Physics of Energy

Eric E. Johnson

ericejohnson.com

How to deal with documents you understand incompletely

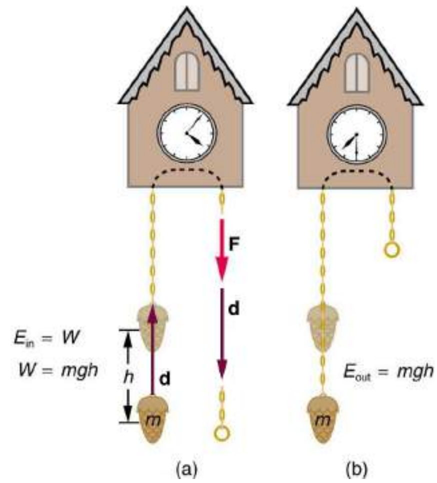
- Have a plan for what you want to get out of them.
- Enjoy the puzzle they present.

facts + law =
legal analysis

facts + law =
lawyering

Figure 7.5

(a) The work done to lift the weight is stored in the mass-Earth system as gravitational potential energy.
(b) As the weight moves downward, this gravitational potential energy is transferred to the cuckoo clock.



Conservative Forces and Potential Energy

"Potential energy is the energy a system has due to position shape, or configuration. It is stored energy that is completely recoverable."

CP p. 252

Potential Energy and Conservative Forces

Potential energy is the energy a system has due to position, shape, or configuration. It is stored energy that is completely recoverable.

A conservative force is one for which work done by or against it depends only on the starting and ending points of a motion and not on the path taken.

We can define a potential energy (PE) for any conservative force. The work done against a conservative force to reach a final configuration depends on the configuration, not the path followed, and is the potential energy added.

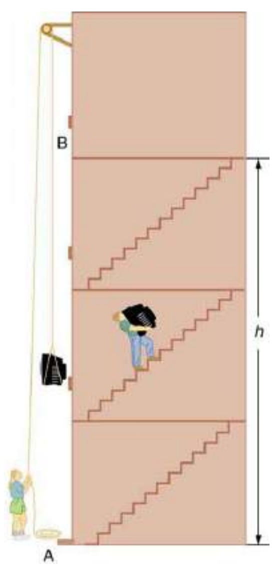
7.6 Conservation of Energy

Law of Conservation of Energy

Energy, as we have noted, is conserved, making it one of the most important physical quantities in nature. The **law of conservation of energy** can be stated as follows:

Total energy is constant in any process. It may change in form or be transferred from one system to another, but the total remains the same.

Figure 7.6



- The change in gravitational potential energy (ΔPE_g) between points A and B is independent of the path. $\Delta PE_g = mgh$ for any path between the two points. Gravity is one of a small class of forces where the work done by or against the force depends only on the starting and ending points, not on the path between them.


PE
KE
PE
KE

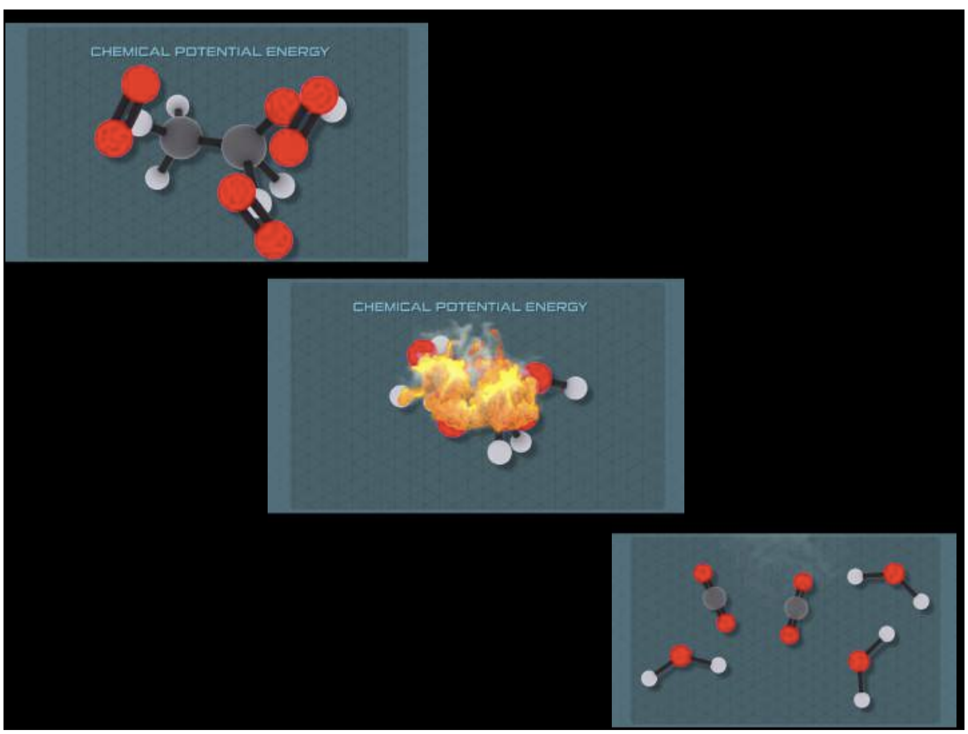
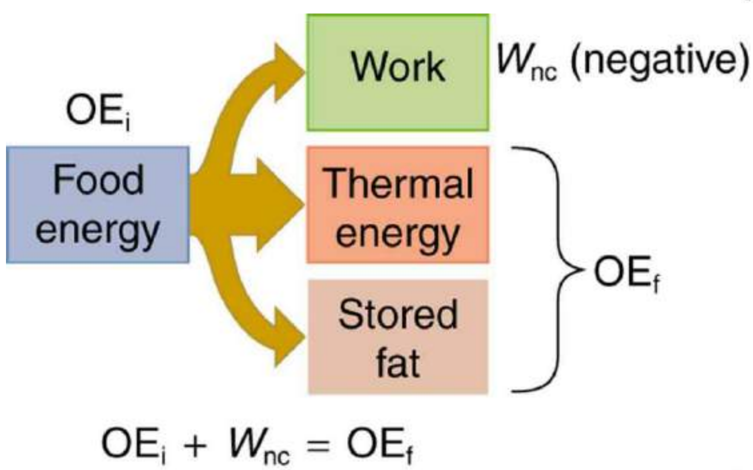

