Moments and Mechanical Advantage

Needed Supplies: Pressure gauge, ruler

Instructions: Now that you know how cylinders produce force, we will investigate how that force is delivered through the arms of the excavator.

Background
- **Moment**
  - Moments occur when a force is applied to a point from a distance.
  
  $M = F \times D$
  
  - $M$ is the moment (in – lbf)
  - $F$ is the force (lbf)
  - $D$ is the distance at which the force is applied (in)
  
- The moment that $F_{in}$ creates on the diagram above is:
  
  $M = (F_{in}) \times (D_{in})$
  
- The moment that $F_{out}$ creates on the diagram above is:
- \( M = (\text{Fout}) \times (\text{Dout}) \)
  - Since \( \text{Fin} \) and \( \text{Fout} \) moments act upon the same point (the red triangle), they are equal:
    - \( (\text{Fin}) \times (\text{Din}) = (\text{Fout}) \times (\text{Dout}) \)
  - Knowing this, if you apply a force to the lever, \( \text{Fin} \), you will produce another force \( \text{Fout} \), that is equal to:
    - \( \text{Fout} = \frac{[(\text{Fin}) \times (\text{Din})]}{(\text{Dout})} \)

- **Mechanical Advantage**
  - Mechanical advantage is the ratio of the output force (\( \text{Fout} \)) to the input force (\( \text{Fin} \)).
  - \( \text{MechAdv} = \frac{\text{Fout}}{\text{Fin}} \)

- **Moments and Mechanical Advantage on the excavator**
  - The excavator uses the principles of moments and mechanical advantage to do work, with the cylinders providing the force.
  - In the picture below, the top cylinder is extending:

**Experiment**

- Determine the force produced by the top cylinder when it extends
  - Attach pressure gauge at appropriate port
- Move the valve that extends the top cylinder, and record the pressure at the gauge
  - P = _________ psi
  - Ac = .88 in²
  - Fin = PAc = (_______ psi)(_______ in²)
  - Fin = _______ lbf

- Measure Din and Dout on the excavator arm
  - Din = ________ in
  - Dout = ________ in

- What is Fout equal to?
  - Fout = [(Fin) x (Din)] / (Dout) = __________
  - Fout = _________ lbf

- What is the mechanical advantage of the excavator arm?
  - MechAdv = Fout / Fin = ________
  - MechAdv = ________

**Discussion**
- Is the mechanical advantage different when retracting the cylinder? Explain your answer.
- What would happen to Fout and the MechAdv if Din were decreased?
- Compare the distances that each end of the excavator arm travels. Which travels further when the cylinder extends, the cylinder end, or the bucket end?