forms of energy

Energy can exist in numerous forms such as thermal, mechanical, kinetic, potential, electric, magnetic, chemical, and nuclear, and their sum constitutes the total energy E of a system. The total energy of a system on a *unit mass* basis is denoted by e and is expressed as

$$e = \frac{E}{m} \qquad \text{(kJ/kg)}$$

The **macroscopic** forms of energy are those a system possesses as a whole with respect to some outside reference frame, such as kinetic and potential energies The macroscopic energy of a system is related to motion and the influence of some external effects such as gravity, magnetism, electricity, and surface tension.. The **microscopic** forms of energy are those related to the molecular structure of a system and the degree of the molecular activity, and they are independent of outside reference frames. The sum of all the microscopic forms of energy is called the **internal energy** of a system and is denoted by U

The energy that a system possesses as a result of its motion relative to some reference frame is called **kinetic energy (KE).** When all parts of a system move with the same velocity, the kinetic energy is expressed as

$$\text{KE} = m\frac{V^2}{2} \qquad \text{(kJ)}$$

$$\text{ke} = \frac{V^2}{2} \qquad \text{(kJ/kg)}$$

where V denotes the velocity of the system relative to some fixed reference frame. The kinetic energy of a rotating solid body is given by $\frac{1}{2}I\omega^2$

where I is the moment of inertia of the body and ω is the angular velocity.

EXAMPLE 2–9 Power Needs of a Car to Accelerate

Determine the power required to accelerate a 900-kg car shown in Fig. 2–38 from rest to a velocity of 80 km/h in 20 s on a level road.

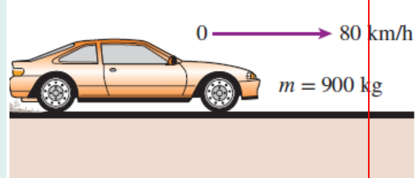
SOLUTION The power required to accelerate a car to a specified velocity is to be determined.

Analysis The work needed to accelerate a body is simply the change in the kinetic energy of the body,

$$W_a = \tfrac{1}{2}m(V_2^2 - V_1^2) = \tfrac{1}{2}(900\ \text{kg})\left[\left(\frac{80{,}000\ \text{m}}{3600\ \text{s}}\right)^2 - 0^2\right]\left(\frac{1\ \text{kJ/kg}}{1000\ \text{m}^2/\text{s}^2}\right)$$
$$= 222\ \text{kJ}$$

The average power is determined from

$$\dot{W}_a = \frac{W_a}{\Delta t} = \frac{222\ \text{kJ}}{20\ \text{s}} = \mathbf{11.1\ kW} \qquad \text{(or 14.9 hp)}$$



Discussion This is in addition to the power required to overcome friction, rolling resistance, and other imperfections.

The energy that a system possesses as a result of its elevation in a gravitational field is called **potential energy (PE)** and is expressed as

$$\mathrm{PE} = mgz \qquad (\mathrm{kJ})$$

$$\mathrm{pe} = gz \qquad (\mathrm{kJ/kg})$$

where g is the gravitational acceleration and z is the elevation of the center of gravity of a system relative to some arbitrarily selected reference level.

The magnetic, electric, and surface tension effects are significant in some specialized cases only and are usually ignored. In the absence of such effects, the total energy of a system consists of the kinetic, potential, and internal energies and is expressed as

$$E = U + \mathrm{KE} + \mathrm{PE} = U + m\frac{V^2}{2} + mgz \qquad (\mathrm{kJ})$$

Closed systems whose velocity and elevation of the center of gravity remain constant during a process are often referred to as stationary systems.

The change in the total energy ΔE of a stationary system is identical to the change in its internal energy ΔU.

Control volumes typically involve fluid flow for long periods of time, and it is convenient to express the energy flow associated with a fluid stream inthe rate form. This is done by incorporating the **mass flow rate** $\dot{m}$, which is *the amount of mass flowing through a cross section per unit time.* It is related to the **volume flow rate** $\dot{V}$, which is the volume of a fluid flowing through a cross section per unit time, by

$$\dot{m} = \rho \dot{V} = \rho A_c V_{\mathrm{avg}} \qquad (\mathrm{kg/s})$$

which is analogous to $m = \rho V$. Here ρ is the fluid density, *Ac* is the cross sectional area of flow, and V_{avg} is the average flow velocity normal to *Ac*. The dot over a symbol is used to indicate *time rate*.

Energy flow rate: $\dot{E} = \dot{m}e \qquad$ (kJ/s or kW)

which is analogous to $E = me$.

Internal energy was defined earlier as the sum of all the *microscopic* forms of energy of a system. It is related to the *molecular structure* and the degree of *molecular activity* and can be viewed as the sum of the *kinetic* and *potential* energies of the molecules.

The portion of the internal energy of a system associated with the **kinetic energies of the molecules is called the sensible energy**

The internal energy associated with the **phase** of a system is called the **latent energy**

The mechanical energy

The mechanical energy can be defined as the form of ***energy*** that can be converted to mechanical work completely and directly by an ideal mechanical device such as an ideal turbine

Kinetic and potential energies are the familiar forms of mechanical energy. Thermal energy is not mechanical energy, however, since it cannot be converted to work directly and completely (the second law of thermodynamics).

the pressure unit Pa is equivalent to

Pa = $N/m^2 = N \cdot m/m^3 = J/m^3$, which is energy per unit volume, and the product

Pv* or its equivalent *P*/*ρ has the unit J/kg, which is energy per unit mass.

