Ministry of Higher Education
Higher Institute for Engineering and Technology at Manzala
Electronics Engineering Dept.

Thermodynamics and Heat Transfer (MEC121)

Lecture 2: Basic Concepts of Thermo.

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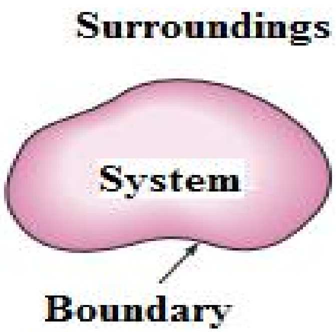
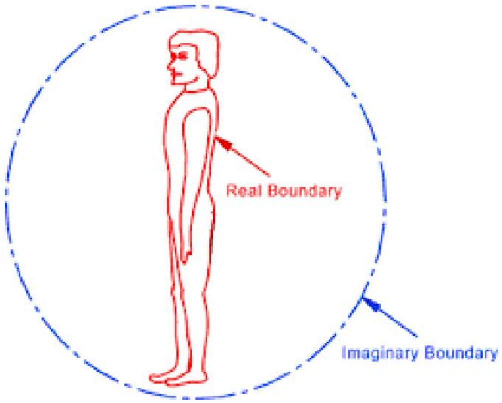
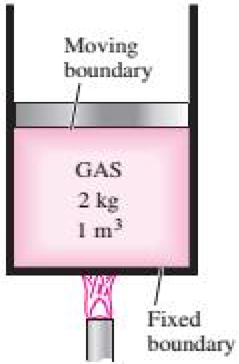
Thermodynamic System

- **A system** is defined as a quantity of matter or a region in space chosen for study.
- The mass or region outside the system is called the **surroundings**.
- The real or imaginary surface that separates the system from its surroundings is called the **boundary**.

