MISCELLANEOUS FACTORS

1 centimeter = 0.3937 inch; 1 inch = 2.54 cm

1 micron (μm) = 10^{-6} m

1 meter = 3.28 ft; 1 foot = 12 in. = 30.48 cm

1 hectare (ha) = 10,000 m^2 = 2.471 acres

1 acre = 43,560 ft^2 = 0.4047 ha

1 liter = 1,000 cm^3 = 0.264 gal

1 gallon = 0.1337 ft^3 = 3.885 liter

1 barrel (bbl) = 42 gal = 159.1 liter

1 kilogram = 2.2046 lb; 1 pound = 16 oz = 0.453 kg

1 cord = 128 ft^3 = 3.624 m^3

1 therm = 100,000 Btu

1 watt = 1 J/sec = 3.41 Btu/hr

1 kilowatt = 1,000 J/sec = 239 cal/sec = 3,413 Btu/hr = 1.341 hp

1 horsepower = 550 ft · lb/sec = 746 W

1 year = 3.15×10^7 sec

1 acre foot = 325,804 gallons

density of water = 1 g/cm^3 = 62.4 lb/ft^3

density of gasoline = 0.70 to 0.78 gm/cm^3; average = 0.72 gm/cm^3

density of diesel fuel = 0.82 to 0.95 gm/cm^3; average = 0.85 gm/cm^3

density of propane = 0.50 gm/cm^3

density of air at STP = 1.293 kg/m^3

heat capacity of air = 1000 J/kg · K = 0.019 $Btu/ft^3 \cdot °F$

ASTRONOMICAL DATA

Mean radius of earth	6.371×10^6 m
Mass of earth	5.975×10^{24} kg
Surface temperature of earth	290 K
Mean distance from earth to sun	1.49×10^{11} m
Mass of sun	1.99×10^{30} kg
Surface temperature of sun	6000 K
Radius of moon	1.741×10^6 m
Mass of moon	7.343×10^{22} kg
Mean distance of moon from earth	3.84×10^8 m

197348

Energy Unit Conversion Factors

		J	kWh	Btu
1 Joule (J)	equals	1	2.78×10^{-7}	9.49×10^{-4}
1 kilowatt hour (kWh)	equals	3.60×10^{6}	1	3413
1 calorie (cal)	equals	4.184	1.19×10^{-6}	3.97×10^{-3}
1 British thermal unit (Btu)	equals	1055	2.93×10^{-4}	1
1 foot-pound (ft · lb)	equals	1.36	3.78×10^{-7}	1.29×10^{-3}
1 electron volt (eV)	equals	1.60×10^{-19}	4.45×10^{-26}	1.52×10^{-22}

Energy Equivalents

	J	kWh	Btu
Crude petroleum (42 gallon barrel)	6.12×10^{9}	1700	5.80×10^{6}
Bituminous coal (1 ton[a])	2.81×10^{10}	7800	2.66×10^{7}
Natural gas (1000 cubic feet[b])	1.09×10^{9}	303	1.035×10^{6}
Gasoline (1 gallon[c])	1.32×10^{8}	36.6	1.25×10^{5}
Uranium = 235 (1 gram)	8.28×10^{10}	2.30×10^{4}	7.84×10^{7}
Deuterium (1 gram)	2.38×10^{11}	6.60×10^{4}	2.25×10^{8}

[a] 1 ton = 2000 lb = 0.907 tonne.
[b] At STP.
[c] The U.S. gallon is used in this text. The Imperial gallon used in Canada and Great Britain equals 1.200 U.S. gallons.

Energy and power can be distinguished by their units: power is measured in Watts (W), or kW and other multiples. 1 W is equivalent to 1 J s^{-1}, so 1 J is the energy produced from a power of 1 W running for 1 s.

Electricity is generally measured in kilowatt hours, kWh (sometimes just called a 'unit' of electricity). 1 kWh means *1 kW for 1 hour* – the energy from 1 kW power running for 1 hour, as in a single bar electric fire for an hour. The kWh is a measure of energy, while the kW is a measure of power.

