

Math Skills Laboratory

MATH ACTIVITY

Solving “Force” Transformer Problems for Fluid Systems

MATH SKILLS LAB OBJECTIVES

When you complete these activities, you should be able to do the following:

1. Solve and interpret “force” transformer problems for fluid systems.
2. Relate ideal mechanical advantage to ratio of piston face areas (or diameters) on input and output sides of the transformer.
3. Relate actual mechanical advantage to ratio of forces (or pressures) on input and output sides of the transformer.

LEARNING PATH

1. Read the Math Skills Lab. Give particular attention to the Math Skills Lab Objectives.
2. Work the problems.

ACTIVITY

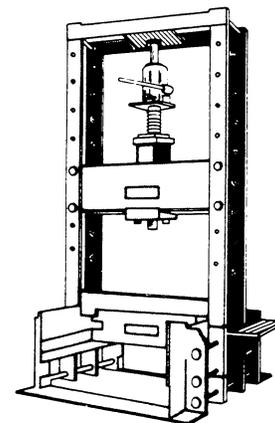
Solving “Force” Transformer Problems for Fluid Systems

In this lab, you’ll work problems that involve “force” transformers in fluid systems. The problems involve fluid pressure intensifiers, fluid jacks and cylinders.

To solve these problems, refer to the formulas in Table 7-4, “Force Transformer Formulas for a Hydraulic Jack,” and Table 7-5, “Force Transformer Formulas for a Pressure Booster.”

Problem 1: Given: Shop Press, Inc., makes presses like the one in this drawing. This press uses a hydraulic jack to apply force to parts that are being put together and taken apart. In fluid systems, pressure is constant throughout the volume containing the fluid. This means that “pressure input” equals “pressure output” in a hydraulic jack. The ideal mechanical advantage of a hydraulic jack can be stated as:

$$IMA = \frac{F_o}{F_i} = \frac{A_o}{A_i}$$



Shop press

(Suppose the input pump piston of the hydraulic jack shown in the drawing has a surface area of 1.77 in^2 .)

- Find:
- Surface area of the output piston face when a 50-pound input force causes the output piston of the jack to raise a 600-pound load.
 - The diameter of the output piston when a 50-pound input force moves a 600-pound load.
 - The distance the load moves if the input piston moves 12 inches, under the conditions of b.

Solution:

Problem 2: Given: Century Construction Company has several hydraulically operated earth-moving machines. Ron Brown works as a hydraulics technician for the company. He's been asked to modify the hydraulic system of one of the machines. He'll replace a small hydraulic cylinder with a larger one. The new cylinder has a usable output piston face area of 10 in^2 . The pump on this machine can provide 1500 psi of pressure in the fluid.

- Find:
- Maximum output force that can be exerted by the cylinder.
 - Output work done by the cylinder to move the cylinder rod out 1 ft against a load.
 - Input force supplied by the pump if the system's ideal mechanical advantage is 12.
 - Input work done by the pump (assuming there are no losses due to friction/resistance).

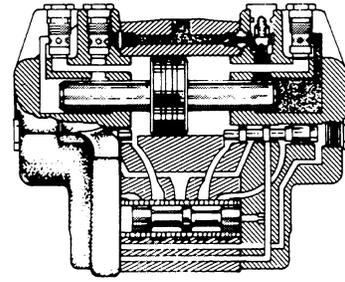
Solution:

Problem 3: Given: Carl Renschler is a machine repair technician for Harris Manufacturing. This company produces copper fittings. These fittings are used by plumbers and makers of heating and cooling equipment. Fitting ends are expanded so that tubes can be eased into the fittings and soldered into place. Fitting ends are expanded in a forming machine that's equipped with an air-to-water pressure booster. The pressure booster is usually operated at 125 psi air pressure. This produces a 20:1 ideal mechanical advantage.

- Find:
- The water pressure applied to the inside surface of the copper fitting.
 - The face area of the output piston if the input piston is 3 inches in diameter.

Solution:

Problem 4: Given: Kali-Alto Laboratories employs Kay Lewis as a standards lab technician. Part of Kay's job is to calibrate high-pressure hydraulic gages. An air-to-hydraulic pressure intensifier is used to pressurize the gages being tested and calibrated. The intensifier has a 3.5-inch-diameter input cylinder and a 0.5-inch-diameter output cylinder.



Intensifier

- Find:
- Maximum pressure available to test the gages if the air pressure is 100 psi.
 - Mechanical advantage of the pressure intensifier.
 - Overall mechanical advantage if the output pressure of the intensifier were connected to the input side of an identical pressure intensifier.

Solution:

Problem 5: Given: Power Systems makes a pressure booster that's used on the power brake system of some cars. One side of the pressure booster is linked to the intake manifold of a car's engine. When the engine runs, a vacuum forms on this side of the pressure booster. When the brake pedal is pushed down, atmospheric air pressure acts on the surface of the large piston. This increases the pressure available to push on the piston in the master cylinder of the hydraulic brake system. A research technician for this company might be asked to provide an answer to the following question.

- Find: If the atmospheric pressure is 14.7 psi and the mechanical advantage of the booster is 12, what's the pressure applied to the piston of the master cylinder?

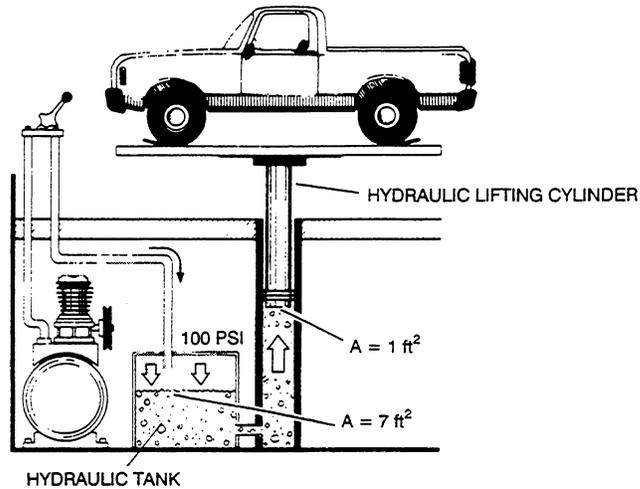
Solution:

Problem 6: Given: Williamsport Tower Company constructs and installs girder towers that support high-voltage electric power lines. These towers are very tall. They must be assembled "on site." Individual pieces of the tower are riveted together with a portable air-to-hydraulic rivet gun. The rivet gun is a pressure intensifier that uses a 50-psi air source.

- Find:
- Mechanical advantage of the pressure intensifier when a 1-in² output piston pushes on a rivet with 600 lb of force.
 - Area of the piston on the air input side of the pressure intensifier.

Solution:

Problem 7: Given: The sketch with this problem shows a type of air-over-hydraulic lift used by automotive garages. In this example, the air compressor is connected to a hydraulic tank that has a cross-sectional area of 7 ft^2 . The tank is connected to a hydraulic lifting cylinder. The cylinder piston has 1 ft^2 of face area in contact with the oil. (Note: Air pressure above fluid in hydraulic tank serves the same function as the input piston in a hydraulic jack.)



- Find:
- The ideal mechanical advantage of this device.
 - The force applied to a load by the movable piston if 100 psi of air pressure is applied to oil in the tank. Remember: $1 \text{ ft}^2 = 144 \text{ in}^2$.
 - How far up the top of the lifting piston a load moves if the oil level in the large tank moves down one foot.

Solution: