ESO 201A: Thermodynamics
2016-2017-I semester

Energy and Energy Transfer-part 2

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Learning objectives

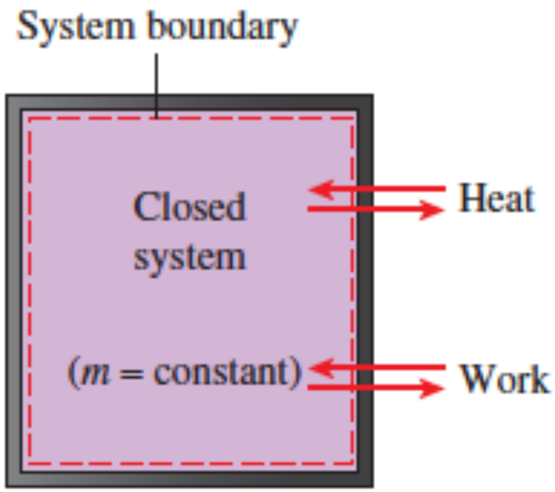
- Introduce the concept of energy and define its various forms.
- Discuss the nature of internal energy.
- Define the concept of heat and the terminology associated with energy transfer by heat.
- Define the concept of work, including electrical work and several forms of mechanical work.
- Introduce the first law of thermodynamics, energy balances, and mechanisms of energy transfer to or from a system.
- Determine that a fluid flowing across a control surface of a control volume carries energy across the control surface in addition to any energy transfer across the control surface that may be in the form of heat and/or work.
- Define energy conversion efficiencies.

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

Unit same as heat kJ

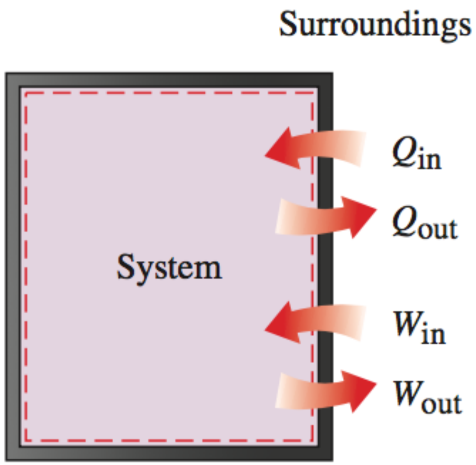


The work done during a process between states 1 and 2 is denoted by W_{12} or simply W. The work done per unit mass of a system is given by:

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

Work done per unit time= power

Formal sign convention



Heat transfer to a system = +ve
Work done on a system = -ve

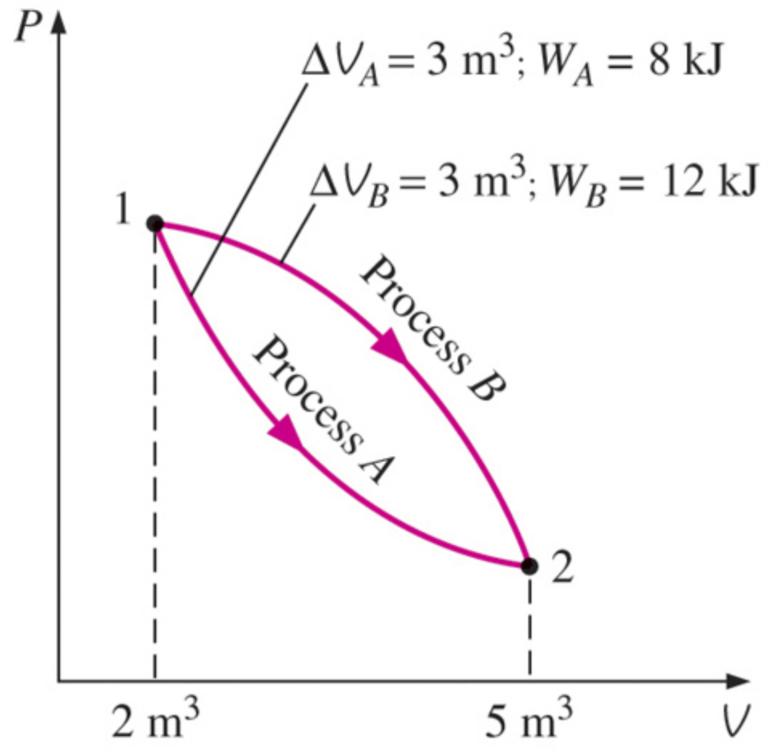
1. Both are recognized at the boundaries of a system as they cross the boundaries. That is, both heat and water are *boundary* phenomena.
2. Systems possess energy, but not heat or work.
3. Both are associated with a *process* not a state. Unlike properties, heat or work has no meaning at a state.
4. Both are *path functions*
   - Their magnitudes depend on the path followed during a process as well as the end states.

