Work is the amount of energy required by a force to move an object a certain distance between two positions. The work is considered positive when the direction of the object's motion is the same with the direction of the force. An example of this case is the free fall of an object where the object's weight is in the same direction with the object's motion. On the other hand, the work is considered negative when the direction of motion is opposite to the force applied on the object. An example of this case is the friction force when it is exerted on an object as it is in motion. In this case, the direction of object's motion is opposite to the direction of the friction force.

Simple machines are devices that make physical work easier to do by decreasing the amount of *force* or changing the direction of *force* required to do *work*. There are six types of simple machines: (i) The lever, (ii) the wheel and axle, (iii) the pulley, (iv) the inclined plane, (v) the wedge, and (vi) the screw. But as a general rule in simple machines remember: *Any force that is saved by using a simple machine must be accounted for in terms of distance.* The amount a simple machine makes work easier is called *Mechanical Advantage (MA)*. We'll refer later on the (MA) after the presentation of levers categories.

Levers are rigid rods that pivot on a point called the fulcrum. A load at one point on the rod can be balanced by applying a force (effort) to another point of the rod. If the distance of the effort force from the fulcrum is greater than the distance of the load from the fulcrum, then a smaller force can move a larger load. This is how the lever makes work easier. There are three types of levers which are shown in the figure 1 below.

In lever of *class 1*, the fulcrum is between the effort force and the load force. Both forces have the same direction, downwards. Note that the load force is always downwards, due to the gravitational attraction. In lever of *class 2*, the load force is between the fulcrum and the effort force. The effort force is directed upward, opposite to the load force and always is smaller than the load force if the rod is in balance. In lever of *class 3*, the effort force is between the load force and the fulcrum. The effort force is upward, as in lever of class 2, but always larger than the load force, if the rod is in balance.

