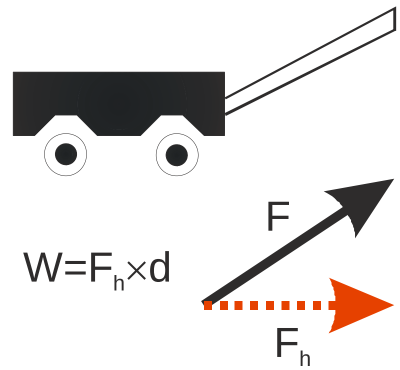
What is Energy?

by James Nickel

A major component of Physics is the study of energy. In the world around us, energy comes in different forms (heat, chemical, etc.), but physicists precisely define it in terms of *work*. Work, W, is done when a force, *F,* moves a body through a distance *d*. Work is force multiplied by distance:

$$W = Fd$$

A fine nuance in this definition of work is that what counts is *only* the force in the *direction* of the motion. I may pull a wagon at an angle, but only the *horizontal* part of the pull does any work. Hence, when a waiter carries a tray of food across the dining room, his support force (of the food on the tray) does *no* work because it is perpendicular (vertical) to the direction of his motion (horizontal).



Energy, E, is defined as the capacity to do work. This means that the release of energy does work and doing work on an object adds energy to it. Hence, energy and work are concepts that are *equivalent*. We write:

$$E = W = Fd$$

Physicists use a system of units to represent and calculate energy. In the metric system, the Newton is the unit of force.[1] The unit of distance is the meter. Multiplying these units, we get the Newton-meter or the *Joule*.[2] Hence, one Joule is the ability to exert a force of one Newton over a distance of one meter.[3]

Energy is undestood in the physical world primarily in two contexts. When I throw a ball, I have to do work to get the ball moving. I exert a force, F, over a distance, d (from my initial starting point of the throw to the release of the ball). By exerting this force over a distance, d, the ball acquires energy, the energy of motion, or, better yet, kinetic energy, KE.[4] If the mass of the ball is *m* and its velocity[5] *v,* we can calculate a formula for KE in terms of *m* and *v* using Newton's second law of motion, F = ma (the force exerted on an object is equal to its mass *m* multiplied by its acceleration *a*). We get:

Equation 1. F = ma
Equation 2. KE = Fd. We substitute F in Equation 1 for F in Equation 2. We get:
Equation 3: KE = mad

We want to represent *d*, the distance traveled, in terms of time and acceleration. Before I throw the ball, t (time) = 0, and v (velocity) = 0. Assume that the ball in my hand undergoes a constant acceleration *a* before I release it. I release the ball after *t* seconds. The ball's velocity at the point of release is defined as v = at. The average speed, for *t* seconds, is the velocity at the beginning plus the velocity at the end divided by 2. We get:

Equation 4: $v_{\text{average}} = \dfrac{0 + at}{2} = \dfrac{1}{2}at$

The distance traveled, *d*, is the average velocity times the time. We get:

Equation 5: $d = \dfrac{1}{2}at(t) = \dfrac{1}{2}at^2$. Substituting Equation 5 into Equation 3, we get:

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[1] One Newton equal to the force that produces an acceleration of one meter per second per second on a mass of one kilogram. This unit is named in the honor of Sir Isaac Newton (1642-1727). It is equivalent to a "gentle push."

[2] The Joule is named after the English physicist James Prescott Joule (1818-1889).

[3] In the British Imperial system, the unit of force is the pound and the distance is in feet. Hence, the foot-pound is the unit of energy in this measurement system.

[4] Kinetic comes from the Greek and means "moving."

[5] Remember, in physics, velocity is a vector; it measures the change of position of an object over time in a certain direction.

Equation 6: $KE = \frac{1}{2}m(at)^2$. Since v = at, then, we get:

Equation 7: $KE = \frac{1}{2}mv^2$ (the physics formula for kinetic energy).

The other way of understanding energy is concept of potential energy, PE. If I lift an object above my head to a height *h*, I have to exert a force W (the weight of the object) over the distance *h*. The weight of any object is defined, using Newton's second law of motion (F = ma), as W = mg where *g* represents the pull of gravity[6] downward on an object of mass *m*.[7] To lift the object, I do work. The work done is Wh. Substituting W = mg, we get:

$$Wh = mgh$$

The object on top of me is not moving after I complete the lift but it has the added energy, potential that is, of mgh because of where it is in the earth's gravitational field. This energy, PE, is defined as:

$$PE = mgh \text{ (the physics formula for potential energy)}$$

If I drop this object, the potential energy of the object, mgh, becomes kinetic energy. As the object falls, it falls faster and faster and the potential energy is gradually converted into kinetic energy. Just before the point of impact of the object on the ground, the potential energy is all used up and the original potential energy has become entirely kinetic energy. We get:

$$mgh = \frac{1}{2}mv^2$$

What is the velocity of the object at the point of impact? Solving for v, we get:

$$\cancel{m}gh = \frac{1}{2}\cancel{m}v^2$$

$$gh = \frac{1}{2}v^2$$

$$v^2 = 2gh$$

$$v = \sqrt{2gh}$$

$mgh = \frac{1}{2}mv^2$ is a mathematical representation of the physical principle called the *conservation of energy*. Energy is neither gained nor lost in the process of letting the object fall to the ground at height *h* although it may be converted.