CHEMICAL POTENTIAL ENERGY
CHEMICAL POTENTIAL ENERGY

Figure 7.25

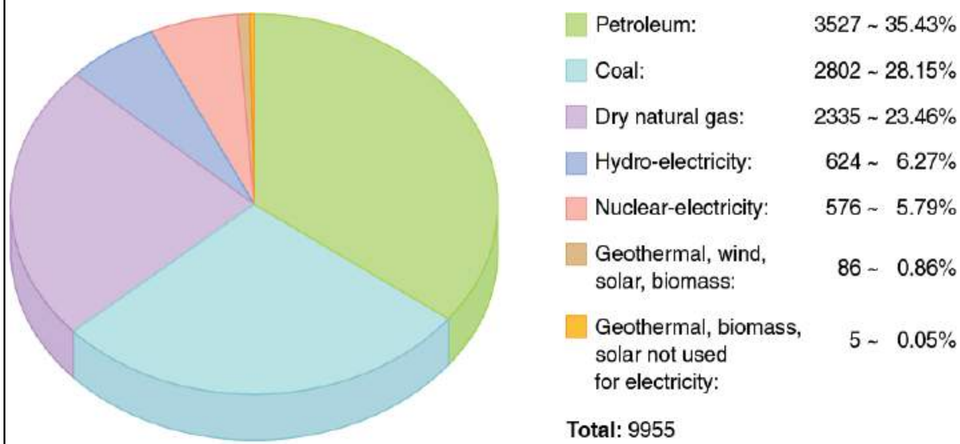
- Tremendous amounts of electric power are generated by coal-fired power plants such as this one in China, but an even larger amount of power goes into heat transfer to the surroundings. The large cooling towers here are needed to transfer heat as rapidly as it is produced. The transfer of heat is not unique to coal plants but is an unavoidable consequence of generating electric power from any fuel—nuclear, coal, oil, natural gas, or the like. (credit: Kleinolive, Wikimedia Commons)

Figure 7.26



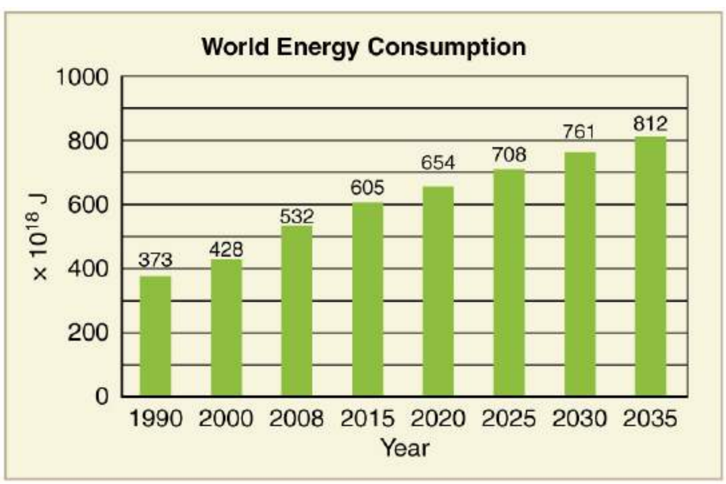
- Energy consumed by humans is converted to work, thermal energy, and stored fat. By far the largest fraction goes to thermal energy, although the fraction varies depending on the type of physical activity.

