WORKSHEET 19 Math Skills

Mechanical Advantage

A wheelbarrow has a mechanical advantage of 2.2. The output distance extends from the load's center of mass to the wheel and the input distance is from the handles to the wheel. For an output distance of 0.45 m, what is the input distance?

1. List the given and unknown values.

Given: *mechanical advantage* = 2.2
output distance = 0.45 m

Unknown: *input distance* = ? m

2. Use the mechanical advantage equation, and rearrange it to solve for output distance and input distance. Because the given information involves only distance, only the second form of the equation is needed.

$$\textit{mechanical advantage} = \frac{\textit{input distance}}{\textit{output distance}}$$

$$\textit{mechanical advantage} \times \textit{output distance} = \frac{\textit{input distance} \times \textit{output distance}}{\textit{output distance}} = \textit{input distance}$$

3. Substitute output distance and mechanical advantage values into the equation, and solve.

$$\textit{input distance} = 2.2 \times 0.45 \text{ m}$$

$$\textit{input distance} = 0.99 \text{ m}$$

Practice

1. If an input force of 202 N is applied to the handles of the wheelbarrow in the sample problem, how large is the output force that just lifts the load?
2. Suppose you need to remove a nail from a board by using a claw hammer. What is the input distance for a claw hammer if the output distance is 2.0 cm and the mechanical advantage is 5.5?
3. The power steering in an automobile has a mechanical advantage of roughly 75. If the input force on the steering wheel is 49 N, what is the output force that turns the car's front wheels?

Sample Problem

A lever and fulcrum are used to raise a heavy rock, which has a weight of 445 N. If the lever has a mechanical advantage of 9.50, what must the input force on the lever be in order to just begin lifting the rock?

1. **List the given and unknown values.**

Given: *mechanical advantage* = 9.50
output force = 445 N
Unknown: *input force* = ? N

2. **Use the mechanical advantage equation, and rearrange it to solve for output force and input force.** Because the given information involves only force, only the first form of the equation is needed.

$$\textit{mechanical advantage} = \frac{\textit{output force}}{\textit{input force}}$$

$$\textit{input force} = \textit{mechanical advantage} \times \frac{\textit{input force}}{\textit{mechanical advantage}}$$

$$= \frac{\textit{output force}}{\textit{input force}} \times \frac{\textit{input force}}{\textit{mechanical advantage}} = \frac{\textit{output force}}{\textit{mechanical advantage}}$$

3. **Substitute output force and mechanical advantage values into the equation, and solve.**

$$\textit{input force} = \frac{445\ \text{N}}{9.50}$$

$$\textit{input force} = 46.8\ \text{N}$$

Practice

4. An axe used to split wood is driven into a piece of wood a distance of 3.0 cm. If the mechanical advantage of the axe is 0.85, how far apart is the wood split?

5. The mechanical advantage of an automobile's wheel and axle is 8.93×10^{-2}. If the wheel's output force is 2.22×10^{3} N, what is the input force that turns the axle?

6. An Archimedean screw is a screw within a closely fitting cover, so that water can be raised when the screw is turned. Suppose the screw has a mechanical advantage of 12.5. If the screw is turned several times, so that the input distance is 1.57 m, how much has water been lifted upward by the screw?

Sample Problem

A pulley is used to raise a heavy crate. The pulley is such that an input force of 223 N is needed to provide an output force of 1784 N. What is the mechanical advantage of this pulley?

1. List the given and unknown values.

Given: *output force* = 1784 N

input force = 223 N

Unknown: *mechanical advantage* = ?

2. Use the mechanical advantage equation. Because the given information involves only force, only the first form of the equation is needed.

$$\textit{mechanical advantage} = \frac{\textit{output force}}{\textit{input force}}$$

3. Substitute output force and input force values into the mechanical advantage equation, and solve.

$$\textit{mechanical advantage} = \frac{1784\ \text{N}}{223\ \text{N}}$$

$$\textit{mechanical advantage} = 8.00$$

Practice

7. A mover uses a ramp to load a crate of nails onto a truck. The crate, which must be lifted 1.4 m from the street to the bed of the truck, is pushed along the length of the ramp. If the ramp is 4.6 m long and friction between the ramp and crate can be ignored, what is the mechanical advantage of the ramp?

8. A complex arrangement of pulleys forms what is called the block in a block and tackle. The rope used to lift the pulleys and the load is the tackle. A block and tackle is used to lift a truck engine, which has a weight of nearly 7406 N. The force required to lift this weight using the block and tackle is 308.6 N. What is the mechanical advantage of the block and tackle?

9. If you try opening a door by pushing too close to the side where the hinges are, you may find it difficult to push open. Suppose you are trying to open a door that is 85 cm wide.

a. If you push on the door at a point 15 cm away from the hinges, what is the mechanical advantage?

b. What is the best mechanical advantage that you can obtain for any door that you simply push open?

Mixed Review

10. It has been proposed that the stones of the Pyramids in Egypt were raised by using ramps. Suppose one of these ramps had a mechanical advantage of 3.86. If an input force of 6350 N was provided by laborers, what would the output force on the stone have been?

11. A wedge with a mechanical advantage of 0.78 is used to raise a house corner from its foundation. If the output force is 7500 N, what is the input force?

12. A pennyfarthing is a style of bicycle with a very large front wheel and a small rear wheel. The cyclist, who sits high above and behind the front wheel, pedals this wheel directly. The distance the pedals are turned (input distance) in one rotation is about 0.64 m. If the mechanical advantage of the pennyfarthing is 0.16, how far does the large wheel turn in one rotation?

13. A block and tackle with a mechanical advantage of 48 is used to lift a piano 11 m to the third floor of a building. Although the arrangement of pulleys in the block and tackle makes it easy to lift the piano, it takes a long time because of the length of rope that must be pulled to lift the piano a small amount. What is this length, or input distance, of the rope that must be pulled?

14. Archimedes is supposed to have said, "Give me a place to stand on and I will move the Earth." Suppose you had an object with a mass equal to that of Earth—5.98×10^{24} kg—and that it experienced gravity equal to that at Earth's surface, so that its weight was 5.87×10^{25} N. If by using a lever you could move this mass with a force of 175 N, what would be the mechanical advantage of the lever?

15. Suppose the fulcrum of the lever in problem 14 is placed 1.00 m away from the mass. How far from the fulcrum would you have to be (what would the input distance be) in order for the lever to have the mechanical advantage you calculated in problem 14? (Note: the nearest galaxy to ours, the Andromeda Nebula, is 2 million light years, or 1.9×10^{22} m, away.)

16. The input distance of a screw is equal to the circumference of the screw multiplied by the number of times it is turned. If a screw with a circumference of 19 mm is turned 4 times, so that it penetrates into a piece of wood a distance of 8.5 mm, what is the screw's mechanical advantage?

17. Over 100 hydraulic jacks were used to lift the massive Ekofisk offshore complex in the North Sea. An output force of 3.9×10^8 N was required to raise the complex. What input force would have to be provided to each jack if the overall mechanical advantage of the jacks was 1500?