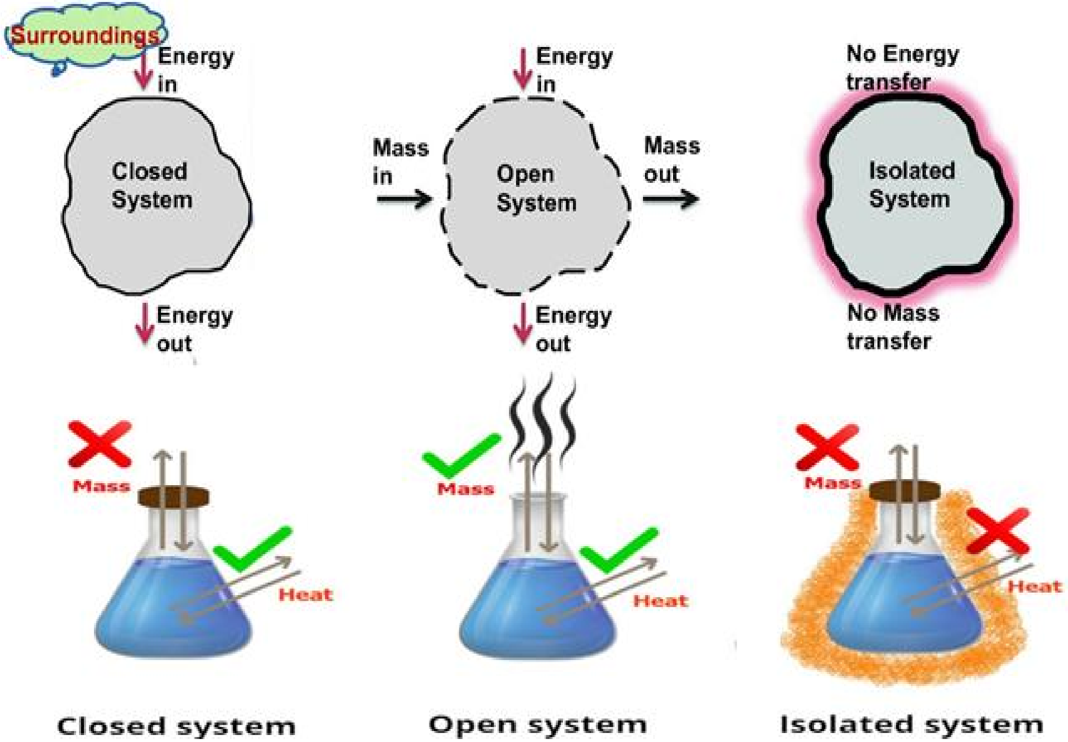




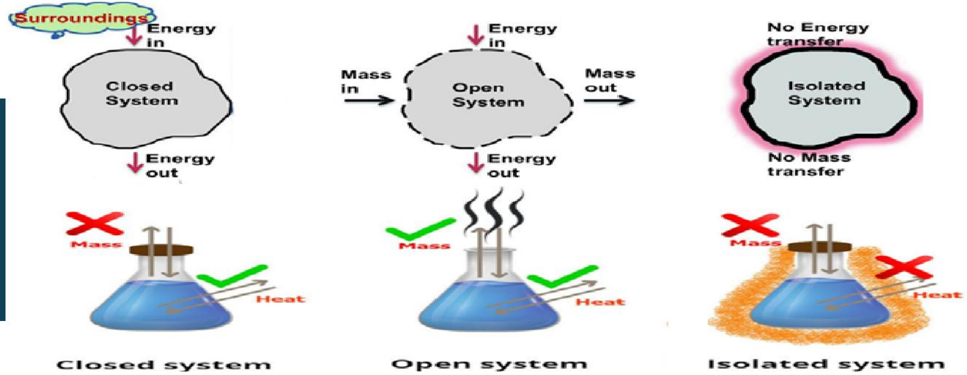
Types of Boundaries
- Moving
- Fixed



Thermodynamic Systems Types



Types of Thermodynamic Systems



- **Closed System**: no matter may enter or leave, however, energy can enter or leave it.

$$\text{Mass interaction} = 0$$
$$\text{Energy interaction} \neq 0$$

- **Open System**: matter and energy flows into or out of the system. Most of the engineering systems are of the open type.

$$\text{Mass interaction} \neq 0$$
$$\text{Energy interaction} \neq 0$$

- **Isolated (Insulated) System**: Neither matter nor energy is exchanged between this system and any other system or with environment.

$$\text{Mass interaction} = 0$$
$$\text{Energy interaction} = 0$$

Properties of System

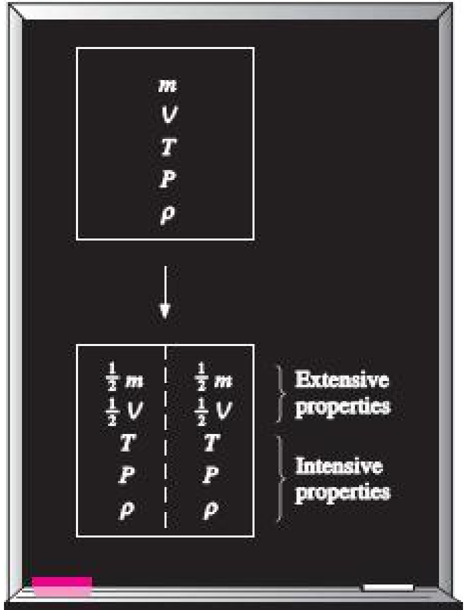
- Any characteristic of a system is called a **property**.
- Some familiar properties are pressure p, temperature T, volume V, and mass m.

هناك بعض الخواص المتعارف عليها (المعتاد أستخدامهم)

- The list can be extended to include less familiar ones such as viscosity, thermal conductivity, and even velocity and elevation. و هناك بعض الخواص الأقل أستخداما مثل

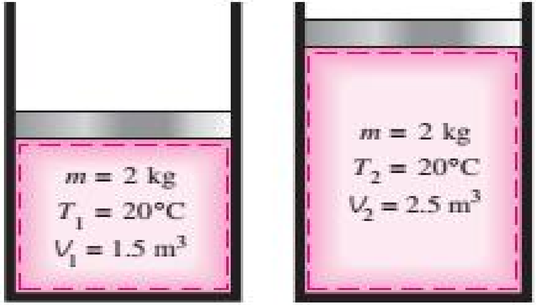
Types of Properties

- **Intensive properties:** independent of the mass of the system, such as T, p and ρ.
- **Extensive properties:** depend on the mass of the system, such as V.



