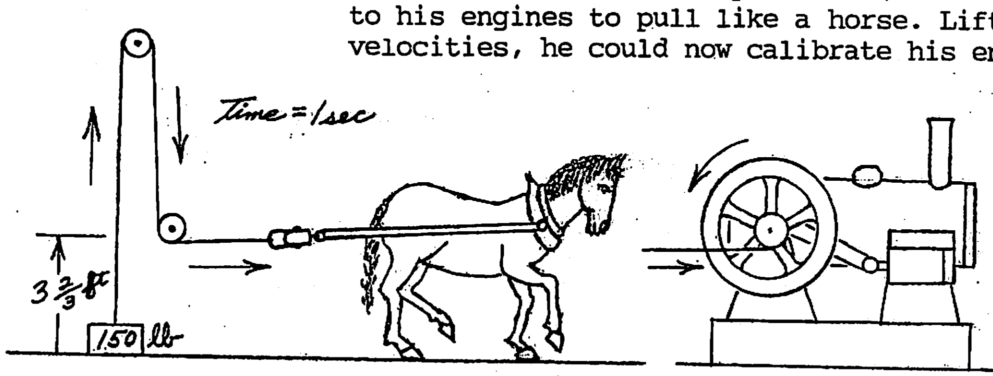
Horsepower

Horsepower and watts are everyday physics terms that originated in 1765 when James Watt (1736-1819) perfected the steam engine at the Univ. of Glascow. Watt, a trained instrument maker, was a technician at the college and had been given the task of repairing a small working model of a Newcomen steam engine which was crude but widely used to pump water out of coal mines. Via a series of major technological innovations, Watt reinvented the steam engine and turned it into a much more efficient and useful machine, one that could be placed almost anywhere to perform many more tasks than waterwheels and windmills. Eventually, of course, the stationary steam engine would be put on boats and railroads.

Watt immediately sought a business partner and found Matthew Boulton in Birmingham. Together they would produce several hundred engines of different sizes but would only lease them to protect their patents. However, they had a marketing problem. How much work could each engine do per hour or how much energy (coal?) would each engine use per hour? They needed a comparison.

In the 18th century horses and humans did most of the work required, but Watt's engines would be more like horses for strength and endurance. Thus, Watt chose the horse and experimented. He learned that a typical farm horse (1,300 lb.?) could move (lift) a 150 lb. weight 3 ft. 8 in. (3 2/3 ft.) per sec. (its velocity). He attached a winch to his engines to pull like a horse. Lifting a weight at different velocities, he could now calibrate his engines in horsepower.



The word power in physics describes how fast work is done or energy is used. A simple equation, the power equation, includes the three variables involved. Using Watt's data above, we arrive at the definition of 1 H.P.

$$\text{Power} = \frac{\text{Work}}{\text{time}} = \frac{\text{Force x Distance}}{\text{time}} = \frac{150 \text{ lb x } 3\ 2/3 \text{ ft}}{1 \text{ sec}} = 550\ \frac{\text{ftlb}}{\text{sec}} = 1 \text{ H.P.}$$

Gasoline engines and larger electric motors are still rated in horsepower.
In the metric system, the power equation remains the same, but the units are different, newtons instead of pounds and meters instead of feet.

$$p = \frac{F \text{ x } S}{t} = \frac{666 \text{ nt x } 1.12 \text{ m}}{1 \text{ sec}} = 746\ \frac{\text{nt m}}{\text{sec}} = 746\ \frac{\text{joules}}{\text{sec}} = 746 \text{ watts} = 1 \text{ H.P.}$$

Thus, a 746 watt (1 H.P.) electric motor uses 746 joules of electrical energy in one second. That is more energy than is used by seven 100 watt light bulbs but less than a 1,200 watt hair dryer.

Another way of looking at power is via the power equation used in electricity.
Power = V×I or watts = volts x amperes   Rearranged, $I = \frac{P}{V} = \frac{746 \text{ watts}}{120 \text{ volts}} = 6.2$ amps

Thus, a 1 H.P. (746 watt) motor is "drawing" (using) 6.2 amps of current to operate.

Surprisingly, all of the units in electricity have been metric for about 120 yrs. You may have noticed that most of the metric units are important physicists' names. In the early 1890's, an international committee of physicists met to standardize a system of metric units for different quantities and tried to match names with their scientific contributions. Lord Kelvin, another famous Scot of the U. of Glascow, made sure that his fellow countryman, James Watt, was honored with the unit of power. His engine had ushered in the industrial revolution and changed the world. Amazingly, Watt's name is now on billions of electrical devices worldwide.

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The words horsepower and watts will be used well into the future, mainly via electricity. The golden age of the steam engine came to an end in 1970. However, the horse and its uniqueness live on. Watt had wisely chosen the horse as his standard. The Amish people and people in the American West still prosper with the use of horses. And feeding horses is not a problem; hay and oats are easy to grow (renewable), unlike coal and oil.

Addendum: Simple horsepower experiments requiring little apparatus are nearly nonexistent, or the apparatus for such is no longer available. However, there is one simple experiment that many high school teachers have used for many years. It is the measurement of a student's leg horsepower. Surprisingly, most of the students enjoy performing this exercise and readily learn from it.

Instead of a horse raising a given weight, the students raise their own weight, via their leg muscles, as they climb a set of stairs. The only apparatus needed is a tape measure to measure the vertical height of the stairs from start to finish and a stopwatch to record the time. The students should know about what they weigh; the teacher doesn't need to know this if privacy is an issue.

All students can participate unless they are handicapped. They can choose to walk or run. For consistency, one student or set of students should operate the stopwatch(es), especially if it gets competitive. Some students will want to race, to achieve the shortest time, so as to maximize their leg horsepower. The students can easily see that performing the task at a slower or faster rate would produce different H.P. numbers; the different weights of students change the H.P. numbers, also. Horses, like people, come in all different sizes (and strengths). In our present system, a 2,300 lb. Budweiser Clydesdale can probably produce a number closer to 2 H.P., but Watt knew that horses of this size were unusual, not common or "average".

Remember, injury is always a risk on stairs; discuss this with the students before the experiment is attempted so they can decide what they want to do, walk or run. This experiment usually requires one lab period or less.

An example:

$$\text{Power} = \frac{\text{Wt} \times h}{t} = \frac{160\ \text{lb} \times 12\ \text{ft}}{5.2\ \text{sec}} = \frac{369\ \frac{\text{ft lb}}{\text{sec}}}{1} \times \frac{1\ \text{H.P.}}{550\ \frac{\text{ft lb}}{\text{sec}}} = 0.67\ \text{H.P.}$$