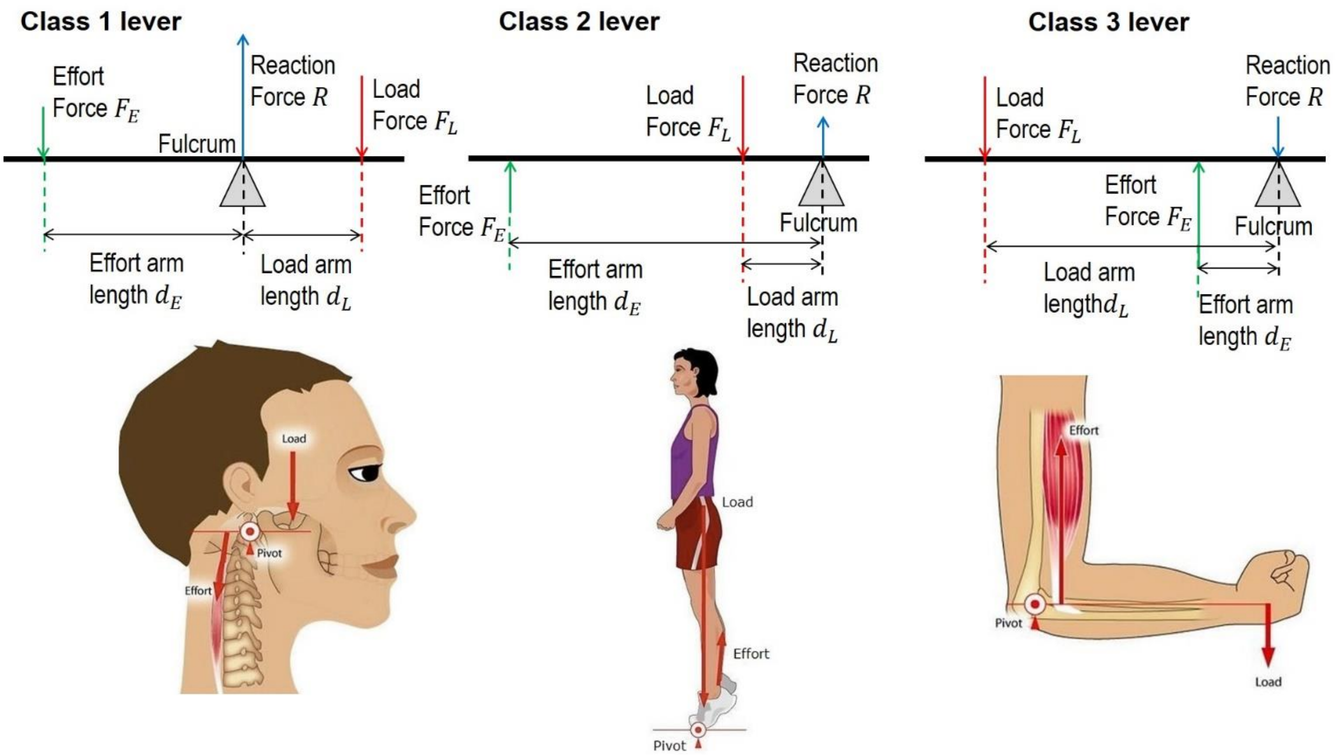


Figure 1: The types of levers, and examples of the levers the human body uses. The length of the effort force has such length so that the body or the part of the body to be in balance.

The balance of the rigid rod for all classes of levers is explained by the equilibrium laws:

a) The total force exerted on the rod is zero, and
b) The total torque on the rod relative to the fulcrum is also zero.

If we use the symbols F_L, F_E, d_L, and d_E for the quantities of the load force, effort force, load arm length, and effort arm length, then for each class of levers we have:

$$R - F_L - F_E = 0 \qquad \text{lever class 1} \tag{1}$$

$$R - F_L + F_E = 0 \qquad \text{lever class 2} \tag{2}$$

$$-R - F_L + F_E = 0 \qquad \text{lever class 3} \tag{3}$$

and for all classes of levers,

$$F_L d_L = F_E d_E \tag{4}$$

A simple machine makes work easier by multiplying the effort force applied to the machine. The multiplication factor is called mechanical advantage of the machine. The mechanical advantage, (MA), is defined as the ratio of the load force over the effort force,

$$(MA) = \frac{\text{Load force}}{\text{Effort force}} = \frac{F_L}{F_E} \quad (5)$$

If the mechanical advantage and the total length L of the rod are known, then we are able to determine the load arm and effort arm lengths. In this way, we can obtain the locations of the load and effort forces from equations (4), (5) and from $d_L + d_E = L$. Alternatively, if we measure the load and effort forces, we can find the mechanical advantage using equation (5). In addition, from equation (4) we can find the ratio of load arm to the effort arm lengths, and if we know the total length of the rod, we can also obtain the positions of the load and effort forces on the rod.

Experimental – Data analysis

The equipment needed to build the lever are shown in figure 1 below:

1. Two (2) 11-hole rods
2. Two (2) 15-hole dual rod
3. Two (2) large frames
4. One (1) 5X13 dual frame
5. Two (2) square frames
6. Two (2) 3-hole dual rod
7. A spring scale
8. One (1) 3-hole cross rod
9. Two (2) 7-hole flat rounded rod
10. One (1) piece of string
11. One (1) small gear
12. Six (6) short anchor pins of green color
13.One (1) anchor pin lever
14. Three (3) joint pins of blue color
15. Eight (8) anchor pins of red color
16. One (1) 7 centimeters long axle
17. One (1) plastic bottle