Figure 7.29



- World energy consumption by source, in billions of kilowatt-hours: 2006. (credit: KVDP)

Figure 7.30



- Past and projected world energy use (source: Based on data from U.S. Energy Information Administration, 2011)

Efficiency

Even though energy is conserved in an energy conversion process, the output of *useful energy* or work will be less than the energy input. The **efficiency** Eff of an energy conversion process is defined as

$$\text{Efficiency}(Eff) = \frac{\text{useful energy or work output}}{\text{total energy input}} = \frac{W_{\text{out}}}{E_{\text{in}}}. \quad (7.68)$$

Table 7.2 lists some efficiencies of mechanical devices and human activities. In a coal-fired power plant, for example, about 40% of the chemical energy in the coal becomes useful electrical energy. The other 60% transforms into other (perhaps less useful) energy forms, such as thermal energy, which is then released to the environment through combustion gases and cooling towers.

Table 7.2 Efficiency of the Human Body and Mechanical Devices

Activity/device	Efficiency (%)[1]
Cycling and climbing	20
Swimming, surface	2
Swimming, submerged	4
Shoveling	3
Weightlifting	9
Steam engine	17
Gasoline engine	30
Diesel engine	35
Nuclear power plant	35
Coal power plant	42
Electric motor	98
Compact fluorescent light	20
Gas heater (residential)	90
Solar cell	10

Problems

7.6 Conservation of Energy

13. Consider the following scenario. A car for which friction is *not* negligible accelerates from rest down a hill, running out of gasoline after a short distance. The driver lets the car coast farther down the hill, then up and over a small crest. He then coasts down that hill into a gas station, where he brakes to a stop and fills the tank with gasoline. Identify the forms of energy the car has, and how they are changed and transferred in this series of events. (See **Figure 7.34**.)

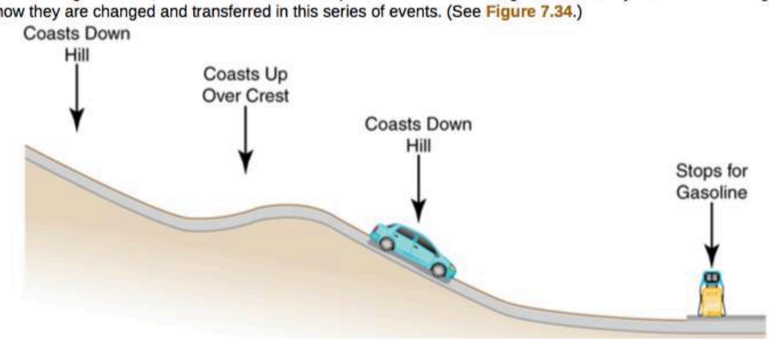


Figure 7.34 A car experiencing non-negligible friction coasts down a hill, over a small crest, then downhill again, and comes to a stop at a gas station.

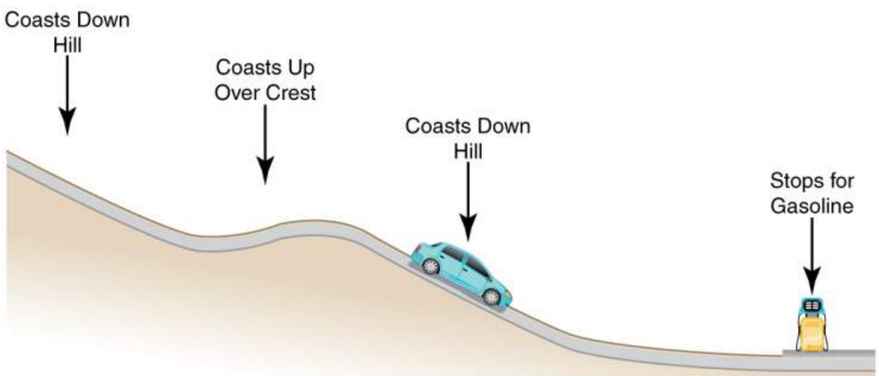
14. Describe the energy transfers and transformations for a javelin, starting from the point at which an athlete picks up the javelin and ending when the javelin is stuck into the ground after being thrown.

