



INTRODUCTION

The word Thermodynamics means heat power , or power developed from heat, reflecting its origin in the analysis of steam engines .As a fully developed modern science , thermodynamics deals with transformations of energy of all kinds from one form to another.

Among the most important are determination of heat and work requirements for physical and chemical reactions and for the transfer of chemical species between phases.

Thermodynamics



DIMENSIONS AND UNITS

Primary units have been set by international agreement, and are codified as the International System of Units ,SI.

Quantity	Unit	Symbol
Time	Second	s
Length	Meter	m
Mass	Kilogram	Kg
Temperature	Kelvin	°K
Amount of substance	Mole	mol

MEASURES OF AMOUNT OR SIZE

Three measures of amount or size are in common use:

- Mass, m ■ Number of moles, n and ■ Total volume, V^t .

Numbers of moles yield from : $n = \frac{m}{M}$, where M is molecular weight



Total volume, representing the size of a system, is a defined quantity given as the product of three lengths. It may be divided by the mass or number of moles of the system to yield *specific* or molar volume:

❖ Specific volume $V = \frac{V^t}{m}$

❖ Molar volume $V = \frac{V^t}{n}$

Specific or molar density is defined as the reciprocal of specific or molar volume: $p = V^{-1}$. These quantities (V and p) are independent of the size of a system, and are examples of intensive thermodynamic variables. They are functions of the temperature, pressure, and composition of a system, additional quantities that are independent of system size.

Force

The force unit is Newton , symbol ,N ,The Newton is defined as the force which when applied to a mass of 1 kg produces an acceleration of 1 m s^{-2} ; thus the Newton is a *derived* unit representing 1 kg m s^{-2}

$$F = m a$$

The kilogram force is equivalent to 9.806 65 N. ($1 \text{ Newton} = \text{Kg} . \text{m} . \text{s}^{-1}$)

In the metric engineering system of units, force is treated as an additional independent dimension along with length, time, and mass. The kilogram force(kg^f) is defined as that force which accelerates 1 kilogram mass 9.806 65 meters per second per second .

$$F = \frac{1}{g_c} m a$$

where

$$1 \text{Kg}^f = \frac{1}{g_c} \times 1 \text{Kg} \times 9.8 \text{m} . \text{s}^{-1}$$

And $g_c = 9080665 \text{ Kg.m.Kg f}^{-1} \text{s}^{-2}$



Weight properly refers to the force of gravity on a body, and is therefore correctly expressed in Newton's or in kilograms force.

Temperature

Temperature is degree of hotness, and it is commonly measured with liquid-in-glass thermometers, wherein the liquid expands when heated. Thus a uniform tube, partially filled with mercury, alcohol, or some other fluid, can indicate degree of "hotness" simply by the length of the fluid column. However, numerical values are assigned to the various degrees of hotness by arbitrary definition.

$$t^{\circ}C = T^{\circ}K - 273.15$$

$$t^{\circ}F = T^{\circ}R - 459.67$$

$$T^{\circ}R = 1.8T^{\circ}K$$

Example 1.1

An astronaut weighs 730 N in Houston, Texas, where the local acceleration of gravity is $g = 9.792 \text{ m s}^{-2}$. What are the astronaut's mass and weight on the moon, where $g = 1.67 \text{ m s}^{-2}$?

Solution 1.1

With $a = g$, Newton's law is: $F = mg$. Whence,

$$m = \frac{F}{g} = \frac{730 \text{ N}}{9.792 \text{ m s}^{-2}} = 74.55 \text{ N m}^{-1} \text{ s}^2$$

Since the newton N has the units kg m s^{-2} ,

$$m = 74.55 \text{ kg}$$

This *mass* of the astronaut is independent of location, but *weight* depends on the local acceleration of gravity. Thus on the moon the astronaut's weight is:

$$F(\text{moon}) = mg(\text{moon}) = 74.55 \text{ kg} \times 1.67 \text{ m s}^{-2}$$

or
$$F(\text{moon}) = 124.5 \text{ kg m s}^{-2} = 124.5 \text{ N}$$



PRESSURE

The pressure P exerted by a fluid on a surface is defined as the normal force exerted by the fluid per unit area of the surface. The unit used is called Pascal , symbol Pa (N.m^{-2}) . In the metric engineering system a common unit is the kilogram force per square centimeter (kgf cm^{-2}). The primary standard for pressure measurement is the dead-weight gauge in which a known force is balanced by a fluid pressure acting on a known area

$$P = \frac{F}{A} = \frac{mg}{A}$$

Where m is mass , g local acceleration , and A is the cross sectional area . Gauges in common use, such as Bourdon gauges, are calibrated by comparison with dead-weight gauges.