Note that pressure itself is not a form of energy, but a pressure force acting

on a fluid through a distance produces work, called *flow work*

Therefore, the mechanical energy of a flowing fluid can be expressed on a unit mass basis as

$$e_{mech} = \frac{P}{\rho} + \frac{V^2}{2} + gz$$

where P/ρ is the *flow energy,*

$V^2/2$ is the *kinetic energy,*

and gz is the *potential energy*

$$\dot{E}_{\text{mech}} = \dot{m}e_{\text{mech}} = \dot{m}\left(\frac{P}{\rho} + \frac{V^2}{2} + gz\right)$$

where $\dot{m}$ is the mass flow rate of the fluid. Then the mechanical energy **change** of a fluid during incompressible (ρ = constant) flow becomes

$$\Delta e_{\text{mech}} = \frac{P_2 - P_1}{\rho} + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1) \qquad \text{(kJ/kg)}$$

and

$$\Delta \dot{E}_{\text{mech}} = \dot{m}\,\Delta e_{\text{mech}} = \dot{m}\left(\frac{P_2 - P_1}{\rho} + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1)\right) \qquad \text{(kW)}$$

ENERGY TRANSFER BY HEAT

Heat is defined as *the form of energy that is transferred between two systems (or a system and its surroundings) by virtue of a temperature difference*

$$q = \frac{Q}{m} \qquad \text{(kJ/kg)}$$

heat has energy units, kJ

Heat is transferred by three mechanisms: **Conduction**, **Convection**, and **Radiation.**

ENERGY TRANSFER BY WORK

work is the energy transfer associated with a force acting through a distance. A rising piston, a rotating shaft, and an electric wire crossing the system boundaries are all associated with **work** interactions. Work is also a form of energy transferred like heat and, therefore, has energy units such as kJ. The work done during a process between states 1 and 2 is denoted by *W*12, or simply *W*. The work done *per unit mass* of a system is

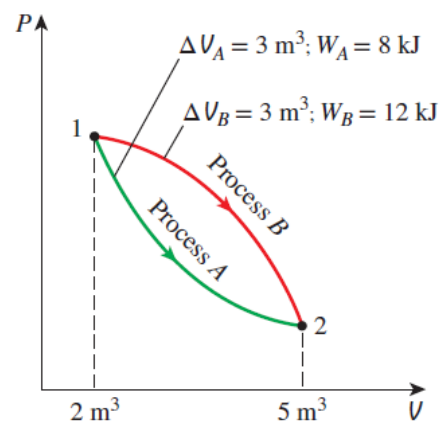
denoted by *w* and is expressed as

$$w = \frac{W}{m} \qquad \text{(kJ/kg)}$$

The work done *per unit time* is called **power** and is denoted $\dot{W}$

The unit of power is kJ/s, or kW

Heat and work are *directional quant**ities*



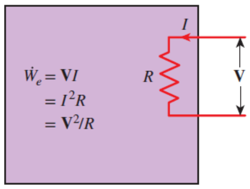
Electrical Work

lectrons crossing the system boundary do electrical work on the system.

$$\dot{W}_e = \mathbf{V}I \qquad \text{(W)}$$

where $\dot{W}_e$ is the **electrical power** and ***I*** is the number of electrical charges flowing per unit time, that is, the *current* both **V** and *I* vary with time, and the electrical work done during a time interval Δt is expressed as

$$W_e = \mathbf{V}I\,\Delta t \qquad \text{(kJ)}$$



When both **V** and *I* remain constant during the time interval Δt

MECHANICAL FORMS OF WORK

He work done by a constant force *F* on a body displaced a distance *s* in the direction of the force is gi\

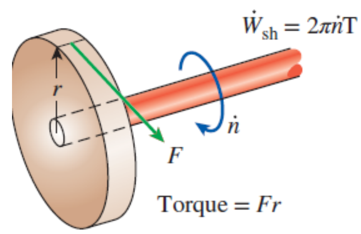
$$W = Fs \qquad \text{(kJ)}$$

There are two requirements for a work interaction between a system and its surroundings to exist: (1) there must be a *force* acting on the boundary, and (2) the boundary must *move.* Therefore, the presence of forces on the boundary without any displacement of the boundary does not constitute a work interaction.

Shaft Work

A force *F* acting through a moment arm *r* generates a torque T of

$$\mathrm{T} = Fr \quad \rightarrow \quad F = \frac{\mathrm{T}}{r}$$



This force acts through a distance *s*, which is related to the radius *r* by

$s = (2\pi r)n$

Then the shaft work is determined from

$$W_{sh} = Fs = \left(\frac{\mathrm{T}}{r}\right)(2\pi rn) = 2\pi n\mathrm{T} \qquad \text{(kJ)}$$

The power transmitted through the shaft is the shaft work done per unit time, which can be expressed as

$$\dot{W}_{sh} = 2\pi\dot{n}\mathrm{T} \qquad \text{(kW)}$$

where $\dot{n}$ is the number of revolutions per unit time