SIMPLE MACHINES, BALANCE BEAM

RST-LAB-001 Rev D

ROCKET SCIENCE TUTORS

NOTE: Student groups of 3 or 4 needed for this lab

A) OBJECTIVE

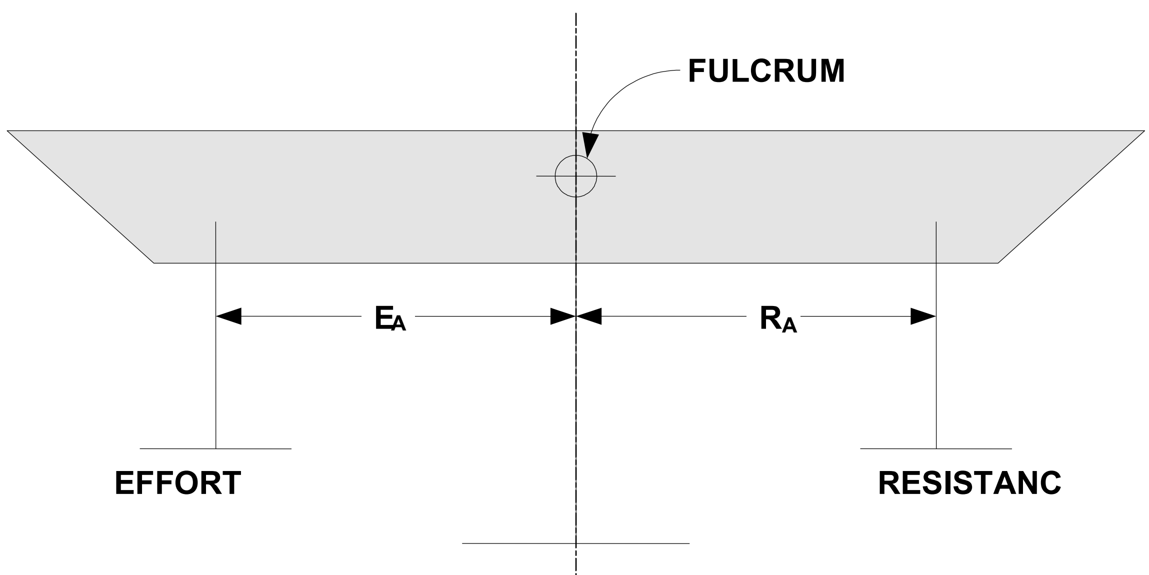
Observe and measure the operation of a First Class Lever as a Balance Beam. Determine the effect of the Mechanical Advantage (MA) and investigate the relationship between distance from the **FULCRUM** and the force needed to attain balance.

B) BACKGROUND

A Simple Machine is a device that performs work by converting forces and distances.
This exercise explores the operation of a type Simple Machine called the Balance Beam which is a *First Class* lever because the **FULCRUM** is located between the **RESISTANCE** and the **EFFORT**.

The **Mechanical Advantage (MA)** of a lever can be calculated as:

$$MA = E_A \text{ (Effort Arm length)} / R_A \text{ (Resistance Arm length)}$$



SHEET 1

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C) PROCEDURE, PART 1: FORCE TO ATTAIN BALANCE

1. Construct the Balance Beam per instructions. Identify the Fulcrum (**F**), Effort Tray (**E**) and Resistance Tray (**R**).

2. Move the **EFFORT** tray exactly **6"** from the **FULCRUM**. Move the **RESISTANCE** tray exactly **4"** from the **FULCRUM.** Attach the force gage to the yellow node on the **EFFORT** ARM approximately 4" from the **FULCRUM** and measure the force needed to attain balance. **NOTE: Make all force measurements from this same point.** Record this value in the Data Table. Place additional nuts on the **RESISTANCE** tray to attain balance. Record this number in Section D) DATA and calculate the Mechanical Advantage per the formula:

$$\textbf{MA} = E_A \textbf{ (Effort Arm length) / } R_A \textbf{ (Resistance Arm length)}$$

3. Remove all nuts from the **RESISTANCE** tray. Move the **EFFORT** tray exactly **8"** from the **FULCRUM**. Keep the **RESISTANCE** tray exactly **4"** from the FULCRUM. ***Using the force gauge at the same location as in Step 2,*** measure the force required to attain balance. Record this value in the D) DATA. Place nuts on the **RESISTANCE** tray to attain balance. Record the number of nuts required in Section D) DATA and calculate the Mechanical Advantage per the formula shown in Step 1.

   While still balanced, move the **RESISTANCE** tray to the lowest point it can be lowered (have someone hold it there) and measure the vertical distance from this point to the point at which it was balanced and record in Section D) DATA. When the **RESISTANCE** tray is at its lowest point, measure the vertical distance of the **EFFORT** tray above the balance point and record in Section D) DATA.