Since a vertical column of a given fluid under the influence of gravity exerts a pressure at its base in direct proportion to its height This is the basis for the use of manometers for pressure measurement. Conversion of height to force per unit area follows from Newton's law applied to the force of gravity acting on the mass of fluid in the column. The mass is given by:

$$P = \frac{F}{A} = \frac{mg}{A} = \frac{Ah \rho g}{A} = \rho gh$$

The pressure to which a fluid height corresponds is determined by the density of the fluid (which depends on its identity and temperature) and the local acceleration of gravity. Thus the (torr) is the pressure equivalent of 1 millimeter of mercury at 273.15 K (0°C) in a standard gravitational field, and is equal to 133.322 Pa.

Another unit of pressure is the standard atmosphere (atm), the approximate average pressure exerted by the earth's atmosphere at sea level, defined as 101 325 Pa, 101.325 kPa, or 0.101 325 MPa. The bar, an SI unit defined as 10^5 Pa, is equal to 0.986 923 atm.

Most pressure gauges give readings which are the difference between the pressure of interest and the pressure of the surrounding atmosphere. These readings are known as gauge pressures, and can be converted to absolute pressures by addition of the barometric pressure. Absolute pressures must be used in thermodynamic calculations.



Example 1.2

A dead-weight gauge with a 1-cm-diameter piston is used to measure pressures very accurately. In a particular instance a mass of 6.14 kg (including piston and pan) brings it into balance. If the local acceleration of gravity is 9.82 m s^{-2} , what is the *gauge* pressure being measured? If the barometric pressure is 748 (torr), what is the *absolute* pressure?

Solution 1.2

The force exerted by gravity on the piston, pan, and weights is:

$$F = mg = (6.14)(9.82) = 60.295 \text{ N}$$

$$\text{Gauge pressure} = \frac{F}{A} = \frac{60.295}{(1/4)(\pi)(0.01)^2} = 76.77 \text{ N m}^{-2}$$

The absolute pressure is therefore:

$$P = (76.77)(10^4) + (748)(0.013 332)(10^4) = 86.74 \times 10^4 \text{ N m}^{-2} = 867.4 \times 10^3 \text{ Pa}$$

or

$$P = 867.4 \text{ kPa}$$

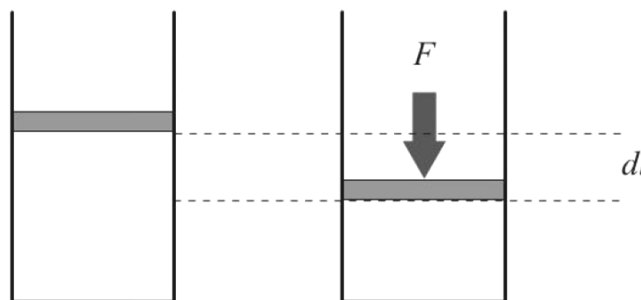
WORK

Work W is performed whenever a force acts through a distance. By definition, the quantity of work is given by the equation:

$$dW = Fdl$$

where F is the component of force acting along the line of the displacement dl .

The work which accompanies a change in volume of a fluid is often encountered in thermodynamics