The energy in 1 kWh can be calculated using Equation (2.3), $E = Pt$:

$$\begin{aligned} 1 \text{ kWh} &= 1 \text{ kW} \times 1 \text{ h} \\ &= 1{,}000 \text{ J s}^{-1} \times 3{,}600 \text{ s} \\ &= 3{,}600{,}000 \text{ J} \\ &= 3.6 \text{ MJ} \end{aligned}$$

Many other units are commonly used to measure energy and power by energy utilities, engineers or in everyday life, listed in Table 2.2. For instance, the calorie is the energy needed to raise the temperature of 1 gram of water by 1°C.

Table 2.2 ***Units of energy and power and their definitions***

Unit	*Definition*	*Equivalent in Joules*
Joule, J	Force of 1 N moving through 1 m	1 J
kWh	1 kW for 1 h	3.6 MJ
calorie, Cal	Heat required to raise temperature of 1 g water by 1°C	4.2 J
British Thermal Unit, BtU	Heat required to raise the temperature of 1 lb of water by 1°F	1,055 J
Therm	100,000 BtU	105.5 MJ
m^3 of gas	1 m^3 natural gas at a given temperature and pressure	40 MJ
Tonne oil equivalent, TOE	1 t crude oil	45 GJ
Tonne coal equivalent, TCE	1 t standard coal	30 GJ
Electron volt, eV (used in atomic physics)	Energy gained by an electron moving through electric field of 1 V	1.6×10^{-19} J
Watt	1 J per second	1 W = 1 J s^{-1}
Horsepower, HP	Measure of power; historical definition	746 W or 746 J s^{-1}

1 Cal = 4.2 J. Bear in mind that in diets, calorie is used to mean kCal, so a diet of 2,000 calories a day actually means 2,000 kCal = 8,400 kJ.

Any of these energy units can be converted into Joules by multiplying by the equivalent in Joules. For instance, if your gas bill shows you to have used 356 m^3 of gas with an energy value of 40 MJ m^{-3}, the amount of energy used is:

$$E = 356 \times 40$$
$$= 14{,}240 \text{ MJ}$$

To convert into kWh, divide by the figure for a kilowatt hour in Joules, 3.6 MJ kWh^{-1}:

$$E = 14{,}240/3.6$$
$$= 3{,}956 \text{ kWh}$$

Kinetic energy and potential energy

Kinetic energy (KE) is the energy of a body due to its motion. When an object accelerates under a force f, Equations (1.1) and (1.4) from Chapter 1 tell us:

$$f = ma$$

and

$$v^2 = u^2 + 2as$$
$$= 2as \quad (\text{as } u = 0)$$

Substituting into Equation (2.2):

$$E = fs$$
$$= mas$$
$$= \tfrac{1}{2}mv^2 \quad (\text{as } as = \tfrac{1}{2}v^2)$$

This is the kinetic energy of an object at velocity v. It doesn't matter what the acceleration was or whether it was constant or in a straight line, due to the principle of conservation of energy: any two bodies with the same mass and velocity must have the same kinetic energy, however they got there.

Potential energy (PE) is energy due to position or height, e.g. energy gained by a skier by riding up a chair lift allows them to then ski down again, converting the PE gained into KE. If a mass is raised against gravity to height h, the force on it is $f = mg$ from gravity.

$$\text{energy} = \text{force} \times \text{distance}$$
$$= mgh$$

Table 1.3. Power Expended in a Sampling of Activities

Power Producers and Users	Power Involved
Lifting a mosquito at 1 cm/s A fly doing one pushup	1 erg/s = 10^{-7} W = 10^{-10} kW
Cricket chirps	10^{-3} W = 10^{-6} kW
Pumping human heart	1.5 W = 1.5×10^{-3} kW
Burning match	10 W = 10^{-2} kW
Electrical output of a 1 m^2 solar cell 10% efficiency	100 W = 0.1 kW
Bright lightbulb	100 W = 0.1 kW
Human hard at work	0.1 kW
Draft horse	1 kW
Portable floor heater	1.5 kW
Compact automobile	100 kW
Queen Elizabeth (giant ocean liner)	200,000 kW
Boeing 747 passenger jet, cruising	250,000 kW
One large coal-fired power plant	1×10^6 kW = 1 GW of electricity
Niagara Falls, hydroelectric plant	2×10^6 kW = 2 GW of electricity
Space Shuttle Orbiter (3 engines) Plus its 2 solid booster rockets at take off	14×10^6 kW = 14 GW
All electric power plants worldwide	2×10^9 kW = 2,000 GW
U.S. automobiles, if all used at the same time (150 million)	15×10^9 kW = 15,000 GW
Humankind's total use in 2005	1.1×10^{10} kW = 1.1×10^4 GW = 400 Q/yr
SUV[a], 15 mpg at 60 mph	160 kW

Sources: Levenspiel (1996) and EIA (1998).
[a]Sport utility vehicle.

