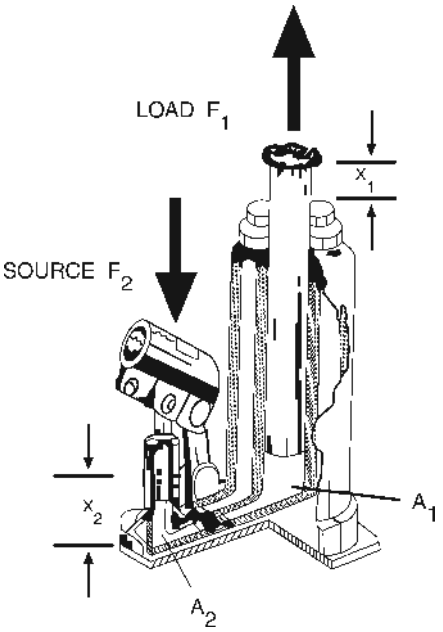
Intro to Machine Rigging 110: Hydraulic Jack

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.

Area of circle (A) = πr^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 in^2

Area of source piston = A_2 = .11 in^2

Force of load = F_1 = 3 ton = 3 x 2000.0 lbs = 6000.0 lbs

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

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

(1.77 in^2)(F_2) = (.11 in^2)(6000 lbs)

(1.77 in^2)(F_2) = 660 in^2-lbs

To solve for F_2, divide out the 1.77 in^2.

$$F_2 = \frac{600\ in^2\ lbs}{1.77\ in^2} = 372.9\ lbs$$

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?