Heat vs. Work

Properties are point functions have exact differentials (d).

$$\int_1^2 dV = V_2 - V_1 = \Delta V$$

Heat and work are path functions (their magnitudes depend on the path followed).



Path functions have inexact differentials

$$\int_1^2 \delta W = W_{12} \qquad (not\ \Delta W)$$

Electrical work

In an electric field, electrons in a wire move under the effect of electromotive forces, doing work.

Electrical work

$$W_e = \mathbf{V}N$$

Electrical power

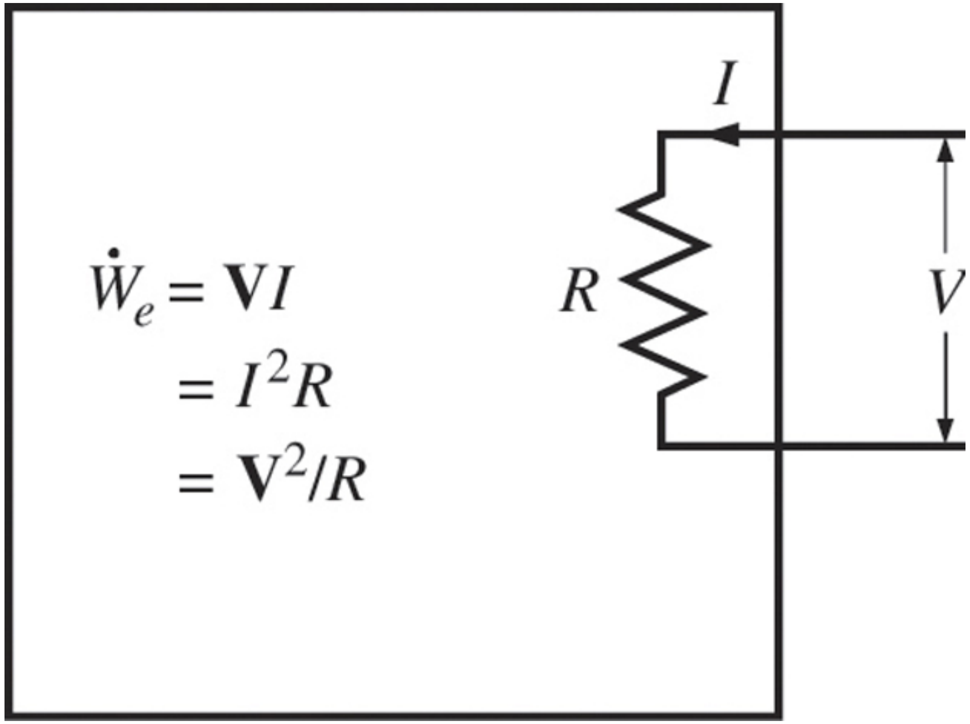
$$\dot{W}_e = \mathbf{V}I \qquad \text{(W)}$$

When potential difference and current change with time

$$W_e = \int_1^2 \mathbf{V}I\,dt \qquad \text{(kJ)}$$

When potential difference and current remain constant

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



Electrical power in terms of resistance R, current I, and potential difference $\mathbf{V}$.