4. Remove all nuts from the **RESISTANCE** tray. Move the **EFFORT** tray exactly **9"** from the **FULCRUM**. Move the **RESISTANCE** tray exactly **3"** from the **FULCRUM**. ***Using the force gauge at the same location as in Step 2,*** measure the force required to attain balance. Record this value in the Data Table. Place nuts on the **RESISTANCE** tray to attain balance. Record this number in Section D) DATA and calculate the Mechanical Advantage per the formula shown in Step 1.

When still balanced, move the **RESISTANCE** tray to the lowest point it can be lowered (have someone hold it there) and measure the vertical distance from this point to the point at which it was balanced and record in Section D) DATA. When the **RESISTANCE** is at its lowest point measure the vertical distance of the **EFFORT** above the balance point and record in Section D) DATA.

5. Remove all nuts from the **RESISTANCE** tray. Move the **EFFORT** tray exactly **8"** from the **FULCRUM**. Move the **RESISTANCE** tray exactly **4"** from the **FULCRM.** ***Using the force gauge at the same location as in Step 2,*** measure the force required to attain balance. Record this value in the Data Table. Place nuts on the **RESISTANCE** tray to attain balance. Record this number in Section D) DATA and calculate the Mechanical Advantage per the formula.
When still balanced, move the resistance tray to the lowest point it can be lowered (have someone hold it there) and measure the vertical distance from this point to the point at which it was balanced and record in Section D) DATA. When the **RESISTANCE** tray is at its lowest point measure the vertical distance of the **EFFORT** tray above the balance point and record in Section D) DATA.

6. Move the **EFFORT** tray exactly **8"** from the **FULCRUM**. Move the **RESISTANCE** tray exactly **8"** from the **FULCRUM**. Using the force gauge, measure the force required to attain balance. Record this value in D) DATA. Place nuts on the **RESISTANCE** tray to attain balance. Record this number in Section D) DATA and calculate the Mechanical Advantage per the formula shown in Step 1.
While balanced, lower the **RESISTANCE** tray to its lowest point (have someone hold it there) and measure the vertical distance from this point to the point at which it was balanced and record in Section D) DATA. When the **RESISTANCE** tray is at its lowest point measure the vertical distance of the **EFFORT** tray above the balance point and record in Section D) DATA.

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D) DATA

STEP	EFFORT ARM E_A(length)	RESISTANCE ARM R_A (length)	RESISTANCE Force to Balance	Mechanical Advantage $MA = E_A / R_A$	EFFORT Force (Nuts) to balance	Distance Moved Up (+) by RES	Distance Moved Down (-) by EFFORT
2							
3							
4							
5							
6							

E) QUESTIONS

1) What happens as the **RESISTANCE** tray is moved closer to the fulcrum? How can this be explained?

2) How does this relate to the definition of a Simple Machine?

3) Looking at the graph, what can be said about the relationship between the Mechanical Advantage and the force (number of nuts) needed to balance?

F) CALCULATIONS

Using graph paper, plot the Mechanical Advantage (MA) (x axis) versus the number of nuts to attain balance (y axis). What do you see?

G) DESIGN CHALLENGE

H) GLOSSARY

- **EFFORT ARM: The side of the lever where the force (Effort Force) is applied (ie where the lever is pushed)**
- **EFFORT FORCE: The total weight of the nuts in the EFFORT tray.**
- **THIRD CLASS LEVER: A lever arranged with the EFFORT between the FULCRUM and the RESISTANCE.**
- **FULCRUM: The point on the lever about which the lever pivots**
- **MECHANICAL ADVANTAGE: The number of times a Simple Machine multiplies the Effort Force. MA = E_A/R_A**
- **RESISTANCE ARM: The side of the lever that has the load (Resistance Force; the object to be moved)**
- **RESISTANCE FORCE: The total weight of the nuts in the RESISTANCE tray**
- **SIMPLE MACHINE: A device that converts Forces and Distances**
- **WORK: The product of (Force in the direction of motion) x (Distance Moved). This term was coined in 1826 by the French Mathematician Coriolis.**

I) UNDERSTANDING

- **SIMPLE MACHINES** convert (trade) **FORCES** and **DISTANCES**
- **LEVERS** are one type of **SIMPLE MACHINE;** a **BALANCE BEAM** is a **FIRST CLASS LEVER**
- **FIRST CLASS LEVERS have the FULCRUM located between the EFFORT and the RESISTANCE**
- The **MECHANICAL ADVANTAGE** is the **RATIO** of the **EFFORT ARM** to the **RESISTANCE ARM**
- The **MECHANICAL ADVANTAGE** (ratio) tells you the factor by which the **FORCES** and **DISTANCES** are converted
- If the **RESISTANCE ARM** is ***shorter*** , the **WORK** is easier **(MECHANICAL ADVANTAGE > 1)**
- If the **EFFORT ARM** is shorter, the **WORK** is harder **(MECHANICAL ADVANTAGE)**
- **WORK** is the product of **(FORCE in the direction of Motion) x (DISTANCE moved)**
- **WORK IN = WORK OUT**