State and Equilibrium

- The **state** of a system at any given **instant** is determined by the values of its **properties** at that instant.



(*a*) State 1 (*b*) State 2

- At any **state**, all the properties of a system have fixed values. If the value of one property changes, the state will change to a different one.

- **Two properties** are necessary and sufficient to define the **state** of a system (should be independent, intensive properties). لازم خاصيتين غير مرتبطين

State and Equilibrium

- Thermodynamics deals with **equilibrium** states.

- A system is not in **thermodynamic equilibrium** unless the conditions of all the types of equilibrium are satisfied: لايقال على النظام أنه فى حالة أتزان ألا أذا حقق كل أنواع الأتزان

   i. **Thermal equilibrium** if the temperature is the same throughout the entire system.

   ii. **Mechanical equilibrium** if there is no change in pressure at any point of the system with time.

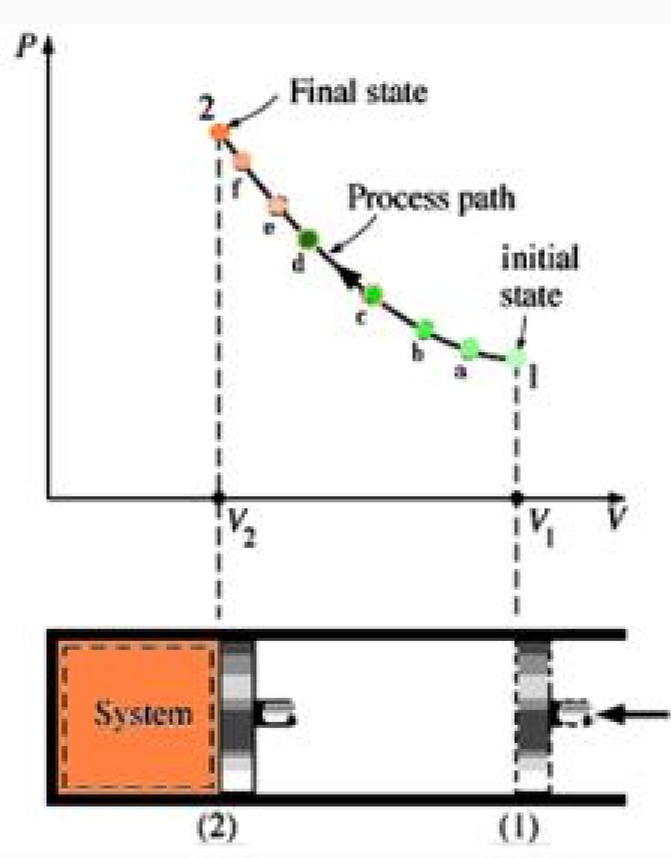
   iii. **Chemical equilibrium** if its chemical composition does not change with time (no chemical reactions occur).

Thermodynamic Process

- Any change that a system undergoes from one equilibrium state to another is called a **process**.

لتغير الذى يحدث فى النظام من حالة الى حالة أخرى

The Process can be plotted by employing thermodynamic properties such as temperature T, pressure P, and volume V (or specific volume **v**).



Energy & Power

- Scientists define **energy** as the ability to do work.
- **Energy units:**
  - √ Total energy (E) is Joule (J)
  - √ Specific energy (e) is joule per kilogram (J/kg)

Types of Energy

Energy of the system

Energy transferred through system boundary

Energy of the system (e)

Heat, work, electrical, etc.