15. Do devices with efficiencies of less than one violate the law of conservation of energy? Explain.

16. List four different forms or types of energy. Give one example of a conversion from each of these forms to another form.

17. List the energy conversions that occur when riding a bicycle.

Figure 7.34



- A car experiencing non-negligible friction coasts down a hill, over a small crest, then downhill again, and comes to a stop at a gas station.

7.8 Work, Energy, and Power in Humans

21. Explain why it is easier to climb a mountain on a zigzag path rather than one straight up the side. Is your increase in gravitational potential energy the same in both cases? Is your energy consumption the same in both?

7.9 World Energy Use

25. What is the difference between energy conservation and the law of conservation of energy? Give some examples of each.

26. If the efficiency of a coal-fired electrical generating plant is 35%, then what do we mean when we say that energy is a conserved quantity?

S1-1. It is not atypical in the North Dakota Bakken Formation for an oil well to produce about 100 barrels per day from a depth of 1,500 meters. What is the change in potential gravitational energy in joules for a change in height of 100 barrels oil from 1,500 m below ground to the surface? Assume that a barrel of oil has a mass of 139 kg.

S1-2. (a) A pumpjack is a type of pump used to lift oil from an oil well to the surface. Assuming a pumpjack were 100% efficient in turning inputted energy into useful work (which it couldn't be, of course), how much energy would it take to lift 100 barrels from 1,500 m below ground to the surface?

(b) Is potential gravitational energy gained or lost in this pumping?

Figure 7.5

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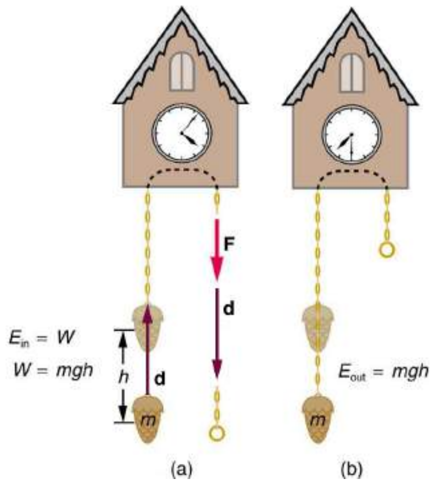
(b) As the weight moves downward, this gravitational potential energy is transferred to the cuckoo clock.



Do these problems, using the chart on p. 263 of CP:

S1-3. What has more energy, one barrel of oil or one ton of TNT?

S1-4. Typically a barrel of oil might produce 19 gallons of gasoline. What has more energy, 19 gallons of gasoline or one barrel of oil? By about how much is one quantity bigger than the other?

Table 7.1 Energy of Various Objects and Phenomena

Object/phenomenon	Energy in joules
Big Bang	10^{68}
Energy released in a supernova	10^{44}
Fusion of all the hydrogen in Earth's oceans	10^{34}
Annual world energy use	4×10^{20}
Large fusion bomb (9 megaton)	3.8×10^{16}
1 kg hydrogen (fusion to helium)	6.4×10^{14}
1 kg uranium (nuclear fission)	8.0×10^{13}
Hiroshima-size fission bomb (10 kiloton)	4.2×10^{13}
90,000-ton aircraft carrier at 30 knots	1.1×10^{10}
1 barrel crude oil	5.9×10^{9}
1 ton TNT	4.2×10^{9}

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1 barrel crude oil	5.9×10^{9}
1 ton TNT	4.2×10^{9}

1 gallon of gasoline	1.2×10^{8}
Daily home electricity use (developed countries)	7×10^{7}
Daily adult food intake (recommended)	1.2×10^{7}
1000-kg car at 90 km/h	3.1×10^{5}
1 g fat (9.3 kcal)	3.9×10^{4}
ATP hydrolysis reaction	3.2×10^{4}
1 g carbohydrate (4.1 kcal)	1.7×10^{4}

1 barrel crude oil	5.9×10^{9}
1 ton TNT	4.2×10^{9}
1 gallon of gasoline	1.2×10^{8}
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1000-kg car at 90 km/h	3.1×10^{5}
1 g fat (9.3 kcal)	3.9×10^{4}
ATP hydrolysis reaction	3.2×10^{4}
1 g carbohydrate (4.1 kcal)	1.7×10^{4}
1 g protein (4.1 kcal)	1.7×10^{4}
Tennis ball at 100 km/h	22
Mosquito $\left(10^{-2}\ \text{g at } 0.5\ \text{m/s}\right)$	1.3×10^{-6}

