

# Intro to Machine Rigging 110: Hydraulic Jack

A hydraulic jack is a tool for lifting large or heavy objects. A piston at the source forces an incompressible fluid through a cylinder to the load piston in order to lift a load (see diagram). Because a much heavier load can be lifted than the force applied at the source, the hydraulic jack has a mechanical advantage.

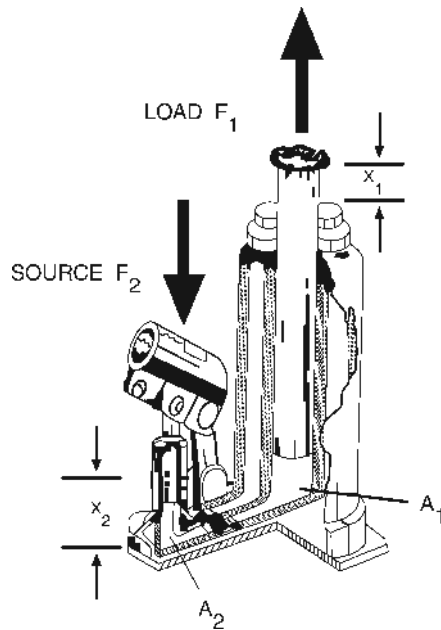


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The mechanical advantage of a hydraulic jack can be calculated with the following formula.

$$M = \frac{A_1}{A_2}$$

where  $M$  = mechanical advantage

$A_1$  = cross-sectional area of piston on the load side

$A_2$  = cross-sectional area of piston on the source side

Because the pistons have a circular cross-sectional area, the area of the pistons can be calculated with the following formula.

$$\text{Area of circle (A)} = \pi r^2$$

where  $\pi \approx 3.14$

$r$  = radius of the circle

The cross-sectional areas of the pistons are also proportional to the forces at the source and load.

$$\frac{A_1}{A_2} = \frac{F_1}{F_2}$$

where  $F_1$  = force or weight of load or lifting capacity of jack  
 $F_2$  = force applied at the source

Knowing the weight of the load or the lifting capacity, and the cross-sectional areas, the force needed at the source can be calculated.

### EXAMPLE:

A 12 ton hydraulic bottle jack has a source piston  $3/8$  inch in diameter and a load piston with a diameter of  $1-1/2$  inches.

- a. Determine the mechanical advantage of this jack.
- b. Determine the force needed on the source piston if the jack is required to lift a load of 3 ton.

### SOLUTION:

a. Area of source piston ( $A_2$ ) =  $\pi r_2^2$

$$r_2 = \frac{\text{diameter of source piston}}{2} = \frac{3/8}{2} = \frac{.375 \text{ in}}{2} = .1875 \text{ in}$$

$$A_2 = (3.14)(.1875 \text{ in})^2 \approx .11 \text{ in}^2$$

Area of load piston ( $A_1$ ) =  $\pi r_1^2$

$$r_1 = \frac{\text{diameter of load piston}}{2} = \frac{1 \frac{1}{2}}{2} = \frac{1.5 \text{ in}}{2} = .75 \text{ in}$$

$$A_1 = (3.14)(.75 \text{ in})^2 \approx 1.77 \text{ in}^2$$

$$\text{Mechanical advantage (M)} = \frac{A_1}{A_2} = \frac{1.77 \text{ in}^2}{.11 \text{ in}^2} \approx 16$$

The mechanical advantage of 16 means that the force applied on the source piston is multiplied by a factor of 16 on the load piston. Whatever force is applied at the source is 16 times larger on the load side.

b. Area of load piston =  $A_1 = 1.77 \text{ in}^2$

Area of source piston =  $A_2 = .11 \text{ in}^2$

Force of load =  $F_1 = 3 \text{ ton} = 3 \times 2000.0 \text{ lbs} = 6000.0 \text{ lbs}$

$$\frac{A_1}{A_2} = \frac{F_1}{F_2} \qquad \frac{1.77 \text{ in}^2}{.11 \text{ in}^2} = \frac{6000 \text{ lbs}}{F_2}$$

The easiest way to solve a proportion is to diagonally cross-multiply across the equal sign.

$$(1.77 \text{ in}^2)(F_2) = (.11 \text{ in}^2)(6000 \text{ lbs})$$

$$(1.77 \text{ in}^2)(F_2) = 660 \text{ in}^2\text{-lbs}$$

To solve for  $F_2$ , divide out the  $1.77 \text{ in}^2$ .

$$F_2 = \frac{660 \text{ in}^2 \text{ lbs}}{1.77 \text{ in}^2} = 372.9 \text{ lbs}$$

Approximately 372.9 lbs of force is needed on the input piston to be able to lift a load of 3 ton or 6000 lbs.

#### EXERCISES:

1. A hydraulic lift has a load piston 9 inches in diameter and a source piston 1 inch in diameter.

a. Determine the mechanical advantages for the lift and explain what it means.

b. Determine the force required on the source piston if a 5000 lb load is lifted.

- c. Referring to part b, if the cross-sectional areas of the pistons and the forces on the pistons are proportional, that means that as the area increases, the force \_\_\_\_\_, and as the area decreases, the force\_\_\_\_\_ .
2. A 20 ton hydraulic bottle jack has a source piston with a 1/2 inch diameter and a load piston with a 2 inch diameter.
- a. Determine the mechanical advantage of the jack.
- b. If a person is able to apply 200 lbs of force on the source piston, how many pounds of load can be lifted?



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