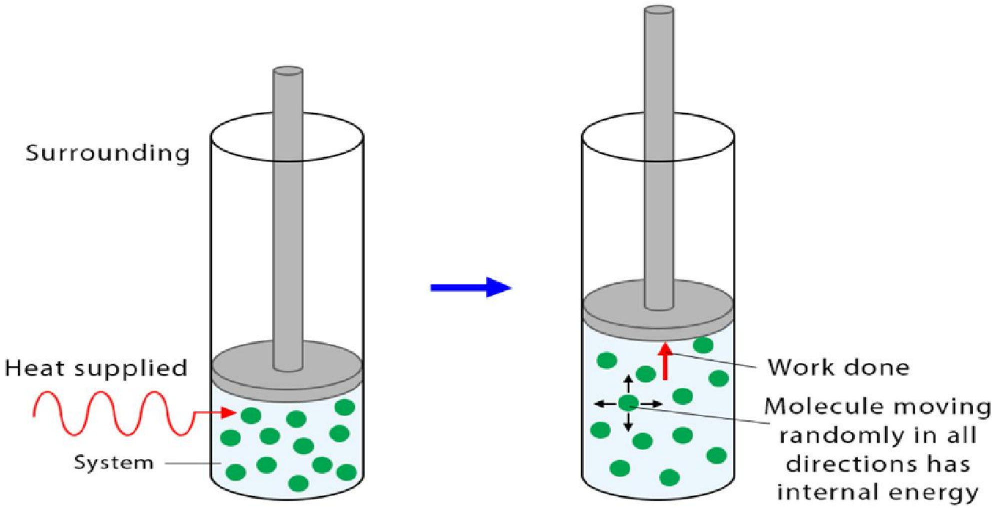
Energy of the System

- The **energy of the system (E)** consists of three terms: internal energy (U), kinetic energy (KE), and potential energy (PE).
- **Internal Energy (U)**:

The sum of the kinetic energy and potential energy of all molecules in a matter.

U is in **J** units.

$$\boxed{u = \frac{U}{m} \quad \left(\frac{\mathbf{J}}{\mathbf{kg}}\right)} \quad \ldots\ldots\ldots\ldots \text{(12)}$$



Energy of the System

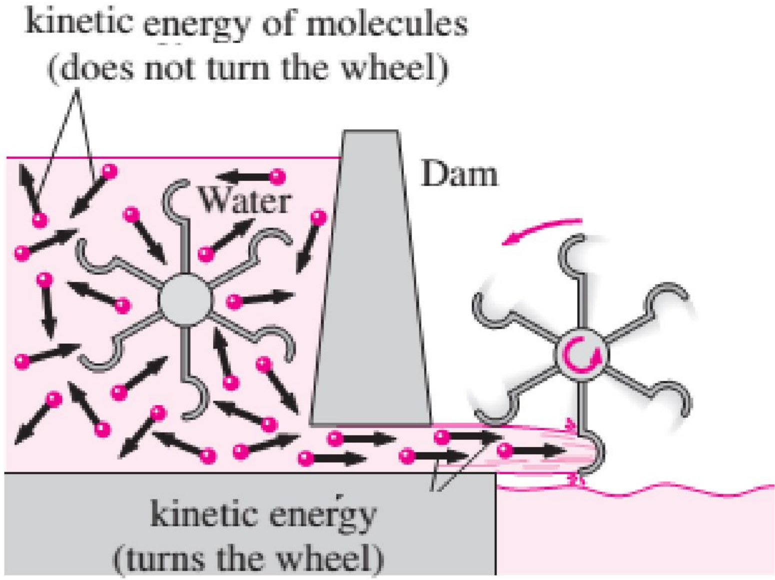
- **Kinetic Energy (KE):**

The energy possessed by an object in motion.

الطاقة التى يمتلكها جسم متحرك

$$\boxed{KE = m\frac{v^2}{2} \quad (J)} \quad \ldots\ldots\ldots \quad (13)$$

$$\boxed{ke = \frac{KE}{m} = \frac{v^2}{2}\left(\frac{J}{kg}\right)} \quad \ldots\ldots \quad (14)$$