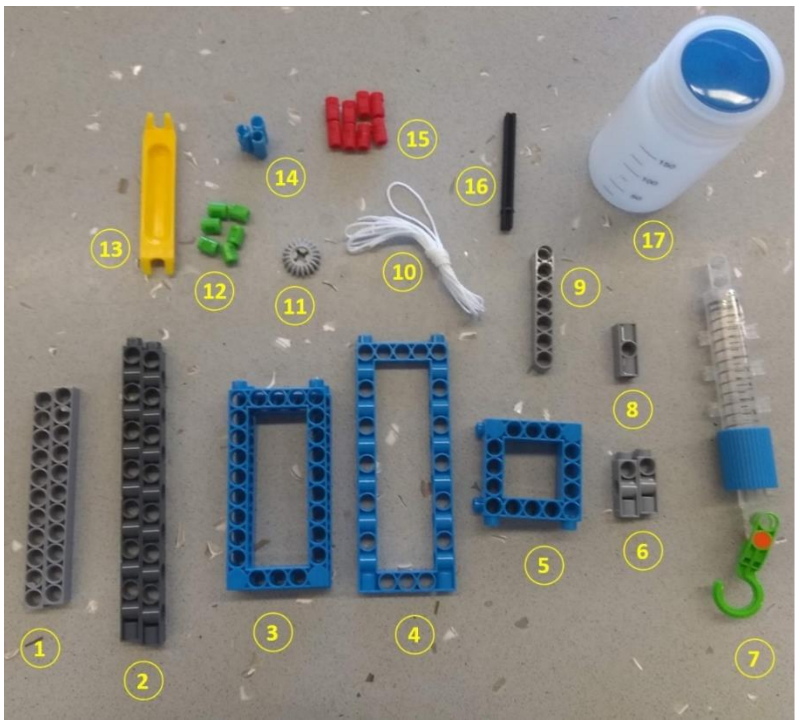


Figure 1: The equipment needed for the building of a lever

Using all of the materials above we build a class 1 lever first, according to the figures 2, 3, and 4 below. In figure 2, it is shown how to build the axle of the lever. This is the first module you will build.

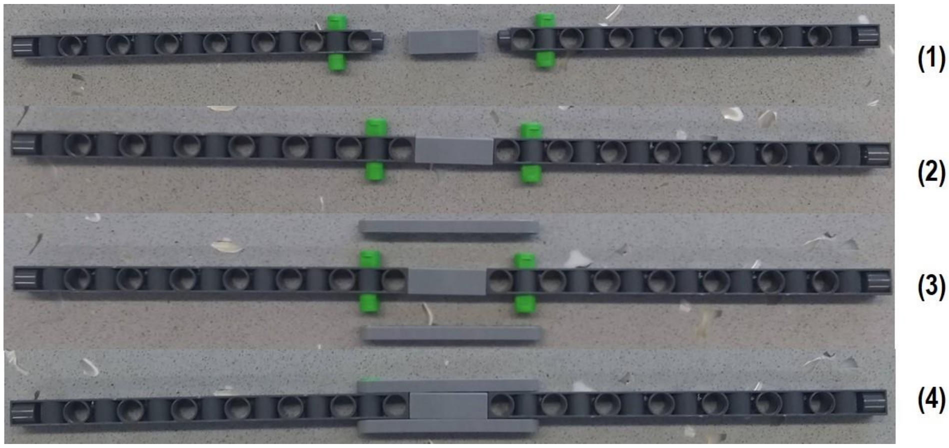


Figure 2: Build the axle shown in step (4) in the present figure, starting from the step (1), then the step (2), then the step (3), and finally the step (4).

The second module you are going to build is the support of the plastic bottle. A string is also used to hook the load over the load arm. Follow the steps in figure 3 below to build the support of the bottle.