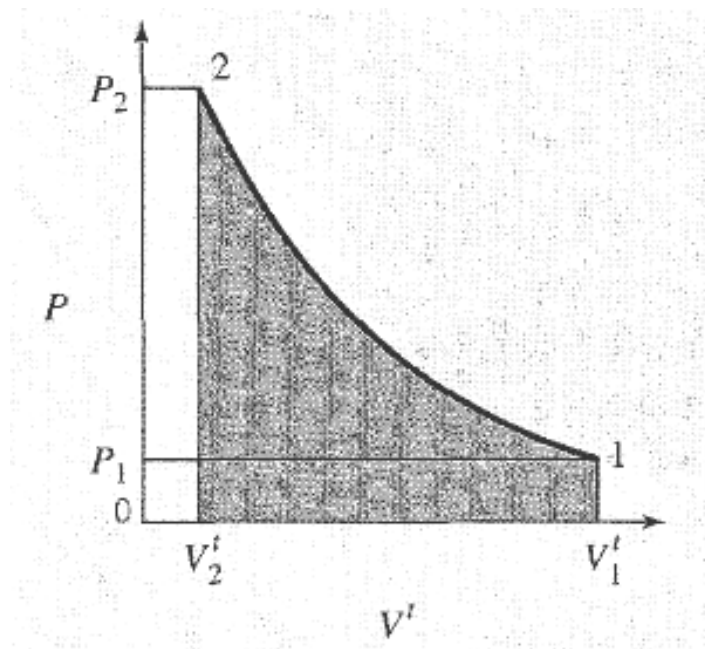
$$dW = -pAd \frac{V}{A}$$

$$dW = -pdV \quad \text{since } A \text{ is constant}$$

$$dW = - \int_{V_1}^{V_2} P dV$$

The minus sign is required because the volume change is negative.

The above equation expresses the work done by a finite compression or expansion process. Figure below shows a path for compression of a gas from point 1 with initial volume V_1 at pressure P_1 to point 2 with volume V_2 at pressure P_2 . This path relates the pressure at any point of the process to the volume. The work required is given by equation and is proportional to the area under the curve of Fig. The SI unit of work is the newton-meter or joule, symbol J. In the metric engineering system the unit often used is the meter-kilogram force (m kgf).





ENERGY

Kinetic Energy

When a body of mass m , acted upon by a force F , is displaced a distance dl during differential interval of time dt ,

$$dW = madl$$

By definition the acceleration is $a = du/dt$, where u is the velocity of the body. Thus

$$dW = m \frac{du}{dt} dl = m \frac{dl}{dt} du = mudu$$

$$W = m \int_{u_1}^{u_2} u du = m \left(\frac{u_2^2}{2} - \frac{u_1^2}{2} \right) = \Delta \left(\frac{mu^2}{2} \right)$$

Each of quantities $\frac{1}{2} mu^2$ is a kinetic energy

$$E_K = \frac{1}{2} mu^2$$

Potential Energy

If a body of mass m is raised from an initial elevation z_1 to a final elevation z_2 , an upward force at least equal to the weight of the body must be exerted on it, and this force must move through the distance $z_2 - z_1$

$$W = F(z_2 - z_1) = mg(z_2 - z_1)$$

$$E_P = mzg$$

- Kinetic energy, E_k
 motion of the system as a whole
- Potential energy, E_p
 position of the system in a potential field
 - gravity field
 - electric field
 - magnetic field



Energy Conservation

In any examination of physical processes, an attempt is made to find or to define quantities which remain constant regardless of the changes which occur. One such quantity, early recognized in the development of mechanics, is mass. The great utility of the law of conservation of mass suggests that further conservation principles could be of comparable value. Thus the development of the concept of energy logically led to the principle of its conservation in mechanical processes. If a body is given energy when it is elevated, then the body conserves or retains this energy until it performs the work of which it is capable. An elevated body, allowed to fall freely, gains in kinetic energy what it loses in potential energy so that its capacity for doing work remains unchanged. For a freely falling body this means that:

$$\Delta E_K + \Delta K_p = 0$$

$$\frac{mu_2^2}{2} - \frac{mu_1^2}{2} + mz_2g - mz_1g = 0$$

The validity of this equation has been confirmed by countless experiments. Success in application to freely falling bodies led to the generalization of the principle of energy conservation to apply to all purely mechanical processes. Ample experimental evidence to justify this generalization was readily obtained.

HEAT

We know from experience that a hot object brought in contact with a cold object becomes cooler, whereas the cold object becomes warmer. Thus we say that heat Q always flows from a higher temperature to a lower one. That means the temperature difference is a driving force for transfer of energy as heat. When energy in the form of heat is added to a body, it is stored not as heat but as kinetic and potential energy of the atoms and molecules making up the body. The British thermal unit (Btu) quantity of heat which when transferred to one pound mass of water raised its temperature from ice-point or 32 °F to steam-point or 212 °F at standard atmospheric pressure. Likewise the calorie written as (cal), was defined as quantity of heat which when transferred to one kilogram mass of water raised its temperature from 0 to 100°C at standard atmospheric pressure.