Mechanical forms of work

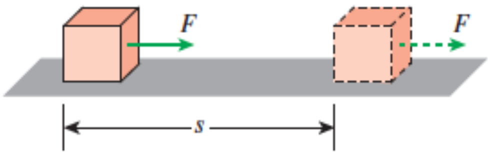
- There are two requirements for a work interaction between a system and its surroundings to exist:
  - there must be a ***force*** acting on the boundary.
  - the boundary must ***move***.

When force is not constant

$$W = \int_1^2 F\, ds \qquad \text{(kJ)}$$

Work = Force x Distance

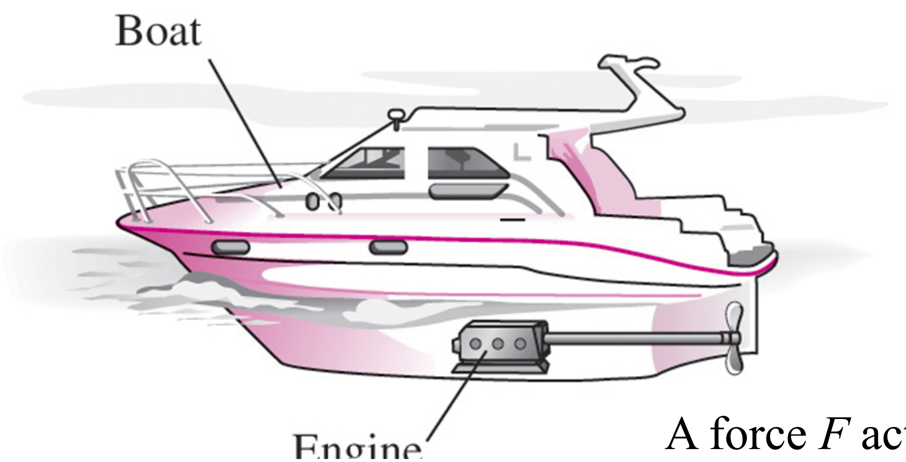
$$W = Fs \qquad \text{(kJ)}$$



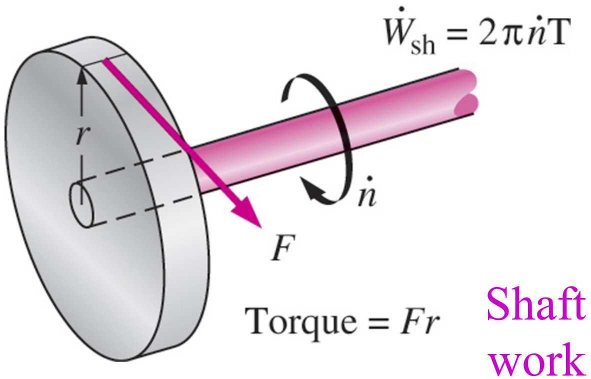
The work done is proportional to the force applied (F) and the distance traveled (s).

If there is no movement, no work is done.

Mechanical form of work: shaft work



Energy transmission through rotating shafts is commonly encountered in practice.



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

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

This force acts through a distance s

$$s = (2\pi r)n$$

Shaft work

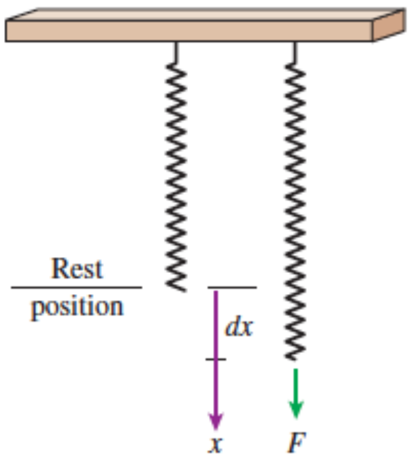
$$W_{sh} = Fs = \left(\frac{\mathrm{T}}{r}\right)(2\pi rn) = 2\pi n\mathrm{T} \qquad \mathrm{(kJ)}$$

The power transmitted through the shaft is the shaft work done per unit time

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

Shaft work is proportional to the torque applied and the number of revolutions of the shaft.

