# Simple Machines

## Objectives

After performing this lab you should be able to (1) determine the mechanical advantage (MA) for three types of simple machines (inclined plane, lever, and pulley) and (2) determine how simple machines can be used to solve practical problems.

## Materials

1. 1-meter stick
2. Hall's carriage
3. Hooked mass set
4. Inclined plane
5. Pulley (double) (2)
6. Pulley (single) (2)
7. Spring scale (one each: blue, brown, yellow)
8. String and scissors
9. Table clamp and rod
10. Three-hole bracket clamp

## Background Information

Simple machines are commonly used to gain a force advantage in lifting heavy objects. In such a case the advantage gained is represented by the mechanical advantage,

$$\text{MA} = \frac{\text{weight lifted}}{\text{force required}}. \tag{1}$$

You don't get something for nothing; besides the relationship of MA to force required, there is a relationship between MA and the distance over which you apply the force. Ideally,

$$\text{MA} = \frac{\text{distance you push (or pull)}}{\text{distance the weight is lifted}}, \tag{2}$$

or even though you may use a smaller force to lift, you may have to push/pull over a longer distance when you use a MA $> 1$.

In some cases we have MA $< 1$, which we call a "force disadvantage". This is acceptable sometimes in order to get an increased range of movement of the "load".

We will consider in this experiment three machines that have been used for centuries.

# Procedure

## Part 1: Inclined Plane

### Problem

Suppose you have a 600-lb freezer that you wish to load onto a truck by rolling it up a ramp (see Figure 1). [Q1] With how many pounds of force must you push or pull the freezer if the ramp is at 10°? [Q2] ... 20°? You should be able to answer this question by first experimenting with adjustable incline, the cart, weights, and scales provided.

Caution: In the metric system force is measured in newtons (N). One kilogram (kg) weighs 9.8 N. Therefore, 100 g weighs 0.98 N. Note that mechanical advantage has units of force/force and is, therefore, dimensionless—i.e., without units. It does not matter what unit you use for force as long as you use the same units in the numerator and denominator.

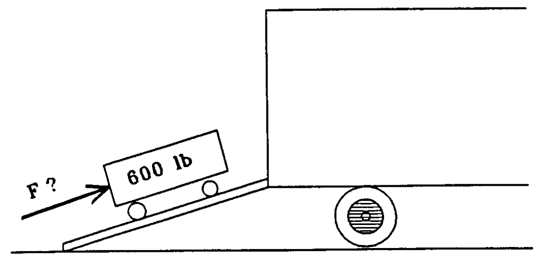



**Figure 1:** *Inclined plane*

## Part 2: Lever

### Problem 1

[D1] How can a 200-lb man use a strong bar to lift a 500-lb object? (Assume that he can exert a force equal to his own weight.) Answer this question by first experimenting with the meter stick and the weights provided. Start with the arrangement shown in Figure 2 with the meter stick supported at its center and with the 200 g (representing the man) hanging 30 cm from the support. [Q3] How far from the support can you put the "load" and have the stick balance?

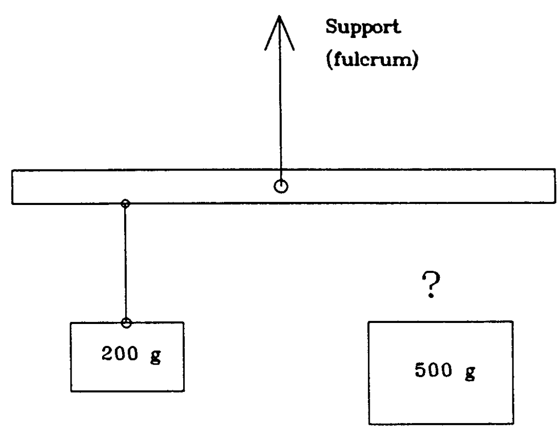
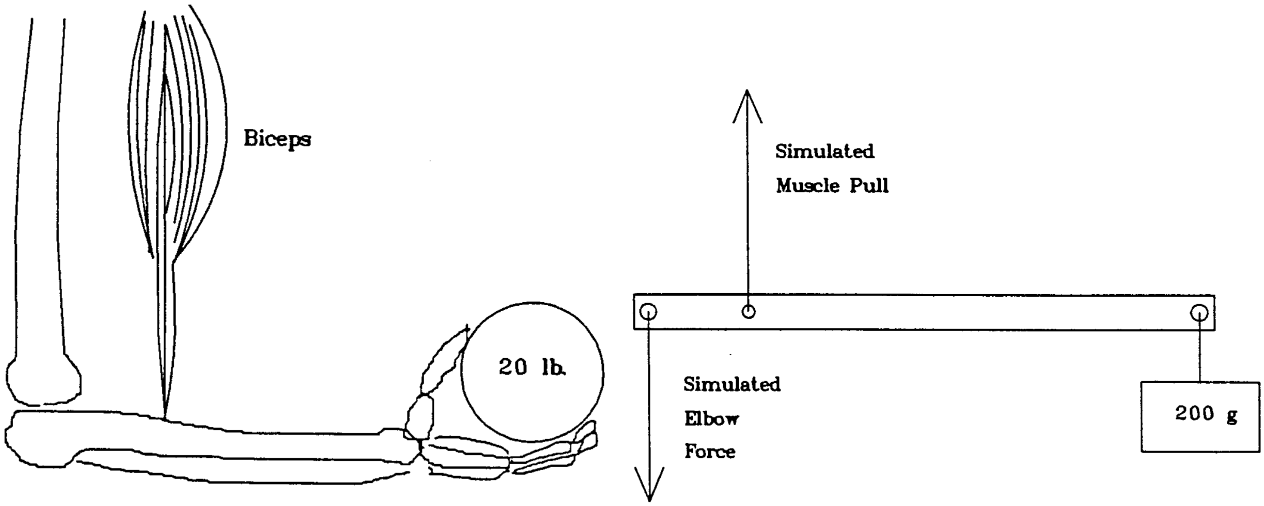



