

Thermodynamics
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Work - Part 5

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- Other forms of work
 - Gravitational work: mgh
 - Shaft work: $T\theta = T(2\pi Nt)$ 
 - Electrical work: When a steady current I flows out of the system at point A and reenters at point B (Voltage $A > B$), the system is said to do positive electrical work
 $P = I \cdot V$ J/s; $W = IVt = I^2 R t$
 - Surface tension work: $\sigma \Delta A$ 
 - Spring work: If k is the spring constant (N/m), the force exerted by the spring = kx
 $W = 0.5kx^2$ 
 $\delta W = kx dx$
 $W = \int kx dx = \frac{kx^2}{2}$



There are forms of work other than displacement work: gravitational work, shaft work, electrical work, surface tension work and spring work.

Gravitational work

We looked at an example of gravitational work being done when we analyzed the case of a falling apple or a falling person. The gravitational work is given by the expression mgh , where m is the mass of the falling object, h is the distance or height through which the object falls and g is acceleration due to gravity. When the object is lowered in a gravity field, its energy reduces (the work is done by the object), whereas its energy increases when it is raised (work is done on the object).

Shaft work

If we apply torque T to a shaft which is free to rotate, it may rotate through some angle θ . Then, the shaft work is given as $T\theta$. $\theta = 2\pi Nt$ where N represents revolutions per second of the shaft and t is the time it rotates for. Hence, shaft work = $T(2\pi Nt)$.

Electrical work

When a steady current I flows out of the system at point A and reenters at point B, the system does a positive electrical work. The system could be a battery sending out current through a load. The system could be a load with resistance R . Below are given the expressions for the electrical work: $W_{\text{electrical}} = IVt = I^2Rt$, where I is the current flowing through the system, R is its resistance, V is the voltage which is causing the current I to flow and R is the resistance of the system ($V = IR$ according to Ohm's law). The choice of a formula to use depends on the system; for a battery, $W_{\text{electrical}} = IVt$ is more suitable, whereas for a resistor, $W_{\text{electrical}} = I^2Rt$ is a correct choice.

Surface tension work (liquids)

Surface tension tries to minimize the surface area of a liquid if disturbed from equilibrium condition. It resists the increase in surface area.

Let's look at an example. Consider a rectangular frame one side of which is movable, i.e. it can slide. Use soap solution to make a rectangular soap film which anchors on the four sides of the frame. Now, slide the movable side so that the area of the soap film increases. When you leave/free the movable side, it comes back to its original position (it slides inwards). This happens because surface tension opposes the increase in surface area of the liquid film and acts to minimize it. This work is given as $\sigma\Delta A$, where σ is the surface tension of the liquid and ΔA is the increase in surface area (caused by the movement of the movable side) of the liquid.

Spring work

A spring opposes its contraction or extension from its equilibrium position. When it is stretched or contracted from its un-stretched equilibrium position, work is done on the spring (work interaction for the spring is negative).

The force with which the spring opposes its contraction or extension is proportional to its displacement from the equilibrium position, $F \propto x$. We can write $F = kx$, where k is a spring constant. Work done by the spring can be obtained by integrating the expression $F = kx$ over the displacement of the spring (from its equilibrium position) as $\int_0^x F dx = \int_0^x kx dx = \frac{1}{2}kx^2$ (k is constant).

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- Quiz: What do the following mean?
- mPa, MPa
- mN, nm, N·m
- mj
- kJ, KJ
- Kg, kg
- sec ^s
- Cms ^{m s} ^{7m}
- The mass of the table is 5 apples & orange &



Figure 1

Writing correct units for different quantities is of utmost importance. It may lead to wrong calculations and eventually result in wrong answers of the numerical problems if appropriate units are not assigned to quantities. The cost is even higher if this happens in actual practice.

Let's try to figure out what the units in Fig. 1 represent.

1. mPa – millipascal, MPa – megapascal (The symbol or the first letter of the symbol is an upper-case letter when the name of the unit is derived from the name of a person, e.g., pascal is named after Louie Pascal.)
2. mN – millinewton, nm – nanometer, $N \cdot m$ – newton meter (Symbols for units formed from other units by multiplication are indicated by means of either a half-high (that is, centered) dot, e.g., $N \cdot m$.)
3. mj – m could be for milli, j is for? (it is not millijoule)
4. kJ – kilojoule, KJ – Kelvin joule
5. Kg – Kelvin gram, kg –kilogram
6. sec – s could be for second, e and c are for?
7. Cms – m and s could be for meter and second, C is for (Unit symbols are unaltered in plural, e.g., cms does not mean centimeters.)

Students are encouraged to go through the **Guide for the Use of the International System of Units (SI) from NIST** for more information. It is freely available.

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- Tips for thermodynamics students

- Pay attention to the definitions

$$\delta W = PdV$$
$$W = mgh$$

- Quasi-static is an important word
- Understand the exact meaning of properties or you may be working on an inexact path!
- Mathematics gives you numbers. Physics tells you what the numbers may mean. Understand the difference

- Most students who get low grades in this course are those who mess up with units!

$$\text{bar}$$
$$\text{ka}$$
$$\text{am}$$



Few important points/definitions to remember:

1. Definitions of a quasi-static process, a property, exact and inexact differentials
2. Math gives you a number. Physics gives meaning to it. (In the example of the apple falling on Newton's head, we can write *gravitational work* = mgh . Math gives us a number. However, we know that the work interaction is zero in that case. Physics gives meaning to numbers.)
3. Do not mess up with units.