Energy of the System

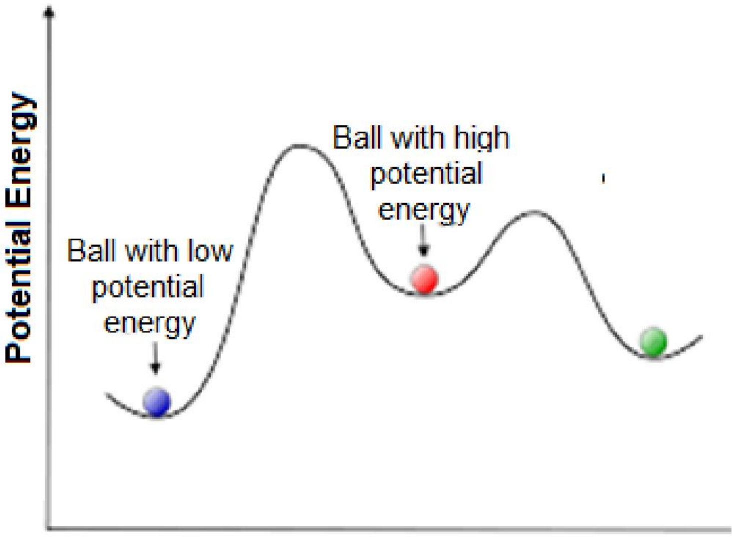
- **<u>Potential Energy (PE)</u>:**

The energy possessed by an object positioned at an elevation from the sea level.

الطاقة التى يمتلكها جسم موجود على أرتفاع معين من سطح البحر

$$\boxed{PE = mgz \quad (J)} \;\dots\dots\dots \; (15)$$

$$\boxed{pe = \frac{PE}{m} = gz \quad \left(\frac{J}{kg}\right)} \;\dots\dots \; (16)$$



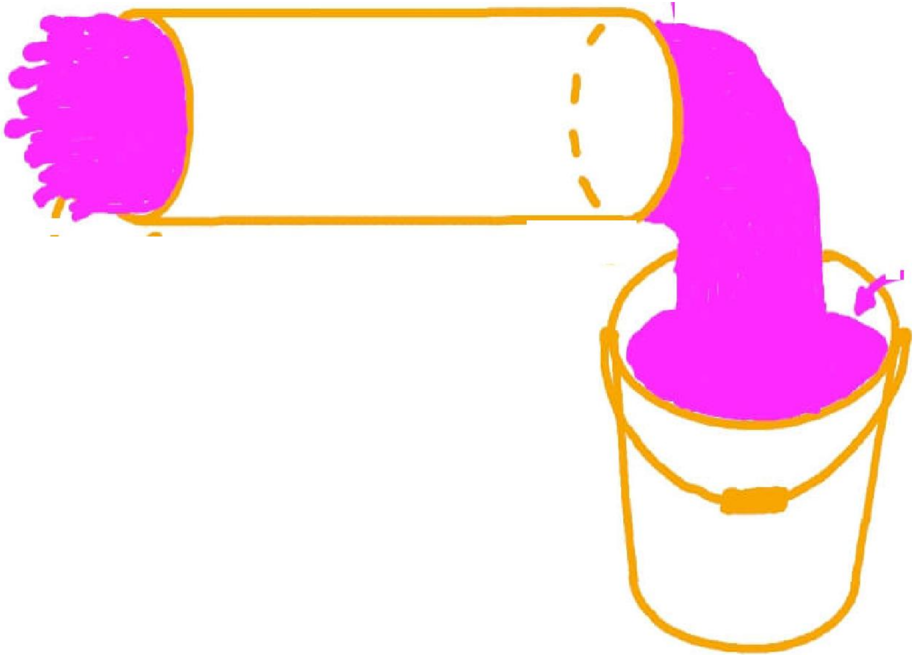
Power

Power and **rate of energy** are written in **J/s** or **W** units.

