

MATH SKILLS● **Efficiency**

A diesel engine with an efficiency of 0.39 requires 750 J of work to be done on its pistons. How much useful work is done by the diesel engine?

- List the given and unknown values.

$$\textit{Given:} \quad \textit{efficiency} = 0.39$$

$$\textit{work done on the machine (input)} = 750 \text{ J}$$

$$\textit{Unknown:} \quad \textit{useful work done by the machine (output)} = ? \text{ J}$$

- Use the efficiency equation, and rearrange it to solve for useful work done by the machine (output).

$$\textit{efficiency} = \frac{\textit{useful work done by the machine (output)}}{\textit{work done on the machine (input)}}$$

$$\textit{efficiency} \times \textit{work done by the machine (input)}$$

$$= \frac{\textit{useful work done by the machine (output)}}{\textit{work done on the machine (input)}} \times \textit{work done on the machine (input)}$$

$$= \textit{useful work done by the machine (output)}$$

- Substitute the values for the work done on the machine and the efficiency into the equation, and solve.

$$\textit{useful work done by the machine (output)} = (0.39) \times (750 \text{ J})$$

$$\textit{useful work done by the machine (output)} = 290 \text{ J}$$

Your Turn to Think

- The resistance of water to an oar in a rowboat limits the oar's efficiency to 0.450. If the rower does 145 J of work on the oar with each stroke, how much useful work is done by the oar?
- A jack requires 808 J of work to be done in raising a load, and ideally would do this amount of useful work. However, internal friction reduces the jack's efficiency to 0.625. How much useful work is done by the jack?
- A large crane lifts a 25 000 kg mass in the air. The amount of work that must be done by the crane's lifting components is $2.2 \times 10^7 \text{ J}$. If the efficiency of the crane is 22 percent, how much useful work is done on the mass?

Sample Problem

A block and tackle does $1.25 \times 10^5 \text{ J}$ of useful work, but friction limits the block and tackle to an efficiency of 0.45. What is the amount of work that must be done on the block and tackle?

MATH SKILLS● **Efficiency** *continued*

- List the given and unknown values.

Given: *efficiency* = 0.45

useful work done by the machine = 1.25×10^5 J

Unknown: *work done on the machine (input)* = ? J

- Use the efficiency equation, and rearrange it to solve for work done on the machine (input).

$$\text{efficiency} = \frac{\text{useful work done by the machine (output)}}{\text{work done on the machine (input)}}$$

- Substitute the values for the useful work done by the machine and the efficiency into the equation, and solve.

$$\text{work done on the machine (input)} = \frac{1.25 \times 10^5 \text{ J}}{0.45}$$

$$\text{work done on the machine (input)} = 2.8 \times 10^5$$

Your Turn to Think

- An automobile gasoline engine is able to do 225 J of useful work with each stroke of its pistons. If the engine has an efficiency of 29.0 percent, what is the amount of work that must be done on the pistons in the engine?
- The most efficient type of steam engine is a steam turbine, which in practice can have an efficiency as high as 30.0 percent. If the useful work done each second by a steam turbine with this efficiency is 2.64×10^6 J, how much work must the steam do on the turbine?
- In contrast to an efficient steam turbine, an early steam engine has an efficiency of only about 5.0 percent. If the work done by the engine is 3.5 kJ, how much work must be done on the engine by the steam?

Sample Problem

An inclined plane allows you to do 280 J of useful work on a refrigerator that you are sliding upward along the plane. If the work that you have to do is 760 J, what is the efficiency of the plane?

- List the given and unknown values.

Given: *work done on the machine (input)* = 760 J

useful work done by the machine (output) = 280 J

Unknown: *efficiency* = ?

MATH SKILLS● **Efficiency** *continued*

2. Write out the equation for efficiency.

$$\text{efficiency} = \frac{\text{useful work done by the machine (output)}}{\text{work done on the machine (input)}}$$

3. Substitute the values for the work done on the machine and the work done by the machine into the efficiency equation, and solve.

$$\text{efficiency} = \frac{280 \text{ J}}{760 \text{ J}} = 0.37$$

To express this as a percentage, multiply by 100 and add the percent sign.

$$\text{efficiency} = 0.37 \times 100 = 37\%$$

Your Turn to Think

7. A forklift developed in Sweden is able to do 1.8×10^6 J of useful work in lifting a heavy load. Suppose 7.6×10^6 J must be done by the lift's motors on the load in order to accomplish this task. What is the efficiency of the forklift?
8. A steam engine does 2500 J of useful work to move a wheel through half a rotation. The energy provided to the steam engine by heat for this work equals 7576 J. Noting that the amount of energy provided to a machine, either by heat or by work, is equivalent to the amount of work that must be done on a machine, calculate the efficiency of the engine.

Mixed Review

9. A pennyfarthing bicycle has an efficiency of 62 percent. How much work is done by the bicycle if a cyclist does 5.4×10^3 J of work on the bicycle?
10. A crate of nails with a mass of 280 kg is pushed up a ramp in order to raise the crate 0.75 m above the ground.
- What is the useful work done by this machine?
 - If the ramp has no friction, and therefore an efficiency of 1.0, what is the force needed to push the crate along the ramp?
 - In reality, friction reduces the ramp's efficiency to 43 percent. What force must now be applied to the crate to push it along the ramp?