**Figure 2:** *Lever*

Relate the ratio of the two distances from the fulcrum (point of support on which the lever turns) to the MA. **Sketch a diagram showing how the man will lift a 500-lb object.**

### Problem 2

[Q4] Suppose your upper arm is vertical and your forearm is horizontal while there is a 20-lb object in your hand (see Figure 3a). What upward force is your biceps muscle exerting on the tendon that connects it to the bone of your forearm?




(a) The bicep (b) A lever

**Figure 3:** *Modeling the bicept as a lever*

You will need to make some measurements on your arm, and you will need to experiment with the type of lever with the fulcrum at one end. The arrangement shown in Figure 3b may be helpful. For example, you may want to let 200 g represent the 20-lb in the hand.

Relate the MA, which in this case is less than 1, to the ratio of the distances from the fulcrum (elbow) to the muscle pull and to the load. The weight of the meter stick and the weight of your forearm are added complications. As a first approximation, you may wish to assume these to be negligible. There will also be other fairly crude estimates here. [D2] What is your best estimate of the force your biceps must exert?

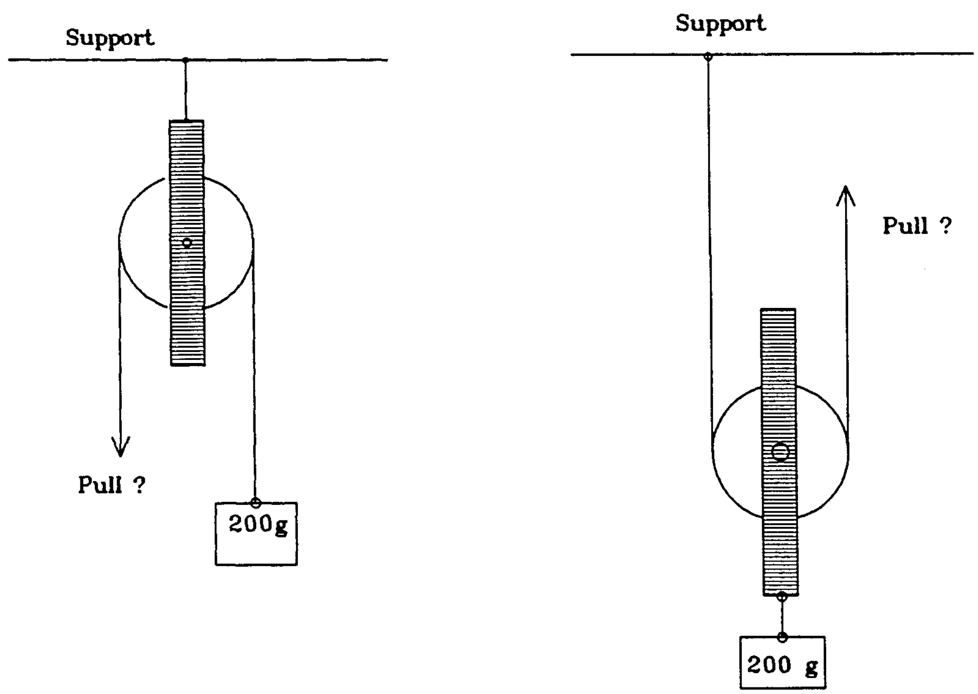
## Part 3: Pulleys

### Problem

How can a 120-lb woman lift a 300-lb load by using a pulley system? Discuss which of the following pulley systems she could use, assuming that the maximum force she can generate is her weight.