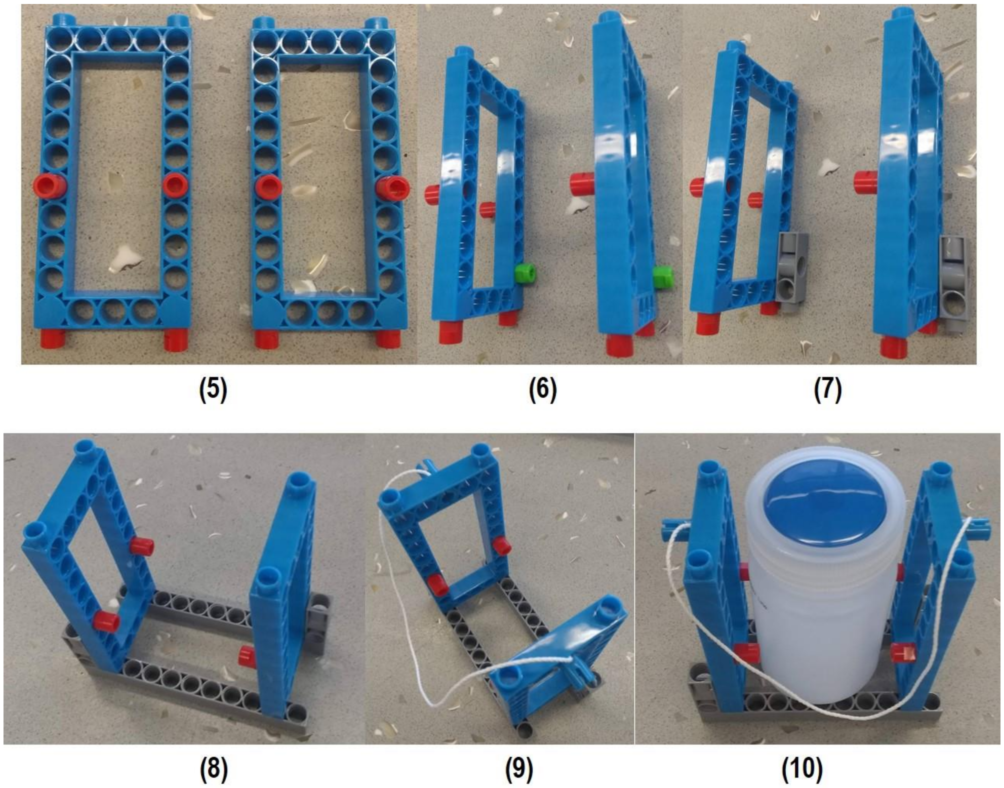
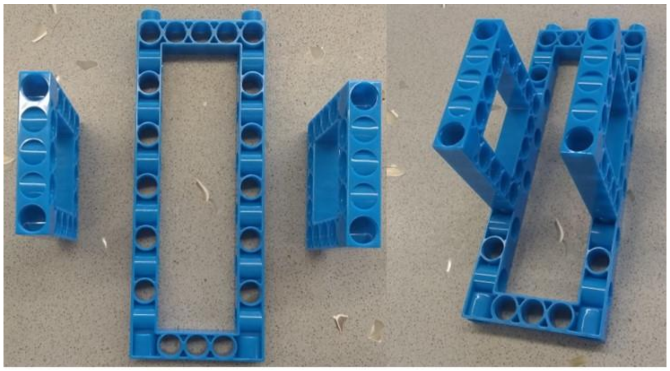


Figure 3: Steps for the building of the bottle’s support.

The third module you'll build is the fulcrum. Follow the steps (11), (12) shown in the figure 4.



(11) (12)

Figure 4: The fulcrum of the lever

Combine the three modules above to build a class1 lever, as shown in the figure 5.

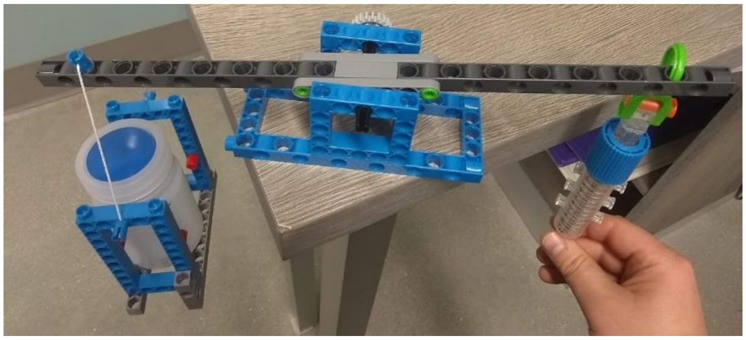


Figure 5: A class 1 lever.

Measurements using the class 1 lever

1) Fill the bottle with water and put it in the basket. This is called the load.

2) Weigh the load with the spring scale.

3) Register the load force on the worksheet at the end of the exercise.

4) Position the model on the corner of the table. One of your classmates holds the blue base of the model.

5) Hook the load over the joint pin on the load arm.

6) Hook the spring scale through each of the holes in the effort arm, starting with the outermost hole.

7) Pull down the scale so that the axle of the lever to be in balance.

8) Read the spring scale.

9) Find the mechanical advantage.

10) Register the result on the worksheet.

11) Repeat the steps 6) to 10) for the remaining holes in the effort arm.

The class 1 lever can be converted into a class 2 lever by changing the location of the fulcrum and joint pin. Hook the load as in figure 6. The load force is applied on the rod at a position between the fulcrum and the effort force.