Power (rate of energy) = $\dot{m}\ e$

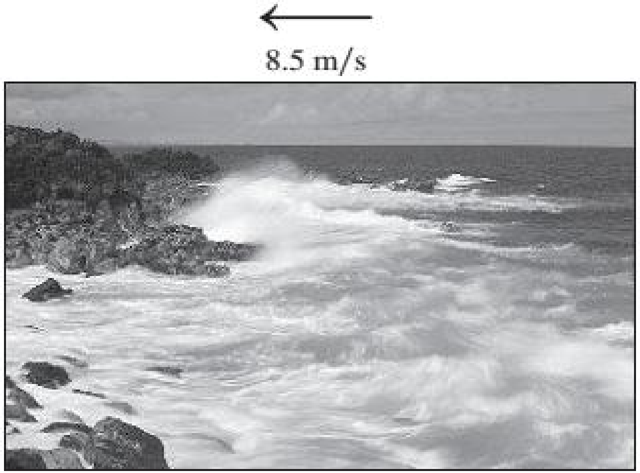
$$\boxed{\dot{E} = \dot{m}.e \quad \mathbf{(W)}}$$

where $\dot{m}$ is the mass flow rate (kg/s)



Example

A site evaluated for a wind farm has steady winds at a speed of 8.5 m/s (see the figure below). Compute the wind energy (a) per unit mass, (b) for a mass of 10 kg, and (c) per second for a flow rate of 1154 kg/s for air.



Example

(*a*) Wind energy per unit mass of air is

$$e = \mathrm{ke} = \frac{V^2}{2} = \frac{(8.5\ \mathrm{m/s})^2}{2}\left(\frac{1\ \mathrm{J/kg}}{1\ \mathrm{m^2/s^2}}\right) = \mathbf{36.1\ J/kg}$$

(*b*) Wind energy for an air mass of 10 kg is

$$E = me = (10\ \mathrm{kg})(36.1\ \mathrm{J/kg}) = \mathbf{361\ J}$$

(*c*) Wind power (energy per unit time) for a mass flow rate of 1154 kg/s is

$$\dot{E} = \dot{m}e = (1154\ \mathrm{kg/s})(36.1\ \mathrm{J/kg})\left(\frac{1\ \mathrm{kW}}{1000\ \mathrm{J/s}}\right) = \mathbf{41.7\ kW}$$

Discussion It can be shown that the specified mass flow rate corresponds to a 12-m diameter flow section when the air density is 1.2 kg/m^3. Therefore, a wind turbine with a wind span diameter of 12 m has a power generation potential of 41.7 kW. Real wind turbines convert only about one-third of this potential to electric power, due to inefficiencies.

Example

Consider a river flowing toward a lake at an average velocity of 3 m/s at a rate of 500 m^3/s at a location 90 m above the lake surface. **Determine** the total energy of the river water per unit mass and the potential power of the entire river at that location.

(Ans. 887.4 J/kg, 441.45 MW)

Energy Transferred Through System Boundary

Types of Energy

Energy of the system

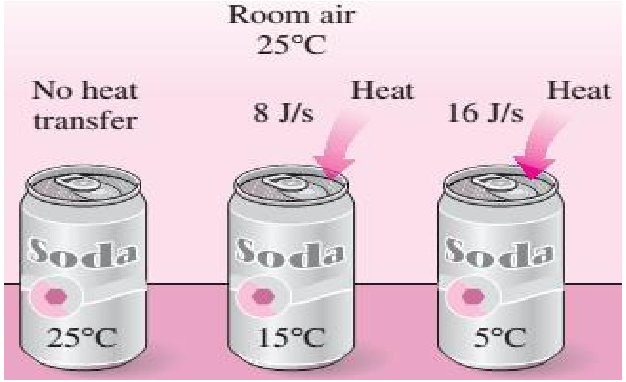
Energy transferred through system boundary

Energy of the system (e)

Heat, work, electrical, etc.

- **Heat (Q):**

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

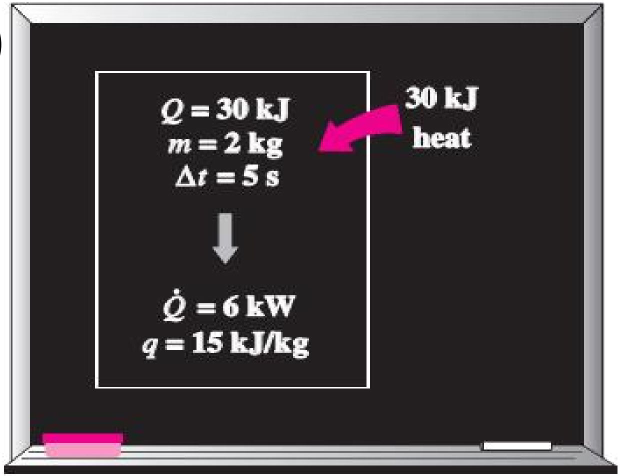


Energy of the System (Heat)