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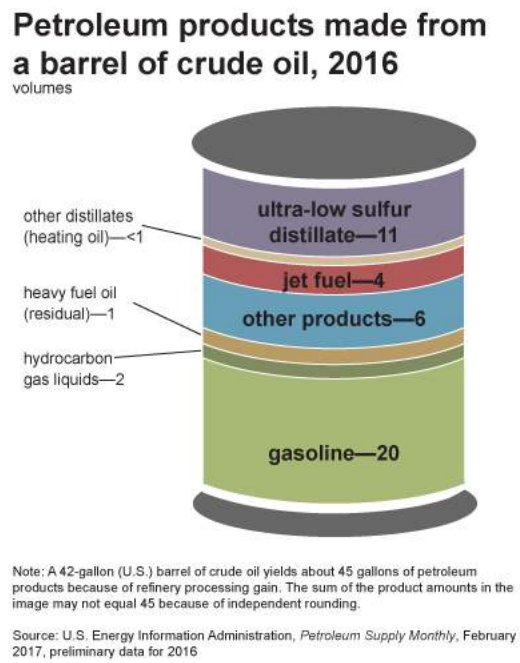


Do these problems, using the chart on p. 272 of CP:

S1-5. What is the United States' share, in percent, of world energy consumption?

S1-6. Oil and natural gas combined account for what percentage of U.S. energy consumption?

S1-7. By what factor is U.S. per capita energy consumption larger than world per capita energy consumption?

Do these problems, using the chart on p. 273 of CP:

S1-8. What is a country that seems to buck the correlation by having a relatively high standard of living, as judged by per capita GDP, compared to per capita energy consumption?

S1-9. What is a country that seems to buck the correlation the other way, having a relatively low per capita GDP compared to per capita energy consumption?

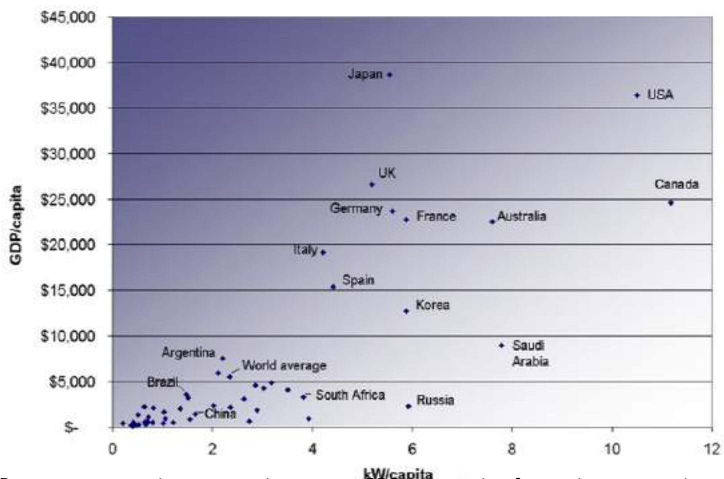
Table 7.6 Energy Consumption—Selected Countries (2006)

Country	Consumption, in EJ (10^{18} J)	Oil	Natural Gas	Coal	Nuclear	Hydro	Other Renewables	Electricity Use per capita (kWh/yr)	Energy Use per capita (GJ/yr)
Australia	5.4	34%	17%	44%	0%	3%	1%	10000	260
Brazil	9.6	48%	7%	5%	1%	35%	2%	2000	50
China	63	22%	3%	69%	1%	6%		1500	35
Egypt	2.4	50%	41%	1%	0%	6%		990	32
Germany	16	37%	24%	24%	11%	1%	3%	6400	173
India	15	34%	7%	52%	1%	5%		470	13
Indonesia	4.9	51%	26%	16%	0%	2%	3%	420	22
Japan	24	48%	14%	21%	12%	4%	1%	7100	176
New Zealand	0.44	32%	26%	6%	0%	11%	19%	8500	102
Russia	31	19%	53%	16%	5%	6%		5700	202
U.S.	105	40%	23%	22%	8%	3%	1%	12500	340
World	**432**	**39%**	**23%**	**24%**	**6%**	**6%**	**2%**	**2600**	**71**

Energy and Economic Well-being

The last two columns in this table examine the energy and electricity use per capita. Economic well-being is dependent upon energy use, and in most countries higher standards of living, as measured by GDP (gross domestic product) per capita, are matched by higher levels of energy consumption per capita. This is borne out in Figure 7.32. Increased efficiency of energy use will change this dependency. A global problem is balancing energy resource development against the harmful effects upon the environment in its extraction and use.

Figure 7.32



- Power consumption per capita versus GDP per capita for various countries. Note the increase in energy usage with increasing GDP. (2007, credit: Frank van Mierlo, Wikimedia Commons)

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