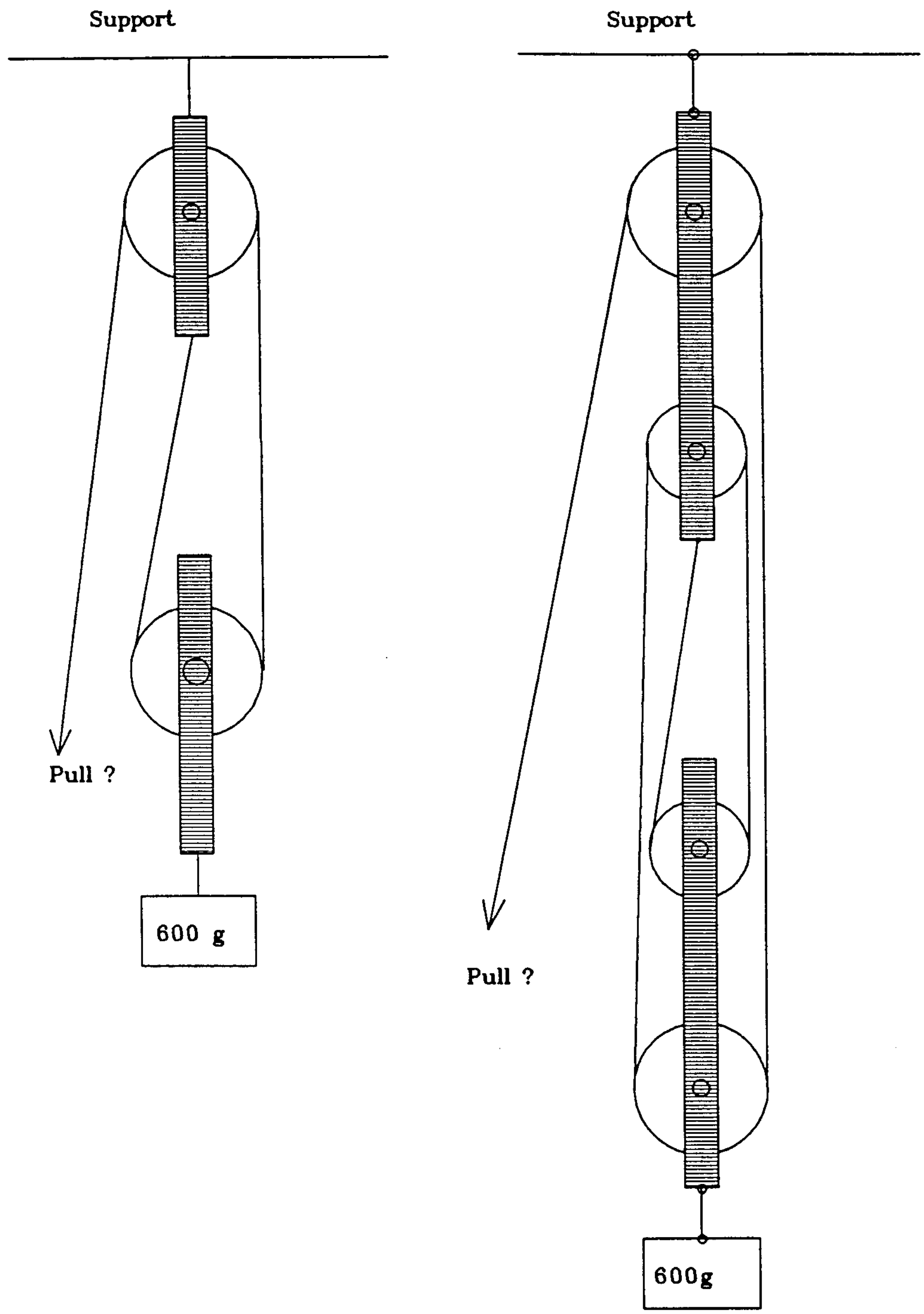
Begin by experimenting with single pulleys (see Figure 4). (Even though they may be attached to other pulleys, just use one for now.) Then move on to more complicated systems such as those show in Figure 5. Note that the two pulleys in Figure 5a cannot be in the same pulley-support frame—i.e., they must be able to move independently.

[D3] Does the MA relate to the number of pulleys? ... to the number of supporting ropes? ... to other properties? [D4] What is the mechanical advantage for each of the systems shown? [D5] Which could the woman use in lifting the 300-lb load? In each case how hard must she pull on the rope? [D6] Give some examples of use of simple machines in everyday life.




(a) (b)

**Figure 4:** *Single pullies*




(a) (b)

**Figure 5:** *Multiple pullies*