- The transfer of heat into a system is frequently referred to as **heat addition** and the transfer of heat out of a system as **heat rejection**.
- Heat transfer per unit mass of a system is denoted q and is determined from:

$$\boxed{q = \frac{Q}{m} \quad \left(\frac{J}{kg}\right)} \;\ldots\ldots\ldots\ldots (17)$$

- The rate of heat transfer, $\dot{Q}$ (the amount of heat transferred per unit time) is used instead of the total heat transferred over some time interval, Q.
- The heat transfer rate $\dot{Q}$ has the unit kJ/s, which is equivalent to kW.



Energy of the System (Work)

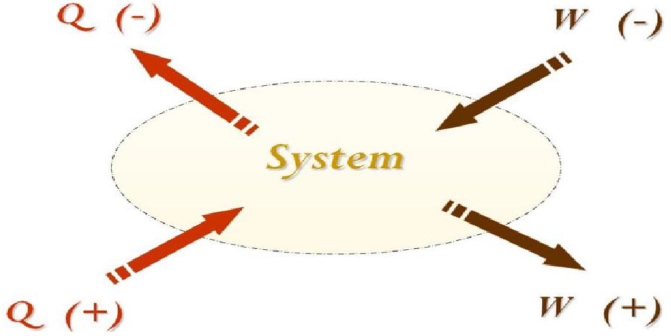
- **<u>Work (W)</u>:**

work is the energy transfer associated with a force acting through a distance.

$$\boxed{w = \frac{W}{m} \quad \left(\frac{J}{kg}\right)} \quad \ldots\ldots\ldots (18)$$

- The work done per unit time is called power and is denoted $\dot{W}$. The unit of power is J/s, or W.

- Heat and work are directional quantities, and thus the complete description of a heat or work requires the specification of both the **<u>magnitude and direction</u>**.



Energy of the System

- For example, a work input of 5 kJ can be expressed as W = -5 kJ, while a heat loss of 3 kJ can be expressed as Q = -3 kJ.

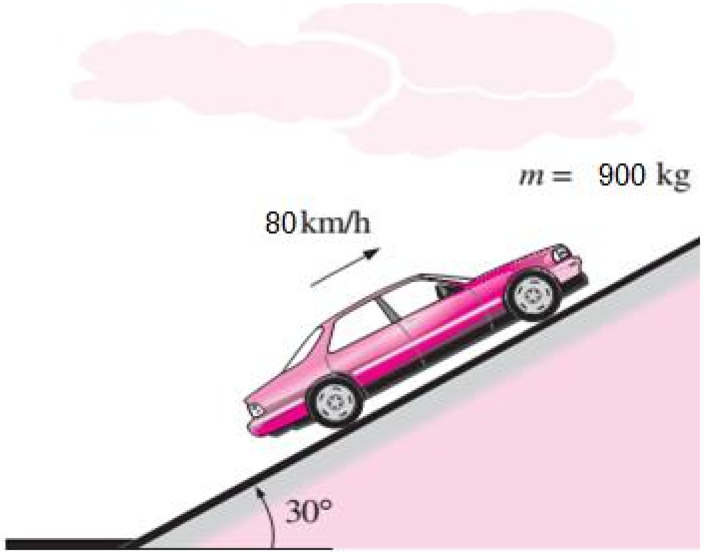
✓ **Heat and work are recognized at the boundaries of a system as they cross the boundaries.**

✓ **Neither heat nor work can be possessedيمتلك by a system. Systems possess energy, but not heat or work.**

✓ **Heat and work are associated with مصاحب ل a process. Unlike properties, heat or work has no meaning in a state.**

Example

Determine the average power required to accelerate a 900-kg car, shown in the figure below, from rest to a velocity of 80 km/h in 20 seconds on a level road.



Example

Solution 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

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

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

Discussion About

- Any questions?