In the context of the conservation of energy, what happens when the object hits the ground? Some of the kinetic energy is converted into sound. Some energy goes to distorting the ground (if the object has sufficient mass) and some energy may even distort the object (it may break or bend). Finally, some, probably most, of the energy is converted into heat. The object and the ground are a little warmer after the impact because the impact "jiggles" their molecules and heat is measure of the kinetic energy of billions of vibrating molecules.

[6] This pull of gravity is an downward *acceleration*.

[7] This pull is 32 feet per second every second in British Imperial units and 9.8 meters per second every second in the Metric system.

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Take careful note of what we have done. We have defined the concepts of work and energy and we have been able to quantify these concepts using mathematical equations and the foundational laws of mechanics; i.e., Newton's second law of motion. Note that we have described, quantitatively, what energy does and how to calculate it. We have *not* defined what energy *is*.

In the study of philosophy, *ontology* deals with the question of existence or being. It is the most basic of all questions we could ask about the nature of life in the universe. What is the foundation for existence? What is the starting point? What is the Alpha? Unless we know the starting point, the Alpha, we will not be able to understand the ending point, the Omega. Our starting point will ultimately determine our ending point. Subsidiary to the question of existence are these questions:

1. What is the nature of existence?
2. What is the nature of life?
3. What is the foundation (source) of existence?
4. What is the nature and source or reality?
5. What is the nature of energy?

Let's consider the nature of energy. What, really, is it? When I lifted the object above my head, I put energy into it. Where did that energy come from? I used my muscles so this energy came from muscular energy. Muscular energy is, in turn, released chemical energy caused by food oxidizing in my body. This chemical energy is a form of potential energy, owing, technically, to the positions of electrons in the electrical fields of molecules in my body. This chemical energy came from a plant that I ate or an animal that eats plants. The plant, the source of food for animals and man, converted the radiant energy of the Sun into chemical energy via the process of photosynthesis. The energy of the sunlight comes from nuclear fission and from whence is the source of the Sun's hydrogen nuclei?

There are many possible answers to this question, but there are relatively few categories of answers. The source of the Sun's hydrogen nuclei is either a supernatural force or a tentatively posited or "yet to be discovered" non-supernatural or natural force.[8] The Alpha (starting point) is either supernatural or natural. In the last several hundred years, ideational leaders have abandoned the idea of the Supernatural God of Scripture. As a result, today's post-modern man is facing a dilemma. Post-modern man has come to the conclusion that there is no answer to this question on the basis of the non-supernatural (e.g., nature). Because there is no answer, the question of existence and the subsidiary question of "What is energy?" are nonsensical. *You cannot even ask the question because there are no answers to it.* Hence, the question of existence and the question of "What is energy?" do not really matter because it is absurd.

Isn't something going "tilt" here? The post-modern intellectual is left in despair that leads to cynicism, despair, and skepticism. This is indeed a sandy foundation upon which to build a civilization. Because of this post-modern cynicism, despair, and skepticism, life does not really matter because all is absurdity. So, let's eat, drink, and be merry! Who cares about these questions (i.e., we shall ignore them), we are here (i.e., we exist), we can calculate equations about energy, so we only need to know how to get "on with the job." But, how do we know where to go or what to do? What is the standard for knowledge and goals (teleology)? From what source (starting point) do we draw our bearings?

By the logical force of seeking to determine the ultimate source of energy, we must answer the critical question of ontology.

[8] The "Big Bang" theory, a burst of colossal energy, is currently in vogue regarding the non-supernatural origins of the Sun's hydrogen nuclei. Associated with this theory is the conjecture of the existence of "dark energy" and "dark matter." It is worth noting that the popular acceptance of this theory hides its many problems.

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The mathematical formulas governing the calculation of energy and work are "fine and dandy" but they lead beyond the point of practical application. *By the logical force of seeking to determine the ultimate source of energy, we must answer the critical question of ontology.* We cannot escape this question and we cannot escape the question of "What is energy?"; *these questions must and will be answered either by design or by default.*