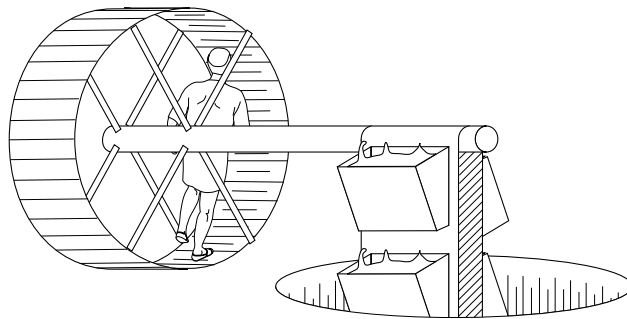


**Work and Machines** ▪ *Enrich*

## An Ancient Machine

Ancient societies did not have machines that ran on electricity, coal, or gasoline. For this reason, ancient engineers needed to use the power of human and animal muscles as efficiently as possible. One example of an ancient machine is the *treadmill*. This was a hollow wheel, large enough for someone to stand inside.

In the example below, a treadmill is used to lift water from a well. As the man tries to walk up the curved inner surface of the wheel, the force of gravity pulls his body back to the bottom and turns the wheel. The work performed by the man in the wheel drives a belt that moves buckets down into a well, where they fill with water, and then come back up. The man turning the wheel supplies the input force, and water is pulled up from the well by the output force. In this example, the man has a mass of 75 kg. With each step, he raises his body 0.5 m, and is pulled back down by the force of gravity. Each step that he takes causes the conveyor to lift 750 kg of water a distance of 0.05 m.



*Answer the questions below on a separate sheet. Show your calculations.*

1. When the man inside the treadmill steps up, what force pulls him back? In what direction does this force move him?
2. Gravity accelerates objects downward at  $9.8 \text{ m/s}^2$ . How much downward force does the man generate with each step he takes? How much work is performed when gravity pulls him down 0.5 m after each step?
3. How much force is exerted to lift 750 kg of water in the well against the force of gravity? How much work is done to lift this water 0.05 m? How does this compare to the work done by the man in the treadmill?
4. Remember, the treadmill is a machine. What is the input force exerted by the man inside the wheel? What is the output force exerted upon the water rising from the well? What is the mechanical advantage of this machine?
5. Calculate the efficiency of this treadmill. Is this likely? What factor might cause a real treadmill to be less efficient?