Teacher Tune-up

Quick Content Refresher for Busy Professionals

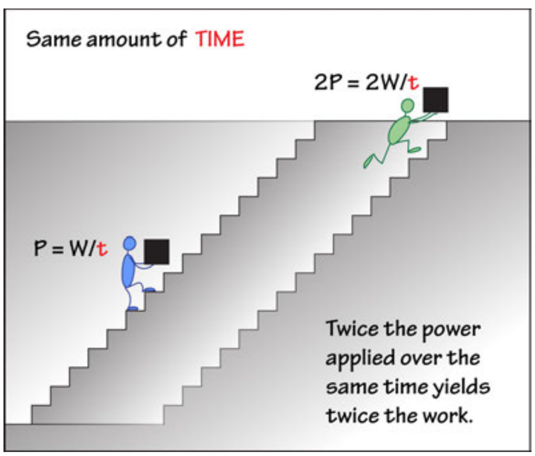
What does "power" mean when talking about work and energy?

The term power retains echoes of its everyday meaning in scientific usage—ability, strength, forcefulness—but different scientific fields define it differently, and certainly more narrowly. Optical power, exponential power, and statistical power, for example, all have specialized meanings. We'll focus here on how physicists and engineers use "power" to talk about work and energy.

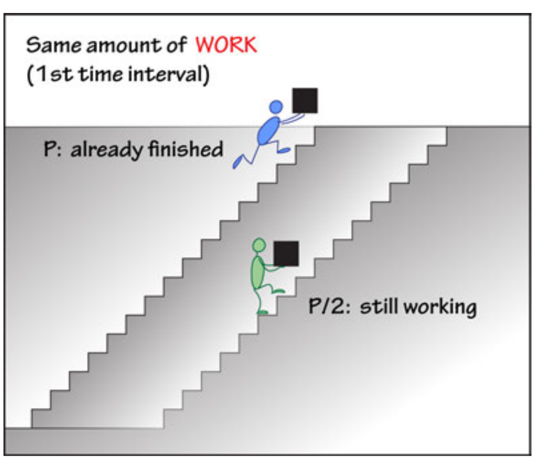
In this context, ***power** is the rate of transfer of energy.* Or, stated a little differently, power *is the time rate of work.*

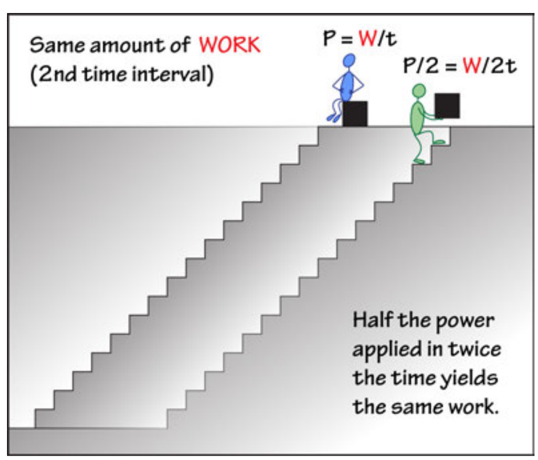
$$Power = \frac{work}{time}$$

Power, then, is *directly* related to work and *inversely* related to time. Looking at the formula P = W/t, we can see that if time is held constant, doing more work requires more power.

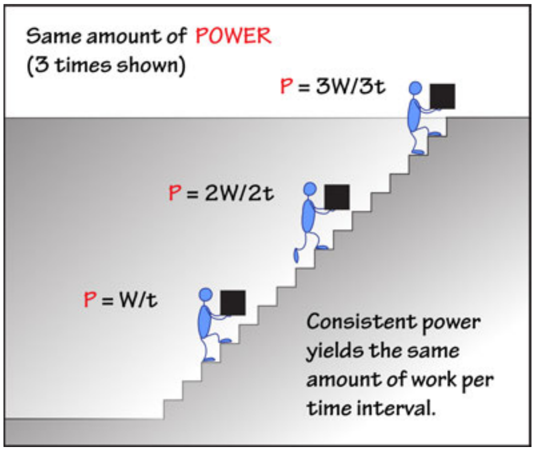


Or if the amount of work is held constant, then the longer the time interval the work is spread over, the less power it takes.





Or if power is held constant, then work will increase by the same factor as the time in which work is done.



Note: In the illustrations above, all the objects the people are carrying are assumed to have the same weight, making elevation a common index of gravitational potential energy, and of work done.