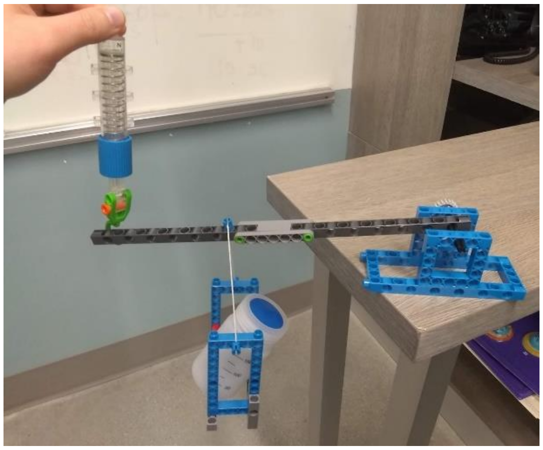


Figure 6: A class 2 lever.

Measurements using the class 2 lever

1) Position the model on the corner of the table. One of your classmates holds the blue base of the model.

2) Hook the load over the joint pin on the load arm, see figure 6.

3) Hook the spring scale through each of the holes in the effort arm, on the left of the load, starting with the outermost hole.

4) Pull up the scale so that the axle of the lever to be in balance.

5) Read the spring scale.

6) Register the reading on the worksheet.

7) Find the mechanical advantage.

8) Register the result on the worksheet.

9) Repeat the steps 3) to 8) for the remaining holes in the effort arm, the part of the lever on the left to the load.

The class 2 lever can easily be converted to a class 3 lever by changing the location of the joint pin, as shown in figure 7.
In the class 3 lever, the effort force is between the fulcrum and the load force.

Measurements using the class 3 lever

1) Position the model on the corner of the table. One of your classmates holds the blue base of the model.
2) Hook the load over the joint pin on the load arm, see figure 7.

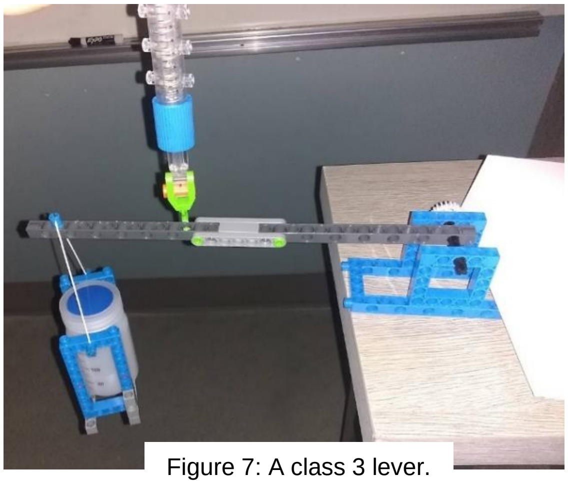


Figure 7: A class 3 lever.

3) Hook the spring scale through each of the holes in the effort arm, the holes between the load and the fulcrum, starting with the hole closer to the load.

4) Pull up the scale so that the axle of the lever to be in balance.

5) Read the spring scale.

6) Register the reading on the worksheet.

7) Find the mechanical advantage.

8) Register the result on the worksheet.

9) Repeat the steps 3) to 8) for the remaining holes in the effort arm, the holes between the load and the fulcrum.

Questions

Answer to the following questions:

1) What is the maximum mechanical advantage for the class 1 lever? Assume fixed the load position.

2) What is the maximum mechanical advantage for the class 2 lever? Assume fixed the load position.

3) What is the maximum mechanical advantage for the class 3 lever? Assume fixed the load position.

4) Prove that the mechanical advantage is the ratio of the effort arm length over the load arm length.

Discussion and general comments

In the last section of your report, you describe briefly the task(s) of this laboratory session. Then you have to write comments on what you measured and how the theory is compared to the data. As an option, you may also write some thoughts for the improvement of the accuracy of the measurements.

Simple machines: Levers

Student's worksheet – Lab 3

Student's name: ______________________________ Grade: _________ Date: __________

Lab partner(s): ____

Class 1 lever

Load force (in Newtons) = N

Effort force (N)						
Mechanical Advantage (MA)						

Class 2 lever

Load force (in Newtons) = N

Effort force (N)						
Mechanical Advantage (MA)						

Class 3 lever

Load force (in Newtons) = N

Effort force (N)						
Mechanical Advantage (MA)						