Energy Conversion Factors Chart

To convert from the first column units to other units, multiply by the factors shown in the appropriate row (e.g., 1 Btu = 252 calories)

Key: MWy = megawatt-year; bbls = barrels; tonnes = metric tons = 1,000 kg = 2204.6 lb; MCF = thousand cubic feet; EJ = exajoule = 10^{18}J. Nominal calorific values assumed for coal, oil, and gas.

	Btus	quads	calories	kWh	MWy
Btus	1	10^{-15}	252	2.93×10^{-4}	3.35×10^{-11}
quads	10^{15}	1	2.52×10^{17}	2.93×10^{11}	3.35×10^{4}
calories	3.97×10^{-3}	3.97×10^{-18}	1	1.16×10^{-6}	1.33×10^{-13}
kWh	3413	3.41×10^{-12}	8.60×10^{5}	1	1.14×10^{-7}
MWy	2.99×10^{10}	2.99×10^{-5}	7.53×10^{12}	8.76×10^{6}	1
bbls oil	5.50×10^{6}	5.50×10^{-9}	1.38×10^{9}	1612	1.84×10^{-4}
tonnes oil	4.04×10^{7}	4.04×10^{-8}	1.02×10^{10}	1.18×10^{4}	1.35×10^{-3}
kg coal	2.78×10^{4}	2.78×10^{-11}	7×10^{6}	8.14	9.29×10^{-7}
tonnes coal	2.78×10^{7}	2.78×10^{-8}	7×10^{9}	8139	9.29×10^{-4}
MCF gas	10^{6}	10^{-9}	2.52×10^{8}	293	3.35×10^{-5}
joules	9.48×10^{-4}	9.48×10^{-19}	0.239	2.78×10^{-7}	3.17×10^{-14}
EJ	9.48×10^{14}	0.948	2.39×10^{17}	2.78×10^{11}	3.17×10^{4}

	bbls oil equivalent	tonnes oil equivalent	kg coal equivalent	tonnes coal equivalent	MCF gas equivalent	joules	EJ
Btus	1.82×10^{-7}	2.48×10^{-8}	3.6×10^{-5}	3.6×10^{-8}	10^{-6}	1055	1.06×10^{-15}
quads	1.82×10^{8}	2.48×10^{7}	3.6×10^{10}	3.6×10^{7}	10^{9}	1.06×10^{18}	1.06
calories	7.21×10^{-10}	9.82×10^{-11}	1.43×10^{-7}	1.43×10^{-10}	3.97×10^{-9}	4.19	4.19×10^{-18}
kWh	6.20×10^{-4}	8.45×10^{-5}	0.123	1.23×10^{-4}	3.41×10^{-3}	3.6×10^{6}	3.6×10^{-12}
MWy	5435	740	1.08×10^{6}	1076	2.99×10^{4}	3.15×10^{13}	3.15×10^{-5}
bbls oil	1	0.136	198	0.198	5.50	5.80×10^{9}	5.80×10^{-9}
tonnes oil	7.35	1	1455	1.45	40.4	4.26×10^{10}	4.26×10^{-8}
kg coal	5.05×10^{-3}	6.88×10^{-4}	1	0.001	0.0278	2.93×10^{7}	2.93×10^{-11}
tonnes coal	5.05	0.688	1000	1	27.8	2.93×10^{10}	2.93×10^{-8}
MCF gas	0.182	0.0248	36	0.036	1	1.06×10^{9}	1.06×10^{-9}
joules	1.72×10^{-10}	2.35×10^{-11}	3.41×10^{-8}	3.41×10^{-11}	9.48×10^{-10}	1	10^{-18}
EJ	1.72×10^{8}	2.35×10^{7}	3.41×10^{10}	3.41×10^{7}	9.48×10^{8}	10^{18}	1