Mechanical forms of work



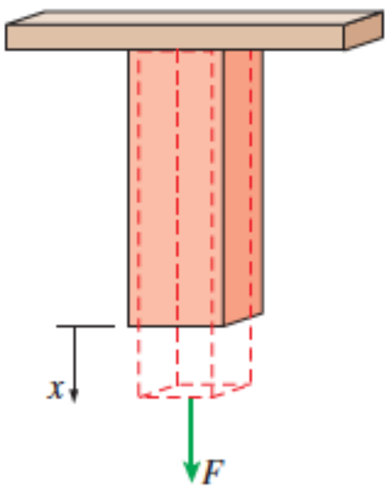
Spring work

$$\delta W_{spring} = F\,dx$$

$$F = kx$$

For linear elastic springs, the displacement x is proportional to the force applied

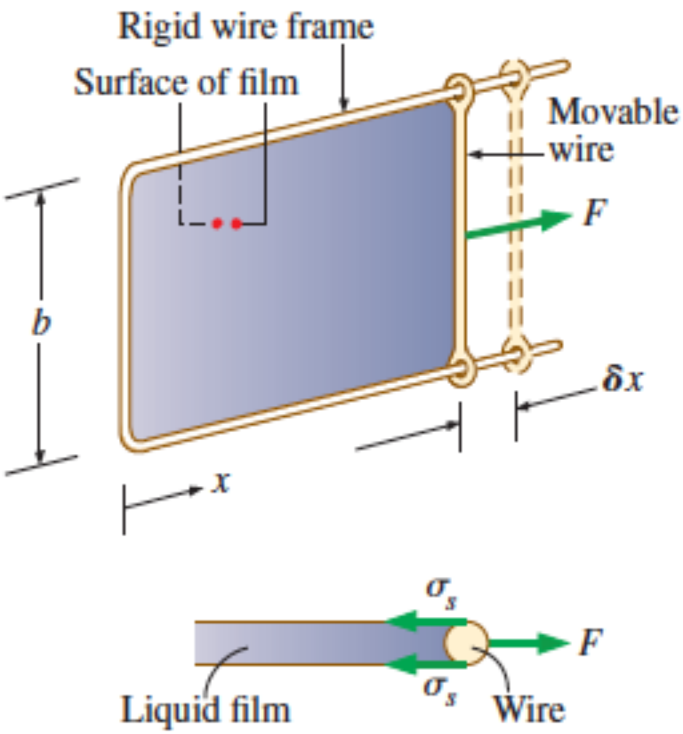
$$W_{spring} = \tfrac{1}{2}k(x_2^2 - x_1^2)$$



Work done on elastic solid bar

$$W_{elastic} = \int_1^2 F\,dx = \int_1^2 \sigma_n A\,dx \quad \text{(kJ)}$$

Mechanical forms of work



Work associated with stretching of a liquid film, *surface tension work*

- Force is required to overcome microscopic forces between air-water. $F = 2b\sigma_s$
- Force per unit length is surface tension

$$W_{\text{surface}} = \int_1^2 \sigma_s \, dA \qquad \text{(kJ)}$$

where $dA = 2b\,dx$ is the change in the surface area of the film.

Work done to raise or to accelerate a body

No temperature difference hence it must be work

1. The work transfer needed to raise a body is equal to the change in the potential energy of the body.
2. The work transfer needed to accelerate a body is equal to the change in the kinetic energy of the body.

Non mechanical work

-electric work

-magnetic work

-electric polarization work

Next lecture

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- Define energy conversion efficiencies.
- Discuss the implications of energy conversion on the environment.