The relationship between power and energy (or power and work) is like the relationship between speed and distance. Speed is the time rate of distance, or the rate at which distance flows; power is the time rate of work, or the rate at which energy flows. Just as it would be incorrect to say, “There is a lot of speed separating Boston and Phoenix,” it would be incorrect (in physics usage) to say, “There is a lot of power stored in that battery.” What is stored in the battery is energy, rather than power.

Power comes into play when you connect that battery to a light bulb. The time rate at which the bulb uses energy is measured as power. If we’re measuring energy in joules, then we can measure power in *joules per second,* or **watts.** A 10-watt LED light bulb uses 10 joules of energy per second. A room air conditioner might run at a rate of 600 watts. When we look at whole houses and neighborhoods, we want larger units. So power can be measured in kilowatts (1,000 watts), megawatts (1,000,000 watts), and gigawatts (1,000,000,000 watts). For measuring tiny amounts of power, we can use milliwatts (0.001 watt). The familiar, non-metric unit of one *horsepower* is equal to about 746 watts.

If you know how much power an appliance is drawing, then you can compute the energy used over any specific time period by multiplying the power times the length of time it is used. For example, if that 600-watt air conditioner ran for 8 hours per day for 30 days, the total energy it used would be 600 watts × 8 × 30 hours = 144,000 watt-hours.

What is the meaning of that mixed-up unit, a “watt-hour”? Remember that a watt is a joule per second, a unit of energy divided by a unit of time. So when you multiply it by another time unit (an hour in this case), the dimension of time cancels out and you are back to measuring energy. A watt-hour, then, is a measure of energy, specifically the amount of energy that would be used over a period of 1 hour if you were to use it at a rate of 1 joule per second, which is to say 3,600 joules. Of course, that amount of energy can be consumed at different rates. For example, a 60-watt light blub uses 1 watt-hour of energy per minute (because 60 joules per second times 60 seconds equals 3,600 joules). And at 600 watts, our room air conditioner uses 1 watt-hour every 6 seconds (600 joules per second times 6 seconds equals 3,600 joules).

Back to our consumption of 144,000 watt-hours of energy for one month of air conditioning: To save on zeros, a utility bill would record 144,000 watt-hours as 144 kilowatt-hours (kWh). A kilowatt-hour is 3,600,000 joules. For comparison, one kilogram of exploding TNT releases roughly 4,000,000 joules of energy. With the TNT, joules are nearly equal to watts, because the whole point of an explosion is that it yields energy at a rate of oh-here-just-take-it-all-at-once! It’s just as well an air conditioner does that amount of work at a different time rate, a different power.

Here’s a table with some Imperial units (i.e. the old non-metric units many of us are used to) alongside SI units. The Imperial foot-pound unit of energy wears its work-equals-force-times-distance nature on its sleeve, while the term joule (honoring nineteenth-century scientist and beer brewer James Prescott Joule) hides its secret but more descriptive identity: the newton-meter.

System	Unit	Symbol	Measures	Calculation	Usage
Imperial	Foot	ft.	Distance	(measured)	The distance to the kitchen is 25 feet.
Imperial	Pound	lb.	Force	(measured)	I lifted a 50-pound sack of sugar.
Imperial	Foot-pound	Ft-lb.	Energy	distance × force	Ava's arrows hit the target with 43 foot-pounds of energy.
SI	Joule	J	Energy	distance × force	One joule is one newton-meter, and one joule per second is a watt.
Imperial / SI	Watt	W	Power	energy / time	I'd like to change my 60-watt bulb for a more energy-efficient LED bulb.
Imperial / SI	Kilowatt	kW	Power	energy / time	My new windmill generates 10 kilowatts.
Imperial / SI	Kilowatt-hour	kWh	Energy	power × time	Our energy bill shows we used 180 kWh.

Can power be negative?

In ordinary physics, energy is not negative. However, the *work* done on an object can be negative if the flow of energy is away from the object. This happens when a moving object is stopped, for example, reducing its kinetic energy. Another example is the loss of gravitational potential that an object experiences when it moves to a lower location.

Like work, power can be described as negative when that's useful. You could talk about a battery supplying 3 watts of power to a light, and you could also talk about a charger supplying 5 watts of power to the battery. But if you need to keep a balanced account, you might prefer to describe the power out the battery as -3 watts and the power into the battery as +5 watts.